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ABSTRACT

This eleventh annual report of the National Science Board presents the fourth assessment of the state of science in the United States. The assessment includes reports on the status of science, with the following indicators reviewed within the report: international science and technology, resources for research and development, resources for basic research, industrial research and development, and scientific and engineering personnel. Most indices are presented in graphical form. Numerical data tables are included in an appendix. (CS)

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Science Indicators 1978

National Science Board

1979

SE 030 363

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Letter of Transmittal

March 31, 1979

My Dear Mr. President:

I have the honor of transmitting to you, and through you to the Congress, the Eleventh Annual Report of the National Science Board. This report has been prepared in accordance with Section 4(j) of the National Science Foundation Act, as amended. I hope that it will be of particular interest and use to you.

This report, *Science Indicators—1978*, is the fourth of the Board's annual reports to be devoted to the assessment of U.S. science and technology through the presentation and analysis of quantitative indicators. It represents another step in the Board's continuing effort to develop methods of describing levels of scientific and technological activity, the results of that activity, and its impact on the Nation. It is hoped that this report will make a substantial contribution to the understanding of science and technology in the United States, and will be a basis for further analyses by other investigators in this vital area of national policy.

The National Science Board intends to continue to improve and develop this series of science indicators reports. We, therefore, encourage discussion of the topics and issues treated herein and welcome comments or suggestions from users of the report.

Respectfully yours,

Norman Hackerman
Chairman, National Science Board

The Honorable
The President of the United States

Contents

Introduction

Science and technology have become increasingly intertwined with almost every aspect of modern life. These multifaceted activities have an increasing impact on the everyday quality of the life of individuals as well as on the welfare of the Nation and the world. Because of this important and pervasive role of science and technology, the National Science Board in 1968, responding to a legislative mandate, initiated a series of annual reports to assist in the assessment of the status and health of the scientific enterprise. In 1970, after several years of experience with such reports, the Board felt that there was a need to develop and present quantitative information which could be used as one of the tools for evaluating the American scientific and technological enterprise.

The initial experiment was the fifth annual report of the National Science Board to the Congress: *Science Indicators—1972*. It was realized from the beginning that changes of indicators over time are of major importance, and the indicators reflect this. This, coupled with the favorable reception of the first report, led to a decision to present biennially updated and extended indicator reports. *Science Indicators—1978* is the fourth of the series.

The assessment of the science and technology system presents numerous problems. Its diverse internal operations depend on a variety of personnel and institutional interactions as well as on a host of external factors. Furthermore, the impact of science and technology on the society that supports such activities is pervasive because their successes are having an impact on almost every aspect of modern life. While these effects have generally been beneficial, they have also inevitably produced side effects, some of which might be detrimental and should be recognized. Thus, it appears that the assessment of the status and impact of science and technology in a twentieth century society is a research problem in itself. The nature of the task becomes more evident as one delves into the workings of the system.

An assessment of this nature should deal with both qualitative and quantitative aspects. It should look at the status and environment of the key element in the system, the individual scientist or engineer. It should cover the very nature and substantive status of science and technology, and their contributions should be reviewed. It should review the total system. This requires different tools, different types of information, and fruitful ideas not yet conceived.

The objective of *Science Indicators—1978* is similar to that of its predecessors; namely, the presentation and analysis of primarily quantitative material related to the components required for the system's operation and the effects and results which it produces. It is important to keep this objective in mind and also to realize that the indicator reports by themselves provide only one aspect of assessment. Thus, the indicators presented in this volume are primarily numerical measures, often of an economic nature, related to the operation of the scientific and technological enterprise. A full and balanced indication of the status and progress of science and technology must ultimately include qualitative measures as well, because only by this means can one capture some feeling of the excitement of current scientific discovery. The National Science Board has not been able to include in the current volume such explicit descriptions of the recent progress of science, but hopes that this will be possible in future volumes. Some such material, including reports on technological progress, can be found in *Science and Technology: Annual Report to The Congress*. There are also other reports covering various aspects of American science and technology emanating from the National Science Foundation, other government agencies, and private organizations.

The science indicators series can be improved and expanded through further developments of new methodological techniques, new concepts, and new data. Such progress requires contributions from many individuals who can bring

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to the activity a variety of expertise in substantive and analytical areas. Furthermore, since the indicator series serves many audiences, their varying needs must be considered. The nature of the task and the potential benefits that can be derived from a diversity of views required that preparation of the present volume involve a more extensive review process than that of previous volumes.

Thus, after the publication of *Science Indicators—1976* and prior to the initiation of the current volume, reviews, evaluations, and consideration of previous work were sought. A task force composed of individuals from various organizational elements in the Foundation reviewed previous science indicator reports and provided specific recommendations for improvement. Similarly, a number of external experts examined *Science Indicators—1976* and provided criticism and recommendations. These reviewers were drawn from the scientific and technological community and represented different fields as well as experience in science policy and quantitative data development. Several organizations, such as the Social Science Research Council and the Organisation for Economic Co-operation and Development, provided reviews of previous indicator volumes and organized meetings and symposia to discuss the development of science indicators. In these activities new areas of potential utility were identified and changes in format, approach, and analysis were suggested. Further, the preparation of *Science Indicators—1978* included the first use of external reviewers of individual chapters.

Science Indicators—1978 reflects many of the suggestions that evolved from these deliberations and assessments. A number of significant changes have taken place. More interpretation and analysis of the data presented are incorporated in this report. Primary policy questions, illuminated by the data, are identified. A comprehensive, substantive index has been added to assist in locating relevant information. Increased emphasis has been placed on pointing out alternative interpretations and limitations of data as well as references to other publications. Initial steps have been taken to provide more detailed expositions of selected topics of special current interest. Concise overviews are presented both at the end of comprehensive sections and most of the chapters.

Thus, *Science Indicators—1978* is a familiar yet somewhat different document from previous reports. It represents progress, but there is room for additional improvement. For example, the extensive review process and feedback from the users of indicator reports have indicated again a continuing need for better output indicators and for a better understanding of how levels of effort translate into social benefits. However, suggestions for specific, meaningful, and feasible output indicators are sparse, partly because the effects of science and technology are frequently of a qualitative nature.

Moreover, science and technology are only parts of the spectrum, and it is evident that it is necessary to disentangle their effects from those of other factors in the system. The interpretation and analyses, even of input indicators, are sometimes ineffective because of inadequate models of the system. Several models exist for the technical personnel system but few for the financial allocation process except for those at the institutional level. Thus, it is not surprising that successful matching of outputs to inputs is still almost nonexistent. This means that research on such modeling techniques should be undertaken. Research is needed to develop a better understanding of the factors that affect and influence technical activity. In view of the needs for the development of models and output indicators, a modest research program has been started to explore new approaches. The National Science Foundation has requested proposals which would assist in this effort.

Besides the format and interpretive modifications described above, a few other changes in *Science Indicators—1978* should be pointed out. There is no chapter on public attitudes toward science and technology in this report. The omission reflects recognition of the problems associated with developing accurate information on public attitudes. This has led to a more extensive development of analytical plans and survey instruments to obtain this information. A more sophisticated approach requires considerably more time; and it was not possible to

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incorporate the results in this issue of science indicators. Consequently, the results of the 1979 public attitude survey will be presented separately in a Foundation report to be published in 1980. Subsequent analyses will appear in future science indicator reports.

As is evident from the description of the evaluation of *Science Indicators—1978*, many individuals and groups aided in the preparation of this report. Overall responsibility rested with the National Science Board, assisted by a committee of the Board assigned to this task. Organizational responsibility for the preparation of the report was assigned to the Directorate for Scientific, Technological, and International Affairs (STIA). The draft manuscript was produced by the Science Indicators Unit of the Division of Science Resources Studies (SRS) of STIA. While the staff of the Science Indicators Unit spent full time on the report, all other SRS units aided in the preparation of the document. In addition, some material was provided by the Division of Policy Research and Analysis of STIA.

It is hoped that the current volume will elicit comments which will lead to an improved next version. In order to encourage this interaction, a form is provided at the end of this report which can be used to suggest new indicators and analyses or to comment on the usefulness of *Science Indicators—1978*.

Norman Hackerman
Chairman
National Science Board

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Committee on the Eleventh National Science Board Report

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Chapter 1

International Science and Technology

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International Science and Technology

INDICATOR HIGHLIGHTS

- U.S. investment in research and development is much greater than in most countries, both in terms of expenditures and scientific and technical personnel. However, Japan and West Germany have been increasing their R&D investments more rapidly than the United States. (See pp. 5-8.)
- The number of scientists and engineers engaged in research and development as a proportion of the total labor force is increasing in other countries relative to the United States, although in absolute terms the United States has more R&D scientists and engineers than any other country except the Soviet Union. The U.S. proportion of scientists and engineers in the labor force peaked in 1968, declined through the early 1970's, and has been increasing slightly in recent years. (See pp. 7-8.)
- There are marked differences between countries in the allocation of R&D funds. In Japan and West Germany, industry provides a majority of the R&D funds, and Government funds are highly concentrated in areas directly related to economic growth, e.g., manufacturing, transportation, and telecommunications. In the United States, more than half of the R&D funds are provided by the Government, and more than half of these expenditures are for defense and space objectives. (See pp. 6-7, 9-11.)
- The U.S. civilian R&D per GNP ratio increased during a period when the total R&D per GNP ratio declined, but now seems to have stabilized at a level below that of other nations. Japan and West Germany have the highest ratios of national civilian R&D as a fraction of GNP, a concentration of R&D in civilian areas which may have assisted them to increase productivity rates and be more competitive in world trade. (See pp. 8-9.)
- Contrary to expectations, few countries significantly increased energy R&D expenditures following the 1973 energy crisis; the United States is the only OECD country that has consistently intensified public support of energy R&D since that time. (See p. 11.)
- The U.S. proportion of industrial R&D expenditures by all OECD countries decreased from 62 percent in 1967 to 49 percent in 1975, while Japan's proportion rose from 6 to 12 percent. Over the same period, the amount that the Common Market countries jointly accounted for went from 25 to 29 percent. (See pp. 11-12.)
- R&D expenditures by U.S. affiliates abroad reached $1.5 billion in 1977. Between 1977 and 1978, they increased about the same rate as domestic industrial R&D expenditures. In recent years, foreign R&D expenditures by U.S. companies had been growing slightly faster than domestic industrial R&D, particularly in the drug industry. In absolute terms, domestic company-funded R&D expenditures are about 13 times greater than the R&D expenditures of U.S. affiliates abroad. (See pp. 27-28.)
- Almost 40 percent of the world's influential scientific and technical journal literature is accounted for by U.S. authors. While this overall proportion remained fairly stable over the five year period between 1973 and 1977, individual fields experienced some change. The U.S. fraction of publications declined in all fields except clinical medicine and biomedicine. The largest declines were in the fields of mathematics and biology. However, the influence of U.S. scientific literature increased slightly over this same period so that by 1977, U.S. scientific articles were cited about 30 percent more than could be explained by their proportion of the world's literature. (See pp. 15-16.)
- Foreign patenting activity reflects some international economic effects of technology. At a time when domestic U.S. patents have decreased by almost 25 percent, U.S. patents of foreign origin have increased by more than 70 percent. Thus, the foreign-origin share of total U.S. patents increased from 20 percent in 1966 to 36 percent in 1977. However, interpretation of patent data is not simple and special attention should be paid to the caveats found in the text. (See pp. 16-20.)

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- Inventors from West Germany, Japan, and the United Kingdom have been granted the largest numbers of U.S. patents. Increased activity in foreign patenting in the United States is influenced by a variety of factors, including the commercial attraction of introducing a technology or product to the large, homogeneous U.S. market and the increased R&D and inventive capabilities of foreign nations. While foreign R&D expenditures are highly correlated to patenting activity in the United States, foreign inventiveness (as measured by numbers of domestic patent applications or patents granted) increased substantially only in Japan. U.S. domestic patenting has declined in almost all product fields and may well represent an actual decrease in U.S. inventive activity. (See pp. 16-21.)

- Over the past decade, productivity gains in manufacturing industries in the United States were less than those of Canada, France, West Germany, the United Kingdom, and Japan. However, the U.S. productivity level exceeds those of all these countries. While Japan experienced the largest productivity gains, its productivity level is still only two-thirds that of the United States. Investments in R&D and technological innovation have positive, long-term effects on productivity and economic growth. Had the United States continued to invest in R&D (in constant dollars) at the same rate as in the early and mid-1960's, or had continued to devote at least the same fraction of national resources to R&D as it did in the 1960's, U.S. productivity gains might have been greater. (See pp. 21-23.)

- International technology transfer remains a source of large earnings and returns on investment. Data show that U.S. firms have been increasing their earnings from technology licensing agreements and that U.S. technology transfers to other parts of the globe seem to be growing. U.S. receipts from technology-licensing agreements in 1977 reached $4.7 billion—more than 10 times the amount paid for importing foreign technical know-how. If this indicator is viewed as a rough and partial expression of the salability of the accumulated, as well as current, stock of U.S. technology, then there is no apparent decrease in the international earning power of U.S. technology. (See pp. 24-27.)

- At a time when the overall trade balance of the United States is showing large deficits, the importance of R&D-intensive trade in manufactured goods has increased. While the trade balance for non-R&D-intensive manufactured goods has registered large deficits, the trade balance for R&D-intensive manufactured products has been positive since 1960. However, since 1975 there has been a 6-percent decrease in this balance. Even so, the 1977 balance of R&D-intensive manufactured products was almost 5 times greater than that of 1960 and 2½ times the 1972 level. The United States has a positive trade balance in these products with all its major trading partners except Japan and, recently, West Germany. From 1974 to 1977, the deficit with Japan increased 529 percent, reaching about $3.5 billion. (See pp. 29-33.)

- U.S. universities and colleges have made a significant contribution to the building of world scientific and technical capabilities. They have contributed to the development of foreign universities and have also assumed the role of training many foreign scientists and engineers. Almost 60 percent of all foreign students in the United States are studying in scientific and technical fields; about 15 percent of the scientific and engineering doctoral degrees awarded in the United States in the mid-1970's were to foreign citizens; and 32 percent of the U.S. postdoctoral appointments in science and engineering fields were held by noncitizens in 1977. (See pp. 34-36.)

- As seen from the highlights above, the United States still exceeds most other countries in absolute levels of R&D investment, but Japan and West Germany have been increasing their R&D investments more rapidly. These two foreign countries have been enjoying some of the highest productivity growth rates over the past decade, while the U.S. gains were relatively small. Japan and West Germany also have been granted the largest numbers of U.S. foreign-origin patents and have been highly successful in exporting R&D-intensive manufactured products to the United States.

In a world of increased awareness of the interdependence of nations, increased rapidity of change, and increased speed of communication, it is appropriate to take a broader perspective of science and technology other than a purely national one. This chapter views science and technology in an international context, giving special attention to the U.S. role in world science and technology affairs.

In the middle and late 1960's, much discussion was devoted to the "technological gap" between Europe and the United States. This discussion was stimulated in part by an OECD study[1] that showed the United States ahead of Europe in resource measures devoted to R&D, in the performance of technological innovation, and in the economic effects of R&D activity. A decade later, the situation has somewhat changed; there is now increasing concern in the United States over whether our Nation has lost the technological initiative.[2] The United States still far exceeds most major industrialized nations in terms of absolute levels of R&D investments, GNP, and productivity rates.[3] Nevertheless, other nations are advancing in terms of economic growth and technical prowess. This is not necessarily a bad sign, and may in fact be positive from the viewpoint of global development and even of our own Nation's development. In a changing world of limited resources and increased specialization, it is becoming clear that while striving for excellence is important, a certain amount of division of labor between countries is productive.[4] A country that increases its scientific and technical capabilities has a greater potential to solve its own problems. More effective use of national resources and strengthened local efforts to fight food and energy problems, for instance, are probably the most effective ways to attack such worldwide concerns.

One theme of this chapter is the comparison of the scientific and technological activities of industrialized nations. No single standard or optimal level of R&D investment is known. International comparisons, however, can provide a general framework to evaluate national R&D efforts. Therefore, cross-country comparison is one method to assess the status of U.S. science and technology. Comparisons of absolute levels are important because large investments are often critical to the performance of complex or multifaceted R&D projects in a variety of fields. However, in order to make more meaningful comparisons between countries of different sizes, R&D investments are often normalized in this report by the size of a country's economy or labor force.

A second emphasis of this chapter discusses outputs and impacts of science and technology, i.e., the results of R&D investments. Scientific literature indicators are presented because they are generally accepted as one of the more direct forms of scientific output. Patent indicators are also examined, even though their significance is more problematic.[5] Patent activity can be used as a rough measure (albeit imperfect and partial) of inventive activity. Information on foreign-origin patents can shed light on a nation's tendency to protect or market its technologies abroad. This chapter also examines various trends and impacts of technology flows as represented by royalties and fees, direct investment, and international trade in R&D-intensive product groups.

A third major theme involves the treatment of various aspects of cooperation and interaction in science and technology. Scientific and technological activities do not occur in a vacuum, but rather are cumulative and interdependent efforts that transcend national boundaries. Research findings in one country often form the basis for discoveries or breakthroughs elsewhere. Technology-related activities affect both the domestic economies and international trade positions of nations.

As discussed elsewhere in this report, current understanding of the impact of the science and technology enterprise and its components is limited. It is extremely difficult to separate the effects of R&D from other factors influencing the health of a nation's socioeconomic system. These

[1] "Technological Gaps: Their Nature, Causes and Effects," *The OECD Observer* (April 1968), pp. 18-29; J.J. Servan-Schreiber, *The American Challenge* (New York: Atheneum, 1968); and John Diebold, "Is the Gap Technological?" *Foreign Affairs*, vol. 46 (January 1968), pp. 278-291.

[2] "Technological Innovation and Economic Development: Has the U.S. Lost The Initiative?" Proceedings on a Symposium on Technological Innovation (Washington, D.C.: Energy Research and Development Administration and Massachusetts Institute of Technology, 1976); Don I. Phillips, Patricia S. Curlin, and Ralph Petrilli (eds.), *R&D in the Federal Budget, R&D, Industry and the Economy: Colloquium Proceedings* (Washington, D.C.: American Association for the Advancement of Science, 1978); Harvey Brooks, "What's Happening to the U.S. Lead in Technology?" *Harvard Business Review*, vol. 50 (May-June 1972), pp. 110-118.

[3] See Appendix tables 1-1, 1-3, and 1-16.

[4] "International Scientific Cooperation—A Summary of Tangible Benefits," *Technology and Foreign Affairs*, Department of State, 1976, Appendix I, pp. 1-12.

[5] See the discussion of patent data limitations and caveats in this chapter and in the Industrial Research and Development chapter.

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difficulties are magnified in an international context due to problems of data availability, reliability, and timeliness. Differences in definitions, concepts, data collection methodologies, and statistical reporting procedures exist. Because of these limitations, attention should be paid to large changes rather than small changes and to trends rather than single-year data. Several international organizations, such as the Organisation for Economic Co-operation and Development (OECD) and the United Nations Educational, Scientific and Cultural Organization (UNESCO), have done much to institute uniform standards. Nevertheless, international statistics must rely on national data collection and reporting systems which vary.

Indicators are not meant to be precise measurements; R&D expenditure data reflect scientific activity, and scientific publication counts provide information on just one type of scientific output. If the trends of indicators are considered together rather than separately, their ability to describe adequately the present state of science and technology and to provide clues to future trends is enhanced.

COMPARISON OF INVESTMENTS IN R&D

Cross-country comparisons may provide some information on adequate levels of R&D investment.[6] Aggregated data on R&D expenditures and on scientific and technical personnel are used here as indicators of scientific activity. They attempt to measure the level and type of resources devoted to research and development activities, not the quality or results. Increased research spending does not automatically insure an increase in the world's scientific knowledge. An increased supply of scientific personnel can represent an increased national scientific and technical capability, though the question of quality and level of training must be taken into consideration. Furthermore, data on national totals of scientists and engineers do not indicate the extent to which that capability is actually utilized.

This section presents analyses of R&D trends, national differences in major sources of funding, and Government R&D priorities in areas such as energy, health, and civilian R&D expenditures. Much effort has gone into alleviating problems of data comparability. Comparisons of Soviet R&D data have been particularly difficult because of differences between the Soviet Union and other nations in R&D definitions and GNP accounting. There has been progress in understanding differences between the U.S. and Soviet S&T systems,[7] and this chapter presents only those Soviet data that are relatively comparable to U.S. data.

R&D Expenditures

The ratio of R&D expenditures to gross national product (GNP) is used to make more meaningful comparisons of S&T activity between countries of various sizes. R&D per GNP ratios are also useful because they partially circumvent the problems of adjusting for different rates of inflation and vacillating exchange rates, since inflation affects both R&D costs and GNP figures in a given country.[8]

The U.S. ratio has decreased for more than a decade from a high of 3.0 percent in 1964 to 2.3 percent in 1978 (see figure 1-1). During this same period, the R&D per GNP ratio for West Germany increased from 1.6 percent in 1964 to 2.3 percent in 1978 (surpassing the U.S. in 1975) and Japan's ratio grew from 1.5 percent in 1964 to 1.9 percent in 1976.

The U.S. decline in R&D per GNP is a function of differences in the growth rates of the two components of this ratio; the GNP has been growing at a faster rate than R&D expenditures, even though R&D expenditures have risen. This trend is expected to continue through 1985, when the U.S. ratio of R&D per GNP is projected to be 2.0.[9] Examination of the components of these ratios in France and the United Kingdom shows

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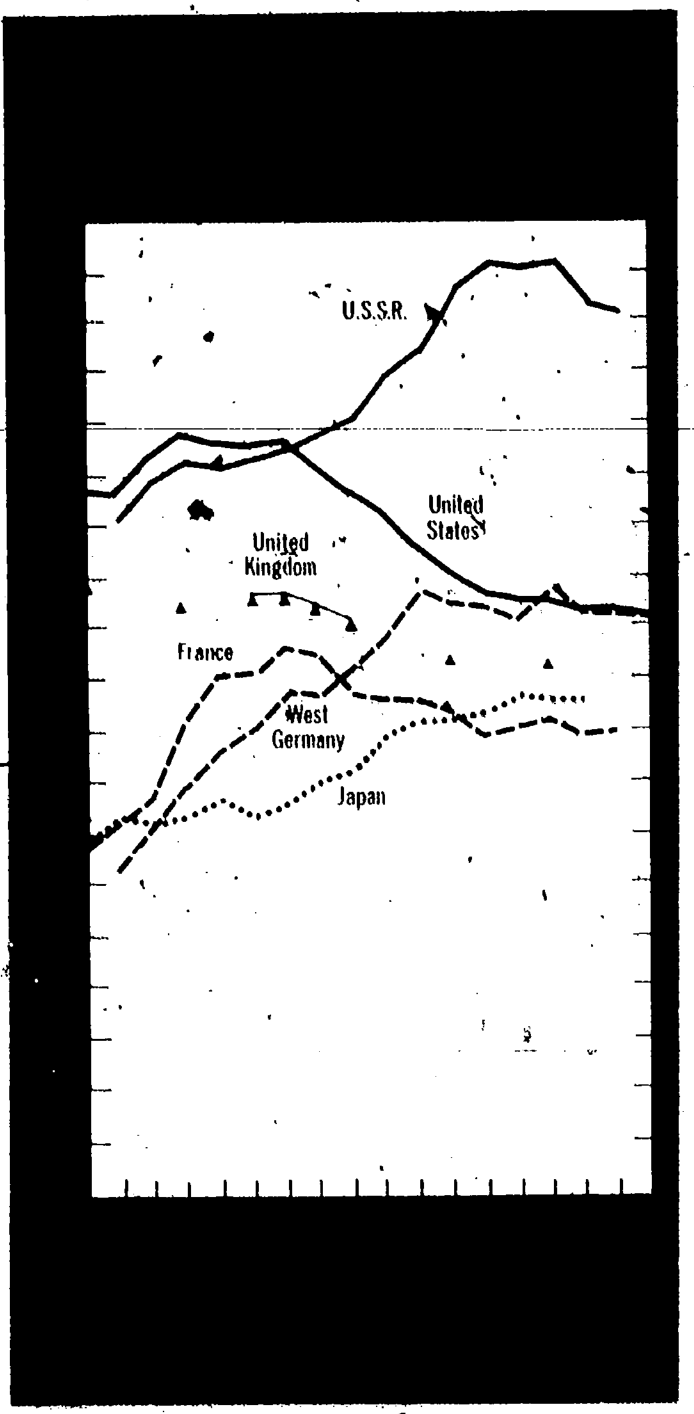
[6] Comparisons are made here with the United Kingdom, France, West Germany, Japan, and the U.S.S.R. because these countries expend large amounts on R&D and represent the majority of world investment in R&D.

[7] Several joint U.S.-U.S.S.R. meetings have been held and reports exchanged on the topics of R&D expenditure and scientific and technical personnel data under the auspices of the Joint Science Policy Working Group of the U.S.-U.S.S.R. Commission on Science and Technology, established by a bilateral agreement signed in Moscow, May 1972. For a complete discussion of estimations of Soviet R&D expenditure and personnel data, see Robert W. Campbell, *Reference Source on Soviet R&D Statistics, 1950-1978*, National Science Foundation, 1978; and *A Comparison of U.S. and U.S.S.R. Training and Utilization of Scientists, Engineers and Technicians*, National Science Foundation, (forthcoming).

[8] These comparisons would be more precise if adequate national R&D deflators were available. Unfortunately, they have not yet been developed. (See the Resources for R&D chapter.) The Organisation for Economic Co-operation and Development has done some experimental work with R&D deflators; see *R&D in Selected OECD Member Countries, 1967-1975*, 42.845 (Paris: Organisation for Economic Co-operation and Development, September 18, 1978), pp. 3-22.

[9] *1985 R&D Funding Projections*, National Science Foundation (NSF 76-314), p. vi.



that declines in R&D per GNP occur for the same reason as declines in the U.S. ratio.

The growth in R&D per GNP ratios in Japan and West Germany is impressive given the rapid overall economic expansion in these countries.[10] It is possible that their relatively healthy economic situation has allowed them greater opportunity to invest in R&D; that is, that R&D is partially a function of GNP. On the other hand, it has been argued that investments in R&D eventually contribute greatly to GNP growth;[11] the results of past large expenditures in R&D may have provided a basis for Japanese and West German economic growth. Because adequate growth-accounting methods and causal models that directly link the contributions of R&D to economic growth are not available, the precise extent to which either of these hypotheses explains the dynamics of the situation is difficult to determine.

In perspective, despite the decrease of R&D per GNP in the United States, the U.S. ratio is still higher than that of most countries, and actual U.S. R&D expenditures far exceed those of all other countries except the Soviet Union. In fact, the United States spends more on R&D than the United Kingdom, France, West Germany, and Japan combined.[12] However, the level of GNP in the United States is also greater than the total for these countries. In addition, R&D as a fraction of GNP has now peaked or seems to be leveling off in each of these countries.[13] Differences in trend direction are as important to examine as absolute values. There is no consensus on whether a low ratio of R&D expenditure to GNP should be interpreted as underinvestment in research and development. Growth rates become harder to sustain or increase as base levels of R&D or GNP become larger. Perhaps a slowdown in the rate of R&D investment is a characteristic pattern once a country reaches a certain economic level.

While absolute levels of investment are important, variations of R&D funding patterns between nations may also affect overall economic growth and R&D per GNP ratios. Industrial R&D expenditures seem to be highly correlated to GNP and are generally intended to have a greater short-term impact on economic growth than government R&D expenditures, which are often aimed at influencing the long-term growth and

[10] For an analysis of real GNP growth, see *International Report of the President*, Council on International Economic Policy, Executive Office of the President, 1977, pp. 3-9.

[11] For a discussion of studies relating R&D investment to increased productivity and economic growth, see the section in this chapter on productivity.

[12] In 1975, R&D expenditures for the United States totaled $36.7 billion, in contrast to $8.8 billion for Japan, $8.8 billion for West Germany, $6.0 billion for France, and $4.6 billion for the United Kingdom (all in U.S. dollars). *International Survey of the Resources Devoted to R&D by OECD Member Countries, International Statistical Year 1975*, DSTI/SPR/79.5 (Paris: Organisation for Economic Co-operation and Development, 1978), p. 42.

[13] Although it is still too early to know with certainty, the ratio of R&D per GNP seems to be leveling off even in West Germany, Japan, and the Soviet Union.

well-being of a nation.[14] This is due in part to the areas and types of R&D that governments feel justified to support (e.g., areas of high risk, high social benefit, and high cost, such as defense, health, and large energy projects).[15] All other things being equal, countries with a high share of industrial R&D funds could be expected to receive greater economic returns than countries with a high concentration of Government R&D funds. Data on sectoral characteristics of R&D funding[16] show that in West Germany and Japan (both of which are enjoying high growth rates of R&D expenditures and GNP), the industrial sector has provided the majority of national R&D funds—generally more than 50 percent and 60 percent, respectively (see figure 1-2). Countries that have been experiencing a decrease in their R&D per GNP ratio—the United States, France, and the United Kingdom—have historically received the largest portion of the national R&D funds from Government and other sources (private nonprofit organizations and higher education). Since the late 1960's, industrial expenditures for R&D as a fraction of GNP have been increasing only in Japan and West Germany while remaining constant or decreasing in other countries studied.

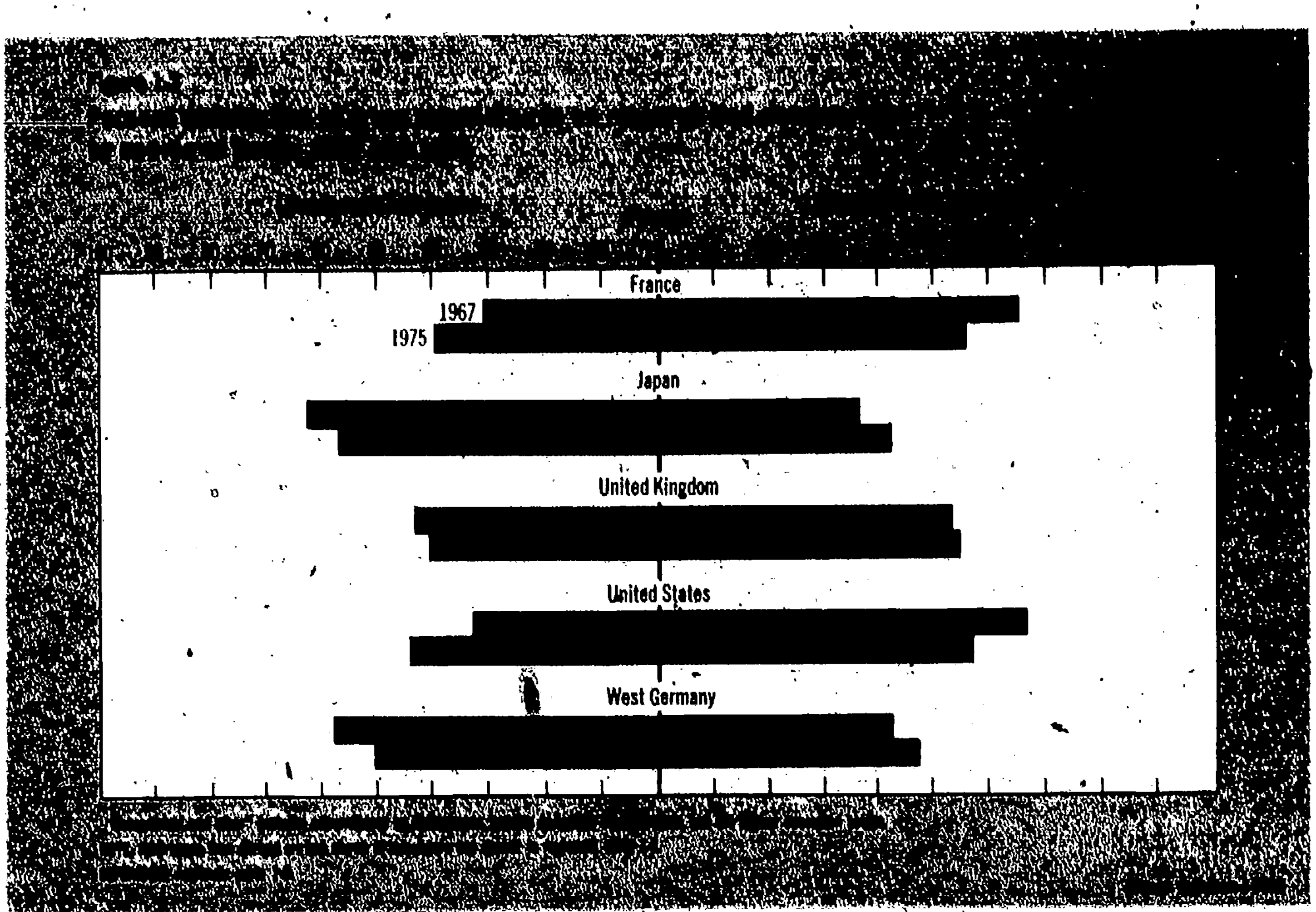
Scientific and Technical Personnel

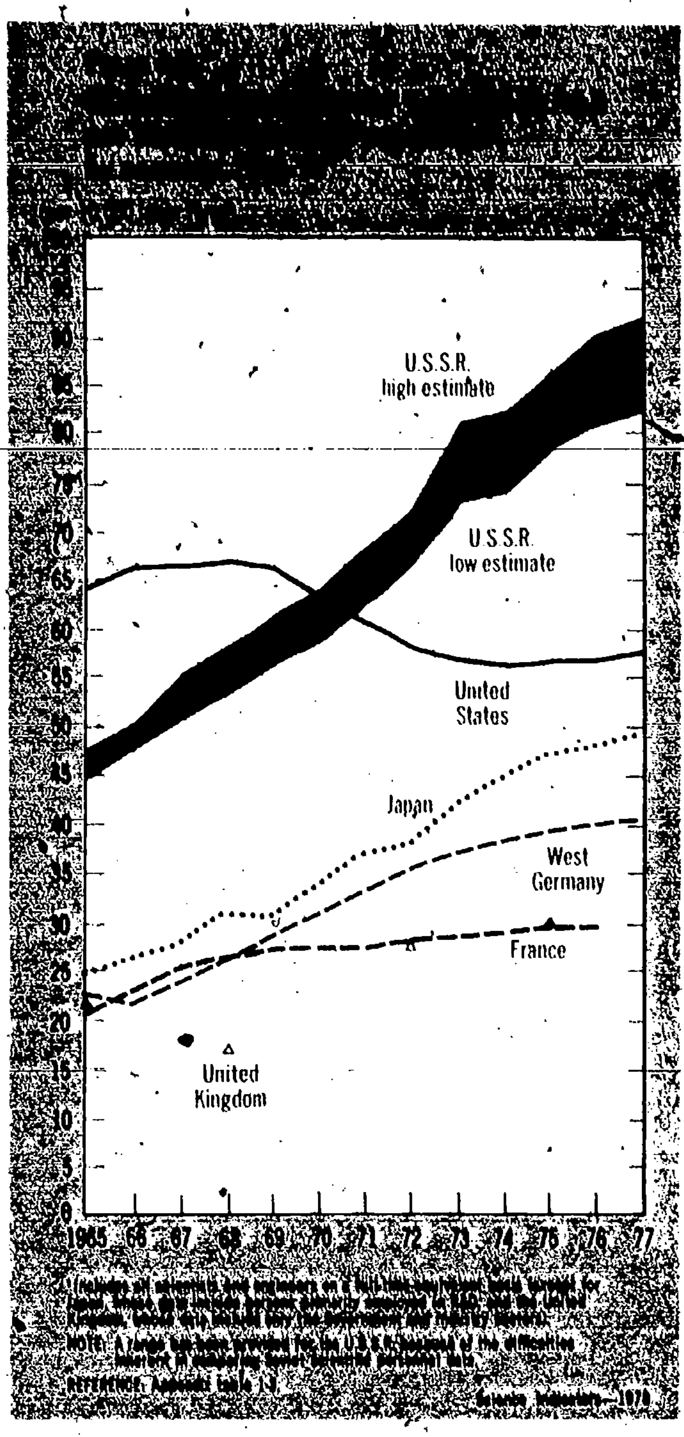
Human resources are important components of any analysis of national resources devoted to science and technology. Figure 1-3 shows that the number of scientists and engineers engaged in research and development as a proportion of the total labor force is increasing in other countries relative to the United States. In absolute terms, however, the United States has more scientists and engineers engaged in R&D (595,000 in 1978) than all other countries except the Soviet Union.

[14] See testimonies of Edwin Mansfield and Nestor E. Terleckyj at Hearings before the Subcommittee on Domestic and International Scientific Planning and Analysis of the Committee on Science and Technology on *Federal Research and Development Expenditures and the National Economy*, U.S. House of Representatives, 94th Cong., April 28, 1976, pp. 39-65, 149-197

[15] See Appendix table 1-4 and the section "Functional Areas of Federally Funded Research and Development," of the chapter on Resources for R&D.

[16] See Appendix table 1-2.





The size of the R&D labor force is only an approximate measure of the depth and direction of a country's R&D effort; it does not indicate capabilities such as the level of sophistication, utilization, or productivity of R&D personnel of nations. The U.S. ratio peaked in 1968 and declined through the early 1970's because the absolute number of R&D scientists and engineers decreased. Since 1973, the U.S. ratio has stabilized and has increased slightly through 1978. At the same time, most other countries have been experiencing increases in this ratio, especially Japan, West Germany, and the Soviet Union.

There are numerous problems involved in comparing U.S. and Soviet scientific personnel statistics, but attempts have been made here to present figures corresponding to U.S. definitions of full-time-equivalent scientists and engineers. Questions about the differences in quality and type of training in either country are not addressed.[17] Because the accuracy of Soviet data is difficult to assess, a range has been provided between low and high estimates.[18] The Soviet ratio of R&D scientists and engineers to labor force surpassed the U.S. ratio sometime in the late 1960's or early 1970's and appears to be increasing.

Civilian R&D

The need for a different balance between U.S. civilian research and development and defense and space R&D has been proposed.[19] It has been argued that more effort should be placed in civilian R&D oriented toward economic and social needs. Space R&D activities can often benefit civilian areas, and both defense and space R&D activities have economic spinoff effects,[20] but they are aimed principally at attaining other public goals, such as national security.

[17] For some discussion of comparability of education training and degrees awarded, see Roger K. Talley, *Soviet Professional Scientific and Technical Manpower*, Defense Intelligence Agency, 1975, pp. 9-36; *A Comparison of U.S. and U.S.S.R. Training and Utilization of Scientists, Engineers, and Technicians*, National Science Foundation (forthcoming); and *Summary of Soviet Report on the Training and Utilization of Scientific Engineering and Technical Personnel*, National Science Foundation (forthcoming).

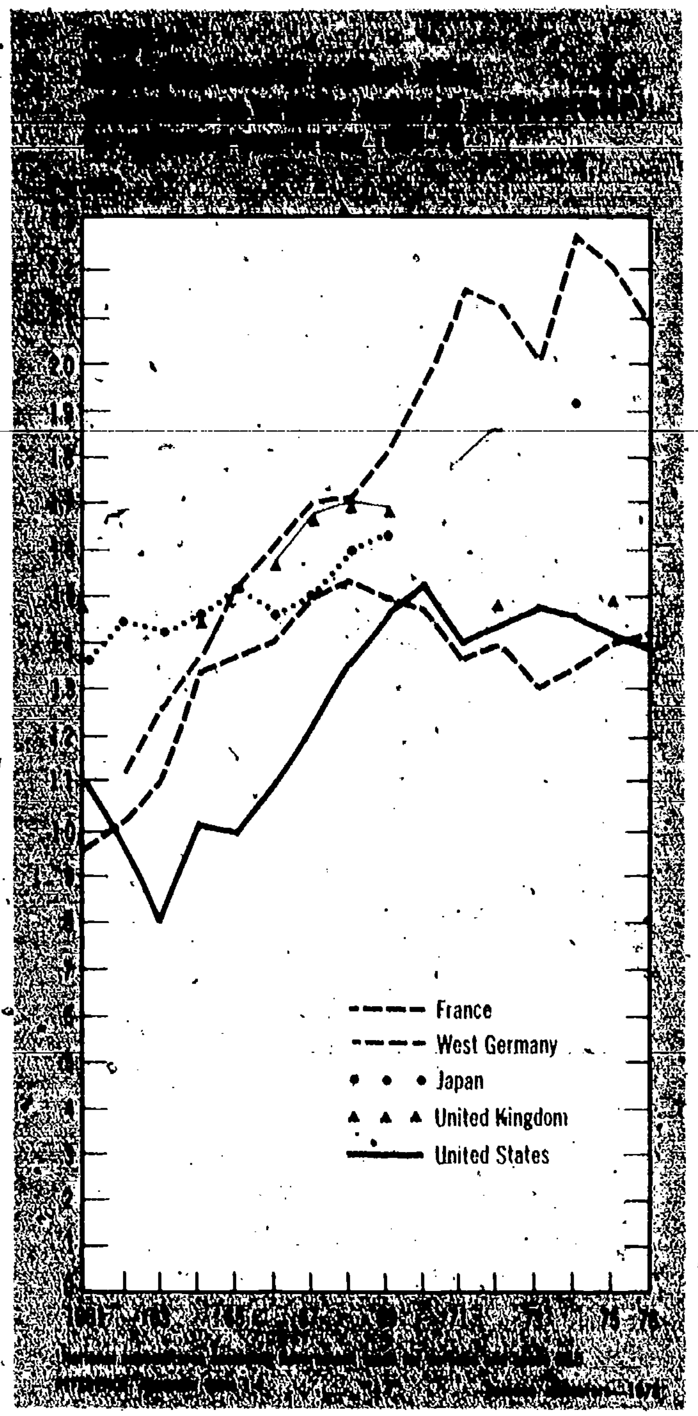
[18] Robert W. Campbell, *Reference Source on Soviet R&D Statistics, 1950-1978*, National Science Foundation, 1978.

[19] For instance, see Harvey Brooks, "What's Happening to the U.S. Lead in Technology?" *Harvard Business Review*, vol. 50 (May-June 1972), pp. 110-118 and Robert Gilpin, *Technology, Economic Growth and International Competitiveness*, Joint Economic Committee of Congress, 1975.

[20] See for example, James M. Utterback and Gilbert E. Murray, "The Influence of Defense Procurement and Sponsorship of Research and Development on the Development of the Civilian Electronics Industries," CPA 77-5 (Cambridge, Mass.: Center for Policy Alternatives, Massachusetts Institute of Technology, 1977); and *The Economic Value of Remote Sensing by Satellite: An ERTS Overview and the Value of Continuity of Service*, prepared for the National Aeronautics and Space Administration, 13 vols. (Princeton, N.J.: ECON, Inc., 1974).

Figure 1-4 provides estimates of national civilian R&D expenditures as a fraction of GNP;[21] it shows that West Germany and Japan have the highest ratios. This is to be expected, however, in light of their post-World War II restrictions on defense-related activities and the fact that a majority of national R&D funds in those countries is supplied by industrial sectors.[22] In fact, the concentration of R&D in civilian areas may have assisted the Japanese and West Germans to increase productivity rates and be more competitive in world trade.[23]

Although U.S. expenditures for total R&D are greater than most countries, the United States devotes relatively less to civilian R&D than do many countries, some of which are our chief economic competitors. The United States still has a relatively low civilian R&D per GNP ratio which seems to have leveled off at about 1.4 percent, but this ratio is much larger than in the early and mid-1960's and is now closer to French and U.K. ratios. The earlier increases in the U.S. civilian R&D per GNP ratio are noteworthy because they occurred largely during a period when the total R&D per GNP ratio was declining in the United States. Even though the United States has extensive, continuing, international security responsibilities, it is important to attempt to maintain or increase a commitment to civilian R&D because of the positive effect of such R&D activities on economic growth.



Government-Funded R&D

How a government distributes its funds among R&D programs provides some indication of its broad R&D priorities in various functional areas. Studies have been conducted by OECD to determine how its member countries have allocated R&D funds among various objectives or priorities.[24] Funding patterns in all countries have been changing (figure 1-5). The trend shown during the past decade reflects a definite

[21] Actual data are not available on national civilian R&D expenditures; only Government R&D expenditures have been categorized by functional objectives. However, it is reasonable to assume that almost all R&D expenditures for defense and space are funded by Government sources; therefore, estimates of national civilian expenditures have been calculated by subtracting Government expenditures for defense and space from gross expenditures for research and development (Appendix tables 1-1 and 1-5). These civilian R&D funds may be slightly overstated and should be considered as approximations. For instance, U.S. industrial firms specializing in defense-oriented research that do a large portion of their business with the Federal Government report as company funds their Independent Research and Development (IR&D) projects that are conducted in areas of potential interest to the Defense Department.

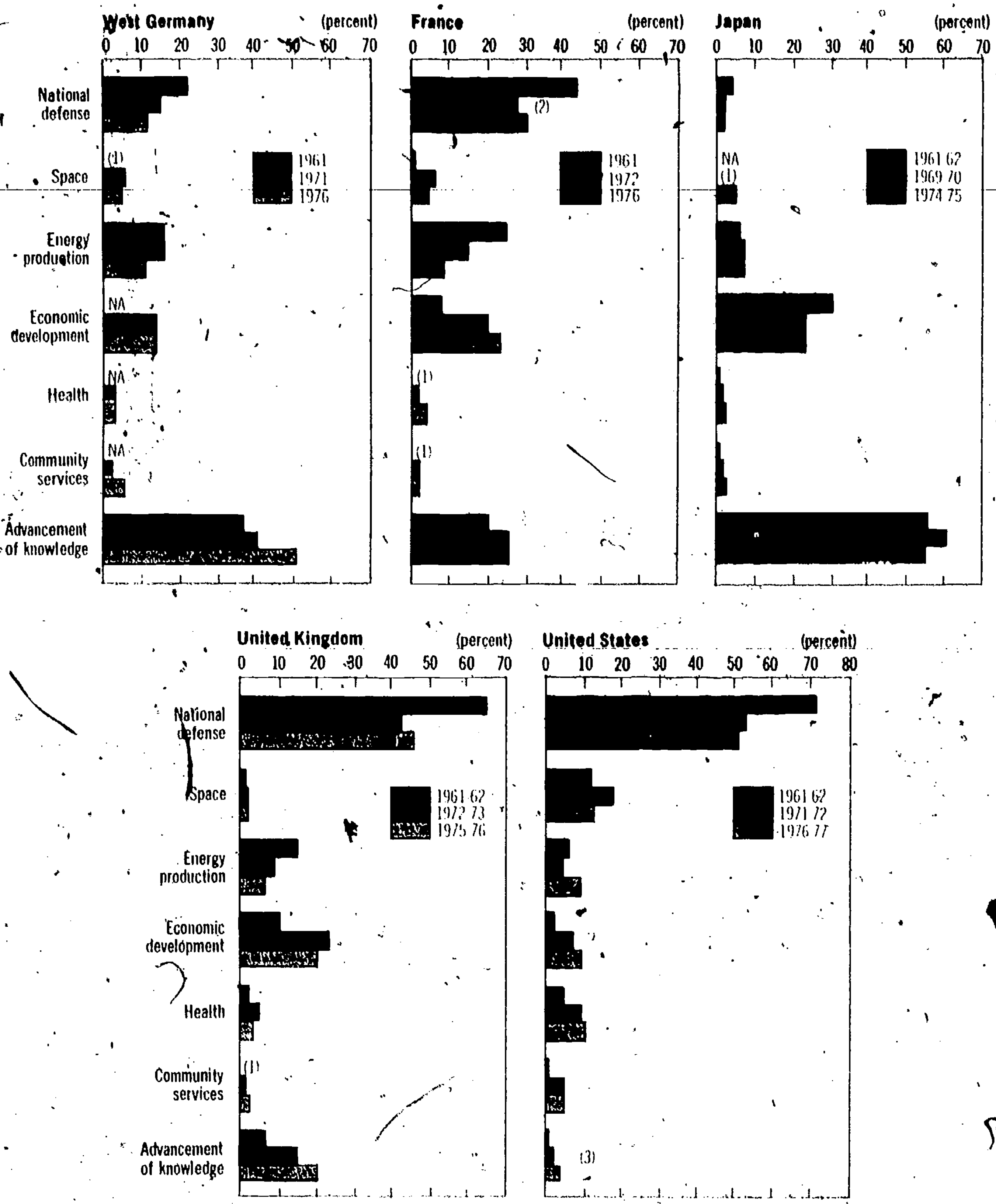
[22] See figure 1-2.

[23] See the "Outputs and Impacts" section of this chapter.

[24] *Changing Priorities for Government R&D* (Paris: Organisation for Economic Co-operation and Development, 1975), and *International Statistical Year—1973: The Objectives of Government R&D Funding 1970-76*, vol. 2B (Paris: Organisation for Economic Co-operation and Development, 1977). These data may not be as comparable internationally as other OECD data because the survey is still in the early stages of development, and a more uniform approach and agreement on some technical problems is still needed. Because the classification methodology is one refined by OECD, the data may differ slightly from data available in national publications.

Figure 1-5

Estimated distribution of Government R&D expenditures among selected national objectives, by country: 1961-77



[1]Less than 0.5 percent

[2]Later estimates indicate that this amount was about 32.0 percent

[3]General University funds are not included in the "Advancement of knowledge" category for the United States

REFERENCE: Appendix tables 1-5 and 1-6

shift from military to civilian R&D applications. In each country, the proportion of total R&D funds spent on defense-related activities declined even though the absolute amounts of defense R&D expenditures have generally continued to increase.

The United States differs significantly from other major R&D-performing nations in that a larger percentage of Government R&D funds is allocated to defense and space programs.[25] This concentration is associated with the major international defense obligations carried by the United States that require large R&D expenditures to ensure future capabilities. In 1976-77, the United States allocated only about 35 percent of Government funds to civilian R&D, although this proportion has almost doubled since the early 1970's. In the United Kingdom, almost half of the Government R&D funds are allocated to defense and space activities, and about a third of French Government R&D funds were devoted to these areas in the mid-1970's. Japan and West Germany, however, have not made large investments in defense R&D and have thus been able to devote more of their national budgets to areas related to economic development and the advancement of knowledge. It should be noted, however, that Japan and West Germany include general university funds (GUF) in the category "advancement of knowledge," while the United States does not include such block grants. In most countries, GUF funds are supplied almost entirely by the ministry of education for R&D in the higher education sector. In the United States, the allocation of these funds is decentralized, often occurring at the state level; therefore, data on this type of funding are is not available. However, the inclusion of such funds would probably not explain the considerable difference in this category between the United States and West Germany or Japan. The differences in allocation of funds for "advancement of knowledge" also reflect national differences on the most effective ways to encourage and support research.

Contrary to expectations, few countries significantly increased energy R&D expenditures following the 1973 energy crisis; the United States is the only OECD country that has consistently increased public support of energy R&D.[26] Since that time, the fraction of U.S. Government funds devoted to energy R&D has grown, and, in absolute terms, Federal obligations for energy R&D increased about 435 percent between 1973 and 1978.[27]

The United States also differs from other countries in the high priority it gives to health R&D; health receives a larger percentage of the U.S. Government R&D budget than it does in any other OECD country. In absolute terms, U.S. health R&D expenditures represent about three-fourths of the total OECD funds in this area.

The distribution pattern of Government R&D funds also influences civilian R&D trends. For Japan and West Germany, it appears that in addition to the fact that industry provides the majority of R&D funds, Government support of R&D is heavily concentrated in the areas of economic development and the advancement of knowledge. In contrast, in the United States and the United Kingdom, not only do Government funds represent a greater percentage of total national R&D funds, but about half of these funds are devoted to space and defense objectives. However, the United States is somewhat limited from shifting to as large a concentration of civilian R&D as some other countries because of the extent of its international responsibilities.

Comparisons of Industrial R&D

Concern about the U.S. trade deficit has helped to focus national attention on industrial R&D investment and on innovation and its role in the competitive position of U.S. industry in world trade.[28] Therefore, international comparisons of industrial R&D are presented here, and economic impacts of R&D on productivity and international trade are discussed in the last part of this chapter.

The U.S. proportion of all industrial R&D expenditures by OECD countries decreased from

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[25] Distribution data are not available for the Soviet Union; it is a controversial and as yet unresolved issue as to whether Soviet military R&D is included in reported total R&D expenditures. One recent study estimated that Soviet expenditures on military research, development, test and evaluation (RDT&E) have nearly doubled in the last decade, exceeding $20 billion in 1977. See Richard B. Foster, "Economic Performance Reflecting Soviet Goals," *Comparative Strategy*, vol. 1 (1978), p. 20.

[26] *Science Resources Newsletter* Organisation for Economic Co-operation and Development (Spring 1977), p. 7.

[27] See the chapter on Resources for R&D and Appendix table 2-16.

[28] See Statement of Lowell W. Steele before the Joint Hearings of the Subcommittee on Science, Technology and Space of the Committee on Commerce, Science and Transportation, U.S. Senate, May 16, 1978; and Frank Press, Testimony at Hearing on the Office of Science and Technology Policy before the Subcommittee on Science, Technology and Space, Committee on Commerce, Science and Transportation, U.S. Senate, February 10, 1978, in which he outlined the reasons for an interagency domestic policy review of industrial innovation.

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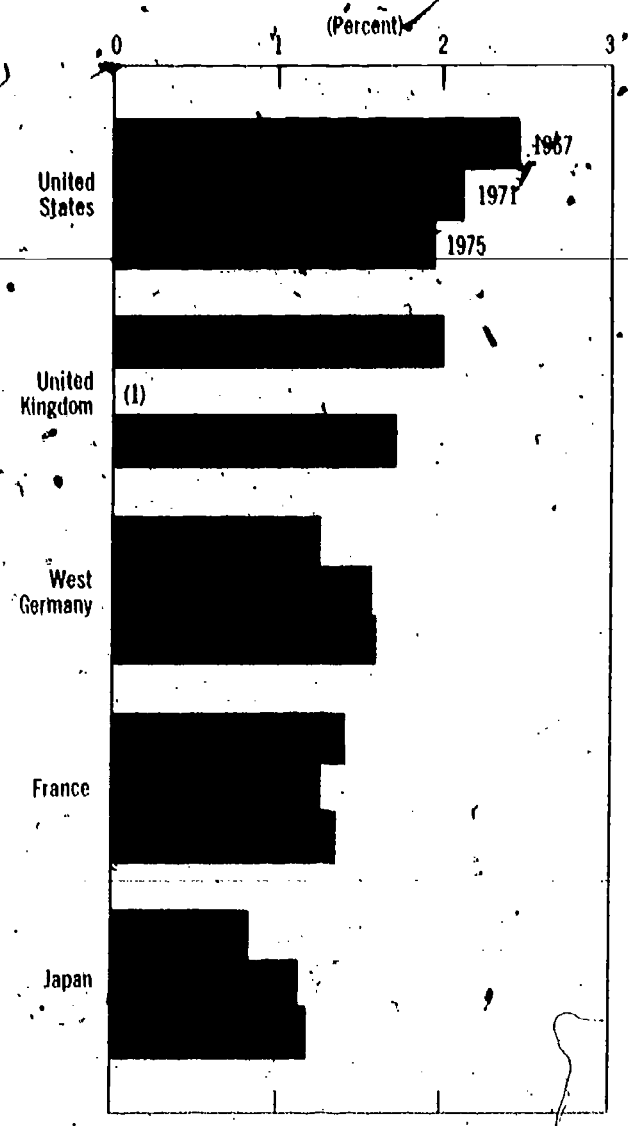
62 percent in 1967 to 49 percent in 1975, while Japan's fraction rose from 6 to 12 percent.[29] Over the same period, the amount that Common Market countries jointly accounted for went from 25 to 29 percent. Although the importance of the U.S. industrial R&D position has declined in terms of its proportion of world activity, in 1975 the United States still was responsible for about half of all OECD R&D expenditures in the electrical and electronic industry group and a third of that conducted in the chemical industry group. The United States spent $3 out of every $4 invested in aerospace R&D in the OECD area.[30]

Industrial R&D Intensity. R&D intensity measures provide information on the relative importance of R&D as an input factor to an industry in producing its output.[31] The same industries in different countries may have different levels of R&D intensity. Industrial R&D intensity can be measured by business expenditures for R&D (BERD) as a ratio of the domestic product industry (DPI).[32] Figure 1-6 shows that U.S. industry is more R&D-intensive than industries in other OECD countries. The figure also shows that of those countries under consideration, the R&D intensity of industry has increased only in Japan and West Germany.

A recent study[33] examined R&D intensities of enterprise-funded R&D in individual manufacturing industries from 1963 to 1973. It showed that within each industry, there was substantial variation across nations in the degree of enterprise-funded R&D intensity. It is possible for the R&D intensity of an individual sector or industry to remain constant while the aggregate national R&D ratio changes; the reverse situation may also occur. The size of a nation's GNP does not seem to be a factor in the rate of enterprise-funding of R&D in manufacturing among OECD countries. The study indicated that, in terms of both levels and trends, the R&D intensity of U.S. industry in the manufacturing

Figure 1-6
Industrial R&D expenditures as a percentage of the domestic product of industry: 1967-75



¹U.K. data for 1971 are not available.
REFERENCE: Appendix table 1-7.
Science Indicators—1978

[29] *Trends in Industrial R&D in Selected OECD Member Countries 1967-75* (Paris: Organisation for Economic Co-operation and Development 1978); *Science Resources Newsletter* (Winter 1977-78); the countries considered in comparisons here—the United States, France, the United Kingdom, West Germany, and Japan—are all members of OECD. *International Survey of the Resources Devoted to R&D, International Statistical Years, 1967, 1975, and 1975* (Paris: Organisation for Economic Co-operation and Development).

[30] The electrical and electronic group includes R&D on computers as well as electrical and electronic equipments; aerospace includes the manufacture of aircraft missiles and rockets, aeronautical electrical equipment and aeronautical measuring instruments; the chemical group includes chemicals proper, drugs, and petroleum products—it does not include rubber and plastic products. These industry groups are more fully defined in *Trends in Industrial R&D in Selected OECD Member Countries 1967-75* (Paris: Organisation for Economic Co-operation and Development, 1978) and *Science Resources Newsletter* (Winter 1977-78).

[31] R&D as a percentage of sales or as a percentage of value added are also often used as measures of R&D intensity. However, these data are either not available or are not available for the most recent years.

[32] Domestic product of industry (DPI) is the sum of the value added of resident producers in industry and is used as an indicator of the total resources available to industry.

[33] Sumiye Okubo, Rolf Piekarz, and Eleanor Thomas, "International Comparison of Enterprise-Funded R&D in Manufacturing." *Proceedings of a Conference on Engineering and Science Research for Industrial Development*, sponsored by the Engineering Foundation Conference in Easton, Md., October 3-7, 1977.

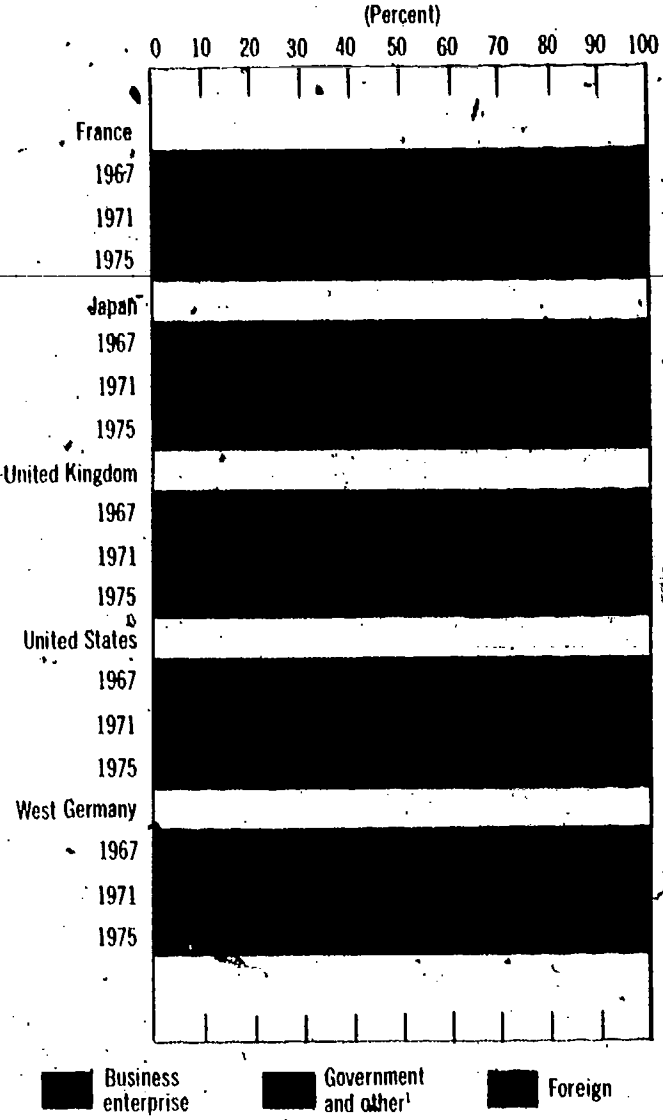
sector compared favorably with other Western industrialized nations, and that enterprise-funded R&D in the United States was more widely dispersed among industry groups than in other industrialized nations.

Government Support of Industrial R&D. Differences in funding patterns between government and industry underlie these intensity ratios and therefore can partially explain their relative levels and changes over time. In absolute terms, U.S. Government funds for industrial R&D far surpass the direct support by other Governments. In the United States, the United Kingdom, and France, the Government funds a significant portion of industrial R&D (see figure 1-7). In the United States, that proportion dropped from more than 50 percent in 1967 to 36 percent in 1975,[34] but it is still larger than that of any other OECD country. Government financial support to industrial research is relatively small in West Germany (about 18 percent of the total) even though the Ministry of Research and Technology (BMFT) provides large grants to industry for R&D in priority areas. Direct Government financial support for industrial R&D is negligible in Japan (about 2 percent of the total). These differences in funding patterns are particularly striking at the individual industry level. For instance, Government provided about half the funds for R&D in the electrical and electronic industry group in the United States and the United Kingdom, but provided only 2 percent in Japan. In France and the United Kingdom, funds from abroad were a significant part of the total source of funds (about 10 percent).[35]

Governments can support research and development through means other than direct funding. For instance, in Japan there has been extensive government-industry-banking cooperation in rebuilding the Japanese economy upon the most advanced technologies.[36] Indirect government assistance can also take the form of tax incentives, protective tariff and regulatory policies, provision of venture capital, policies on

Figure 1-7

R&D performed in the business enterprise sector by source of funds: 1967-75



[1] "Government and other" includes expenditures by Government, private nonprofit organizations, and the higher education sector.

REFERENCE: Appendix table 1-8 — Science Indicators—1978

procurement, patenting, etc. In fact, there is some evidence that suggests that these indirect mechanisms may have more of an impact on R&D and innovation than does direct government involvement.[37] Complex interactions between various government policies and the interrelationship of industries make it difficult to analyze the overall effect of a particular policy. Examination is currently being made of the impact of U.S.

[34] These decreases occurred mainly in the aerospace and electrical and electronic industry groups. See the chapters on Resources for R&D and Industrial R&D.

[35] *Science Resources Newsletter*, Organisation for Economic Co-operation and Development (Winter 1977/78), pp. 4-7. Some of these foreign funds are provided by U.S. firms to their subsidiaries and, therefore, the research results may be available to the United States.

[36] "Japan—the Government-Business Relationship," Department of Commerce, February 1972, and Terutomo Ozawa, *Japan's Technological Challenge to the West, 1950-1970, Motivation and Accomplishment* (Cambridge, Mass.: Massachusetts Institute of Technology Press, 1974).

[37] *National Support for Science and Technology: An Examination of Foreign Experience* (Cambridge, Mass.: Center for Policy Alternatives, Massachusetts Institute of Technology, 1976).

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Government policies on industrial innovation in recognition of the important and complex role that government plays.[38]

Summary of R&D Input Comparisons. In absolute terms, the U.S. investment in research and development is much greater than most countries, both in terms of expenditures and numbers of scientific and technical personnel. However, in terms of relative investments in R&D, the U.S. ratio of R&D per GNP has been declining and the ratio of R&D scientists and engineers in the labor force decreased through the early 1970's but has increased slightly in recent years. These trends in West Germany and Japan have been increasing, but now appear to be leveling off or at least slowing their rate of growth. There are marked differences between countries in the sources and allocation of R&D funds. A higher proportion of U.S. funds for R&D come from Government sources, and over half of these are aimed at defense or space objectives. In contrast, in Japan and West Germany, the majority of R&D funds are provided by industry, and funds provided by Government sources are highly concentrated in areas more directly related to economic growth. West Germany and Japan have the highest ratios of civilian R&D to GNP. Although the U.S. civilian R&D ratio has increased over its level in the early 1960's, it is still far below that of West Germany and Japan. However, in the area of energy R&D, the United States is the only OECD country to have made significant increases in Government investments since the 1973 energy crisis. Health receives a larger percentage of the U.S. Government R&D budget than it does in any other OECD country.

A closer look at industrial R&D shows that U.S. industry still accounts for approximately one-half of all funds devoted to industrial R&D in the OECD area, even though there has been some decline since the late 1960's. The United States conducts a major portion of OECD industrial R&D, particularly in the electrical and electronic, aerospace, and chemical industry groups. In the mid 1970's, the United States had a higher rate of industrial R&D intensity than other Western industrialized nations, in part due to the large degree that the U.S. Government supports industrial R&D. However, from 1967 to 1975, industrial R&D intensity decreased in the United States, while it increased in West Germany.

OUTPUTS AND IMPACTS OF R&D

What are the results of expenditures for research and development? It is impossible to quantify precisely the results of research or determine the incremental advancement of knowledge provided by an increase in R&D funding. However, scientific literature and patent indicators contribute information on R&D outputs.

This section discusses indicators of scientific and technical literature and attempts to analyze the production of new scientific knowledge and its relative influence. The literature data can help determine how much the United States contributes to world science in terms of the number and relative influence of articles written by U.S. scientists and engineers. This section also emphasizes foreign-origin patenting in the United States and patenting by U.S. inventors abroad. Patent activity is affected by a number of factors, including economic or market interests; the propensity to use patents as a method to protect intellectual property rather than trade secrets; the amount of expenditures on R&D; patent laws and regulations; and that elusive quality, "inventiveness."

Significant technological gains by U.S. trading partners, coupled with an increasingly negative U.S. balance of trade have led to concern that the United States is losing the initiative in technological innovation, and that this loss creates a negative impact on our domestic economy and our relative strength in the international economy. More needs to be known about the impacts of the economy on research and development, and vice versa, but it is generally thought that a nation's rate of productivity growth depends heavily on how it uses both domestic and foreign technology. Likewise, high productivity rates have a positive influence on profits, and therefore on the ability to conduct R&D as well as on the competitiveness of exports in general.[39] R&D-intensive goods make an important contribution to the international trade performance of many industrialized nations. Thus, this section also provides comparisons of productivity trends and indicators of international trade in products associated with R&D-intensive industries.

[38] See, for instance, the numerous reports generated by the Domestic Policy Review on Industrial Innovation, headed by the Department of Commerce, and *Government Involvement in the Innovation Process*, Office of Technology Assessment, 1978.

[39] *NSF Colloquium on the Relationships between R&D and Economic Growth/Productivity*, November 9, 1977, National Science Foundation (forthcoming).

Scientific Literature

The publication of scientific and technical findings is one of the more direct forms of scientific output. Such published reports add to the body of scientific knowledge generally accessible, and thus may stimulate new research or help to clarify ongoing scientific investigations.[40]

The indicators presented here are based on a set of over 2,100 highly cited journals.[41] This set of journals was held constant for the years under investigation in order to make valid longitudinal comparisons. Therefore, they do not reflect the growth of articles in the journals which are not "influential" as used here: the more often-cited or larger journals. Critical review of articles preceding publication is a normal policy of these journals, which helps to ensure the quality and significance of this body of literature even though the articles may vary in their theoretical and practical importance.

Scientific literature indicators have several limitations when used for international comparisons. National publishing characteristics or restraints on the number of national journals or the space available per publication can affect the number of articles and the number of references in those articles. Journal refereeing and publishing policies, as well as the availability of R&D funds for the underlying research are other factors that affect the publication of scientific and technical literature.

U.S. scientific and technical publications as a fraction of all world literature shows remarkable stability over the 1973 to 1977 period (text table 1-1). Almost 40 percent of this set of the world's influential scientific and technical journal literature is accounted for by U.S. authors. The largest U.S. share is in the field of psychology (74 percent), whereas the U.S. fraction of chemistry publications is only about 22 percent. The U.S. proportion of publications declined slightly in all fields except clinical medicine and biomedicine. The two fields which showed the largest drop were mathematics (from 48 percent in 1973 to 41 percent in 1977) and biology (from 46 percent to 42 percent). Comparison of the actual numbers of U.S. and foreign articles written shows that the number of U.S. mathematics articles decreased by 25 percent from 1973 to 1977 while non-U.S. articles in this field decreased only 12 percent. Over the same period, U.S. articles in the field of biology decreased 11 percent, while biology articles by foreign authors increased 7 percent.

Because the United States is responsible for a large proportion of the world's influential scientific and technical literature, it is to be expected that the U.S. literature would be highly cited. Relative citation ratios are one way to normalize for this factor. Citation ratios are used as an influence measure on the generally accepted assumption that the most significant literature will be more frequently cited than the routine literature. A number of studies support this assumption by showing high correlations between citations to an author's work and other measures of scientific importance such as

[40] For discussions of publications as measures of the output of science, see: G. Nigel Gilbert and Steve Woolgar, "The Quantitative Study of Science: An Examination of the Literature," *Science Studies*, vol 4 (1974), pp. 279-294; Henry Menard, *Science: Growth and Change* (Cambridge: Harvard University Press, 1971); Derek J. de Solla Price, *Little Science, Big Science* (New York: Columbia University Press, 1963); and Francis Narin, et al., *Evaluative Bibliometrics: The Use of Publication and Citation Analysis in the Evaluation of Scientific Activity* (Cherry Hill, N.J.: Computer Horizons, Inc., 1976).

[41] These 2,100 journals are from the *Science Citation Index* Corporate Tapes of the Institute for Scientific Information. Because investigations show that these journals are more representative of U.S. literature in some fields than of some other countries such as the U.S.S.R. or Japan, the emphasis here is placed on U.S. literature. See the Resources for R&D and Basic Research chapters for a discussion of literature indicators of basic and applied research in the United States.

judgments of researchers in the field.[42] However, some articles may not be readily accessible or available and, therefore, not be highly cited. Other articles may be heavily cited only for the criticisms they provoke. These cases are not generally the norm for the articles in this journal set.

The U.S. scientific literature is widely cited in the publications of all countries. Text table 1-2 shows that the citations (or references) to the U.S. scientific and technical literature are about 30 percent more than could be expected from our share of the world's literature. This citation ratio increased slightly from 1973 to 1977 indicating that foreign scientists and engineers were making relatively more use of the U.S. literature.

Over the same period, the influence of U.S. engineering and technology literature grew from 11 percent to 18 percent more than could be explained by the U.S. share of literature in that field. The citation ratio for U.S. mathematics in the world literature also rose from 14 percent to 20 percent above what could be expected, but this was due in part to the decrease in the U.S. proportion of the world's influential mathematics articles.

The most influential U.S. fields are chemistry and physics, which in 1977 received 42 and 31 percent more citations from non-U.S. articles than the U.S. proportion of literature would explain. Based on this indicator, the least influential U.S. fields were biology, psychology, and engineering, all of which, nevertheless, had an influence in the foreign literature at least proportional to their share of the world's articles.

[42] See "Citation Analysis: A New Tool for Science Administrators," *Science*, vol. 188 (1975) pp. 429-432; Jonathan R. Cole and Stephen Cole, *Social Stratification in Science* (Chicago: University of Chicago Press, 1973); Eugene Garfield, "Citation Analysis as a Tool in Journal Evaluation," *Science*, vol. 178 (1972), pp. 471-478; J. Margolis, "Citation Indexing and Evaluation of Scientific Papers," *Science*, vol. 155 (1967), pp. 1213-1219; C. Roger Myers, "Journal Citations and Scientific Eminence in Contemporary Psychology," *American Psychologist*, vol. 25 (1970) pp. 1041-1048; S. M. Lawani, "Citation Analysis and the Quality of Scientific Productivity," *Bioscience*, vol. 27 (January, 1977), pp. 26-34; and Stephen Cole, "Scientific Reward Systems: A Comparative Analysis," in Robert Alun Jones (ed.), *Research in the Sociology of Knowledge, Science, and Art* (Greenwich, Conn.: Jai Press, 1978)

Foreign Patenting

Patents represent one tangible output of research and development. Aggregate patent

Table 1-2. Citation ratios[1] for U.S. articles[2] by field for U.S. and non-U.S. authors: 1973 and 1977

Field[3]	World articles citing U.S. articles		U.S. articles citing U.S. articles		Non-U.S. articles citing U.S. articles	
	1973	1977	1973	1977	1973	1977
All fields	1.28	1.30	1.51	1.51	1.13	1.18
Clinical medicine	1.31	1.28	1.50	1.44	1.16	1.13
Biomedicine	1.36	1.35	1.49	1.45	1.26	1.26
Biology	1.13	1.17	1.36	1.41	.94	1.00
Chemistry	1.34	1.37	1.94	1.97	1.38	1.42
Physics	1.40	1.41	1.60	1.62	1.26	1.31
Earth and space sciences	1.25	1.28	1.38	1.40	1.12	1.16
Engineering and technology	1.11	1.18	1.44	1.43	.91	1.02
Psychology	1.02	1.08	1.05	1.08	.97	1.01
Mathematics	1.14	1.20	1.25	1.32	1.03	1.11

[1] A citation ratio of 1.00 reflects no over- or under-citing of the U.S. scientific literature, while a higher ratio indicates a greater influence than would have been expected from the number of U.S. publications alone. In the case of chemistry, for example, the United States received 37 percent more citations from the 1977 literature than could be accounted for by its share of the world's chemistry literature.

[2] The numbers of U.S. articles, notes and reviews for these years were 109,000 and 103,000, respectively. The citations came from 279,000 of the world's articles in 1973 and 271,000 in 1977 from over 2,100 of the influential journals of the *Science Citation Index* Corporate Tapes of the Institute for Scientific Information.

[3] See Appendix table 1-10 for a description of the subfields included in these fields.

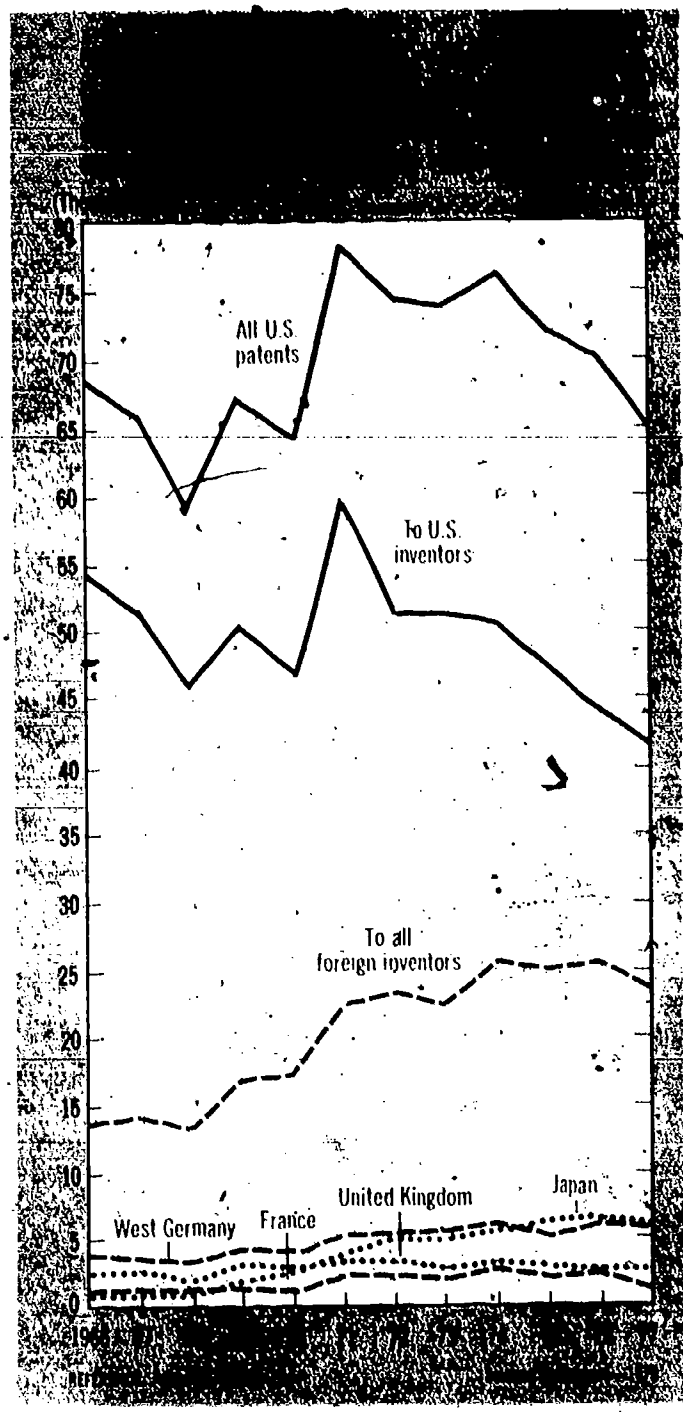
REFERENCE: Appendix table 1-11.

statistics are often used to make comparisons of inventive activity.[43] Patents have an advantage over other output measures of inventive activities in that they are available for many different countries, in greater detail, and over extended periods of time. Because a patent is often a prerequisite for marketing or manufacturing a product or licensing a process, foreign-origin patent counts may also be interpreted as reflecting expected future returns on investment in R&D. The propensity to patent in another country is probably related to the perceived potential of the market in that country.

Many factors influence patent activity. For instance, not all new ideas or inventions are patented, and those that are do not necessarily represent the same level of inventive input or economic value.[44] Patent laws and practices are not always uniform across countries and may be subject to change. For instance, filing requirements such as the rigor of tests and criteria for novelty may vary from country to country. The extent and effectiveness of protection a patent receives and the propensity to protect inventions through the use of patents also vary. Foreign-origin patents, however, must meet the same requirements of novelty as domestic-origin patents and therefore represent approximately the same degree of originality in a given country.

U.S. patents granted to U.S. citizens and organizations decreased 26 percent during the 1971-77 period, whereas foreign-origin U.S. patents increased 16 percent between 1971 and 1976 and decreased 8 percent in 1977 (figure 1-8). Thus, the proportion of foreign-origin patents of total U.S. patents increased from 20 percent in 1966 to 36 percent in 1977. The increases in foreign patenting in the United States were due largely to the increased patent activity of two countries—Japan and West Germany, which represented 23 and 26 percent, respectively, of all foreign-origin U.S. patents in 1977.

Foreign patent activity in the United States has been related to both increased foreign inventive activity and to interest in the U.S. market. For example, foreign patenting activity in the United States for selected OECD countries is significantly correlated with their industrial R&D. This correlation is especially high for the manufacturing sector as a whole and for the chemical,



electrical and electronic, and nonelectrical machinery industries. Over half of all industrial R&D occurs in these three industries. For instance, correlations of the patenting activity in the United States with the export performances of 10 OECD countries show significant correlations between patent activity and export shares, thereby suggesting that invention is an important element in international competitiveness, particularly in chemicals, capital

[43] For a detailed discussion of the significance of patents and their use as an output indicator, see the chapter on Industrial R&D.

[44] See the section on patents in the chapter on Industrial R&D for a detailed discussion of these factors.

goods, and durable consumer goods.[45] However, in terms of patent applications and patents granted, Japan is the only country examined that has shown substantial increases in its own domestic patenting activity.[46]

The increase in foreign patenting in the United States also may have been influenced by certain attractive characteristics of the U.S. patent system. U.S. patents provide protection for the introduction of a technology or product to the large and homogeneous U.S. market, whereas patents granted in another country may represent protection in a smaller market area. A U.S. patent does not have "working" requirements,[47] while those granted by most other countries do. A U.S. patent is not barred by publication or public use of the invention less than a year before the filing date. In the United States, new chemical compounds are patentable, whereas in many countries patents can protect only a particular process. There are no maintenance fees charged after issuance of a U.S. patent; yearly taxes must be paid in most foreign countries.

Patenting by U.S. corporations has decreased for reasons not completely understood.[48] One hypothesis is that there has been a decline in inventive activity in the United States. However, it is thought by some that an increasing number of inventions are not being patented.[49] It is possible that an increased emphasis by U.S. industry on short-term payoff and cost-cutting research rather than on long-term basic research[50] has led to more process rather than product innovations. Since it is generally believed that process inventions are less likely to be patented than new products, it is possible that this change in research emphasis has led to the increased use of trade secrets and decreased patenting activity in some industries. However, since the drop in U.S. domestic patenting has occurred in almost all product fields, it may well be that a decrease in the rate of production of inventions by U.S. industry has actually occurred.[51]

Foreign-origin Patents by Product Field. Foreign patents account for between one-third and one-half of all U.S. patents across a wide spectrum of fields (text table 1-3). However, many of these foreign patents are assigned to U.S. companies or individuals and are thus available for use by their U.S. owners. For instance, although 35 percent of all U.S. patents in the communications equipment product field had

[45] Keith Pavitt and Luc Soete, "Innovative Activities and Export Shares: Some Comparisons between Industries and Countries," in K. Pavitt (ed.), *Technical Innovation and British Economic Performance* (London: MacMillan), (forthcoming).

[46] Appendix table 1-13, and Dennis Schiffel and Carole Kitti, "Rates of Invention: International Patent Comparisons," *Research Policy*, vol. 7 (1978), pp. 324-340.

[47] Working requirements entail the actual utilization of a patent, for instance, for production purposes.

[48] See the section on patents in the chapter on Industrial R&D for a more detailed discussion of this topic.

[49] William D. Nordhaus, *Invention, Growth and Welfare: A Theoretical Treatment of Technological Change* (Cambridge, Mass.: Massachusetts Institute of Technology Press, 1969); L. James Harris and Irving H. Siegal, "Protection of Trade Secrets: Initial Report," *IDEA*, vol. 8 (Fall 1964), pp. 360-376. The latter reference suggests that evidence on shifts toward trade secrets has been largely anecdotal.

[50] See the section on basic research in industry of the Industrial R&D chapter and *Support of Basic Research by Industry* (St. Louis, Mo.: Industrial Research Institute Research Corporation, 1978), p. 43.

[51] See the section on patents in the chapter on Industrial R&D.

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foreign inventors, more than 15 percent of these foreign inventions are owned by U.S. companies or individuals. It is also possible that U.S. laboratory facilities abroad supported the R&D that resulted in the patented invention; U.S. affiliates abroad can assign patents for inventions produced in their firms abroad to the U.S. parent company. About 12 to 15 percent of all foreign-origin patents in the fields of chemicals and drugs and medicines are U.S.-owned; this high concentration may be related to the large U.S. investment and research activity of the chemical industry in foreign countries.[52]

Foreign participation in U.S. patenting activity seems to be highly concentrated in a few countries. For each major product field, over half of the foreign activity from 1963 to 1977 can be attributed to only three countries (figure 1-9). Nonelectrical machinery and chemicals except drugs and medicines are the two product groups in which foreign-origin patents are most often granted; they represent 44 percent of all foreign-origin patents in the United States granted during the period.

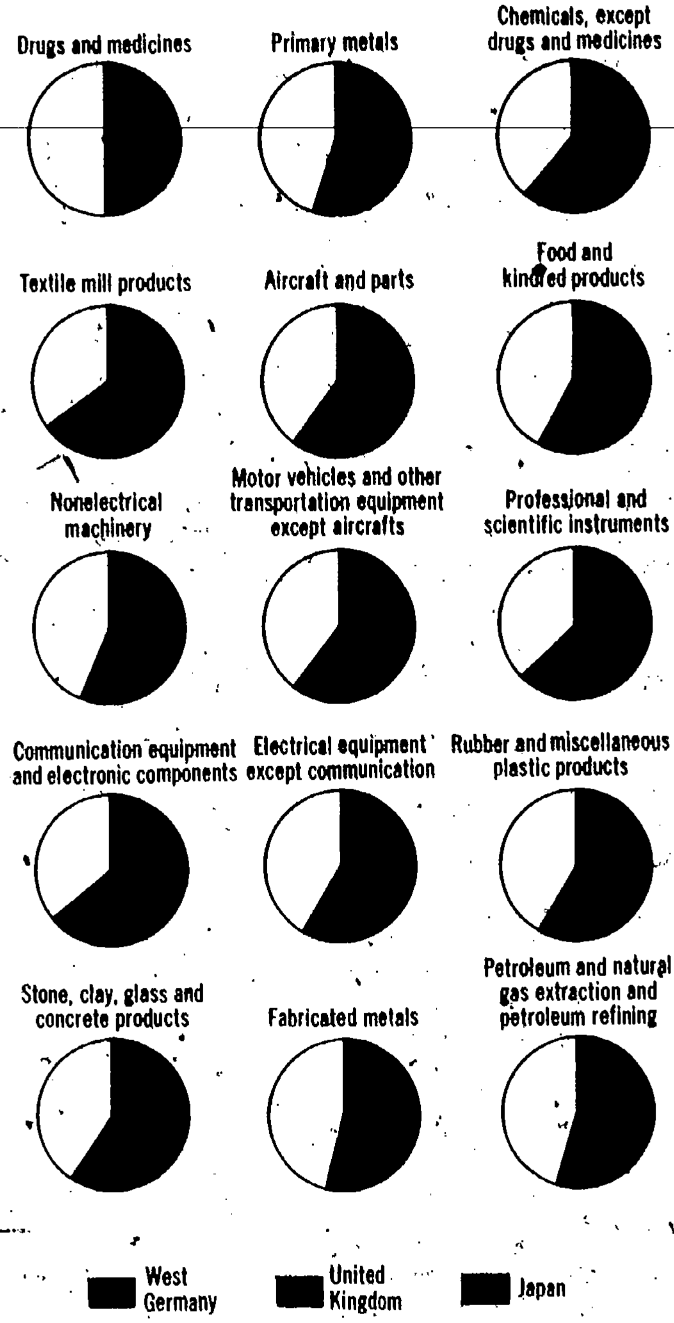
Since 1963, inventors from *West Germany* have received the largest number of foreign-origin U.S. patents (83,220). In fact, among U.S. foreign-origin patents, West Germany was first in 11 of the 15 major product fields and second in the remaining 4. West German patent activity in the United States has been concentrated in the nonelectrical machinery and in the chemicals except drugs and medicines product groups; these two product groups represent almost half of all West German patents granted by the United States.

Japan ranks second in the number of total U.S. patents granted to foreign inventors between 1963 and 1977 (61,510). Japan has the largest number of foreign patents in three product groups—communication equipment and electronic components, food and kindred products, and primary metals—and is second in an additional five product categories. Like West Germany, the product groups in which Japanese inventors have been granted the largest numbers of U.S. patents are nonelectrical machinery and chemicals except drugs and medicines. Since 1970, Japan has dramatically increased its patent activity by over 100 percent in every product field except the two areas in which it already had a

[52] In 1977, the U.S. direct investment position in the chemical and allied product industry was $13.4 billion, and the industry is one of the major U.S. performers of research abroad. (See text table 1-4).

Figure 1-9

Concentration of foreign patenting[1] in the United States for the three most active countries in each product field: 1963-77



[1] Total foreign patenting activity in the United States equals 100 percent

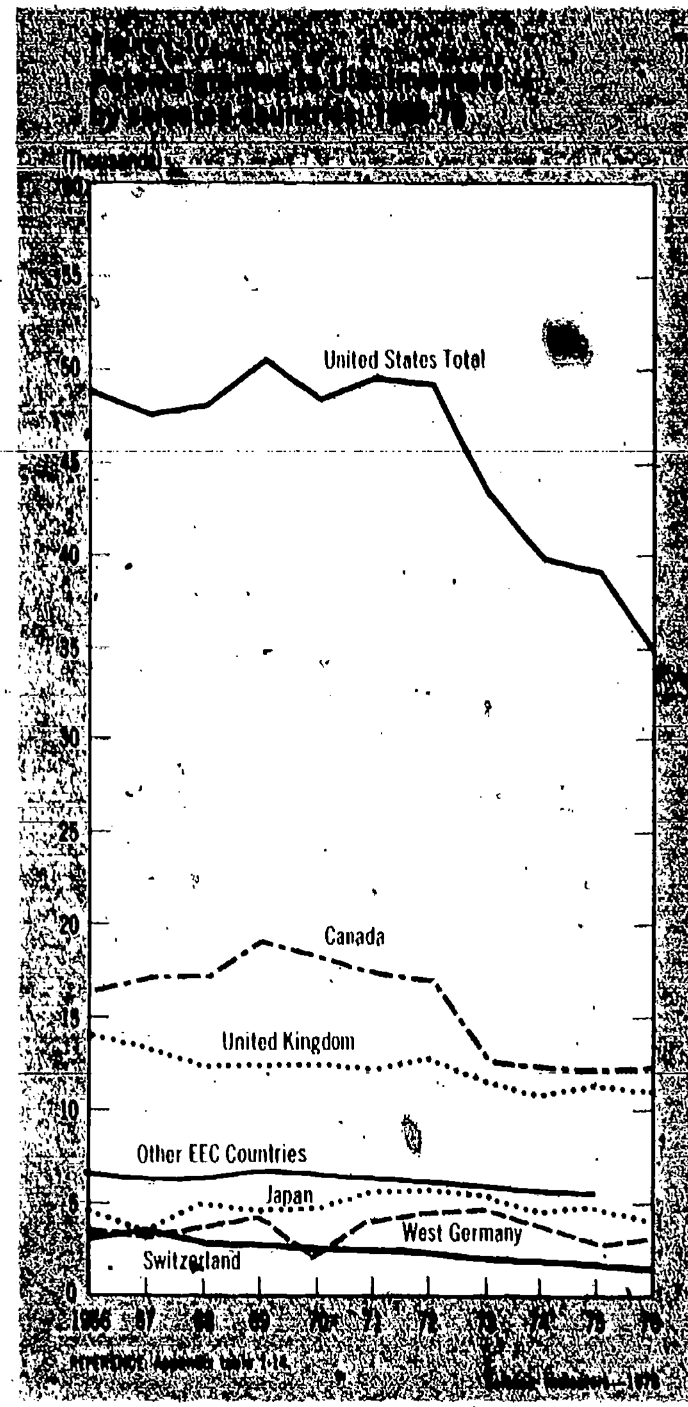
REFERENCE: Appendix table 1-13

Science Indicators—1978

large concentration of patents.[53] This finding is significant in that it seems to dispute the widespread belief that Japanese R&D efforts are narrowly focused on specific technologies. As noted previously, a nation's propensity to patent in another country may be influenced by the perceived potential of the market in that country. This assumption seems to be valid for Japan because increases in patenting activity in the 1970's correspond to the growth of Japanese exports to the United States of R&D-intensive manufactured products.[54]

The *United Kingdom* ranked third in the total number of foreign-origin U.S. patents and first in the petroleum and natural gas extraction and refining product group. In six other product groups, the United Kingdom was second (to West Germany) in the number of U.S. foreign-origin patents granted to its inventors.

U.S. Patenting Abroad. U.S. patenting has decreased abroad as well as at home (figure 1-10); the U.S. proportion of foreign-origin patents in other countries remained constant only in Japan and Switzerland.[55] From 1966 to 1976, U.S. patenting activity abroad declined almost 30 percent in ten industrialized countries.[56] However, most of this decrease occurred in the United Kingdom and Canada. The U.S. proportion of foreign-origin patents granted by the United Kingdom decreased from 44 percent in 1969 to 36 percent in 1976.[57] In fact, the actual number of patents granted to U.S. inventors by the United Kingdom has declined 22 percent over the period 1966 through 1976. The U.S. fraction of foreign-origin patents granted by Canada declined from 72 percent in 1966 to 61 percent in 1976, representing a decrease of 25 percent in the absolute number of patents granted. There was also a sharp drop (25 percent) in the absolute



number of Canadian patents granted to all other foreign countries after 1972.[58]

The decline in foreign patenting activity by the United States may be partially for the same reasons postulated for the decline in domestic patenting; that is, it could be due to a decrease in U.S. inventive activity relative to other countries,

[53] Even these two areas experienced large increases—communication equipment (81 percent) and food and kindred products (73 percent).

[54] See figure 1-17.

[55] Patents are granted to individuals or organizations, not countries. However, to simplify the discussion, country patent counts and shares are used.

[56] West Germany, Japan, the United Kingdom, Switzerland, Canada, Belgium, Denmark, Ireland, Luxembourg, and the Netherlands. Comparable data for Italy are not available. Patents granted by France are not included because of wide fluctuations in French patents granted to foreigners.

[57] The U.S. proportion of foreign-origin patents granted by the United Kingdom cannot be determined for 1966 due to data limitations.

[58] This reduction may have been caused indirectly by new controls placed on foreign companies in Canada. The high degree of U.S. patent activity in Canada has been influenced by the amount of U.S. direct investment and previous relative ease of obtaining a patent in Canada.

an increased propensity to use trade secrets instead of patents as a form of intellectual property protection, or low expectations of economic returns.

Another plausible factor influencing international patenting is the advent and spread of multinational corporations. U.S.-based multinational companies may opt to patent in the United States or have their subsidiaries patent abroad. In the latter case, the U.S. subsidiary assumes the nationality of the host country and thus the patent would be registered as a domestic patent in that country.[59] In addition, some of the factors that make patenting in the United States attractive may act as a deterrent to foreign patent filing by U.S. companies. For instance, the United Kingdom, West Germany, Switzerland, and the Netherlands require that patents be renewed after an initial period by the payment of maintenance fees; some countries have requirements that patents must be used domestically or rights to them be relinquished; British patent law requires that a patent must be worked within 3 years of issue if it is to remain in force; and the costs of obtaining and maintaining patents in some countries may be expensive for some companies, given the small market in which the patent is protected.[60]

Patent Data Overview. Foreign patenting in the United States greatly increased between 1966 and 1977, but most of this growth was due to increases in U.S. patents granted to two countries—Japan and West Germany. One reason for the increase in foreign patenting in the United States may be increased foreign inventive activity. Other reasons may be economic interest in the U.S. market or the existence of fewer restrictions to filing a patent in the United States.

The two countries responsible for the largest growth in foreign patenting in the United States—Japan and West Germany—are the very countries which have experienced the largest growth in R&D investments. These two countries are also undeniably interested in expanding their economic activity with, and in, the United States.[61] It is not clear if growth in foreign patenting in the United States by Japan and West Germany is directly related to increases in foreign inventiveness relative to the United States. In a period when U.S. domestic patenting was declining, only Japan showed substantial increases in its own domestic patenting. There is research to support the link between industrial R&D expenditures of foreign countries and their patenting in the United States. Between 1967 and 1975, industrial R&D investment of foreign countries and their patenting activity in the United States showed similar statistically significant patterns when comparing chemicals, electrical and electronic products, and most nonelectrical machinery product fields. The greatest rate of increase in both foreign industrial R&D resource inputs and U.S. patenting activity occurred in Japan, followed by Sweden and then, as a group, Italy, France, Belgium, and West Germany.

U.S. patenting abroad has declined both in absolute terms and, in some countries, in terms of the U.S. proportion of patents granted to all foreign inventors, but patents granted to the United States declined sharply in only two countries—the United Kingdom and Canada. However, for these two countries, the number of patents granted to U.S. inventors was much larger than the number of patents granted by the United States to their inventors. The decline in U.S. patenting abroad could be attributed to a number of factors, including (1) a relative decline in the U.S. inventive activity, (2) the spread of U.S.-based multinational corporations, and (3) low expectations of economic returns from foreign markets.

Productivity

Research and development are generally considered to be important factors related to increased productivity and economic growth, even though the extent to which R&D affects productivity and growth is still a topic of research. The United States has experienced a lowering of the growth rate of manufacturing productivity over the past decade, while many other nations have increased their productivity more rapidly. Concern has been expressed that a slowdown in U.S. productivity rates bodes ill for our economic

[59] Data on royalties and fees show that receipts from U.S. subsidiaries abroad have been increasing. See figure 1-13.

[60] Some of these burdens were lifted with the signing of the Patent Cooperation Treaty in June 1970, which simplified the filing of patent applications on the same invention in different countries. The treaty went into operation in June 1978 and currently has 19 member states, including the United States, the Soviet Union, France, West Germany, Luxembourg, Sweden, Switzerland, the United Kingdom, Japan, Brazil, the Central African Empire, Senegal, Madagascar, Malawi, Cameroon, the Republic of Chad, Togo, and Gabon.

[61] See the section on international trade in this chapter.

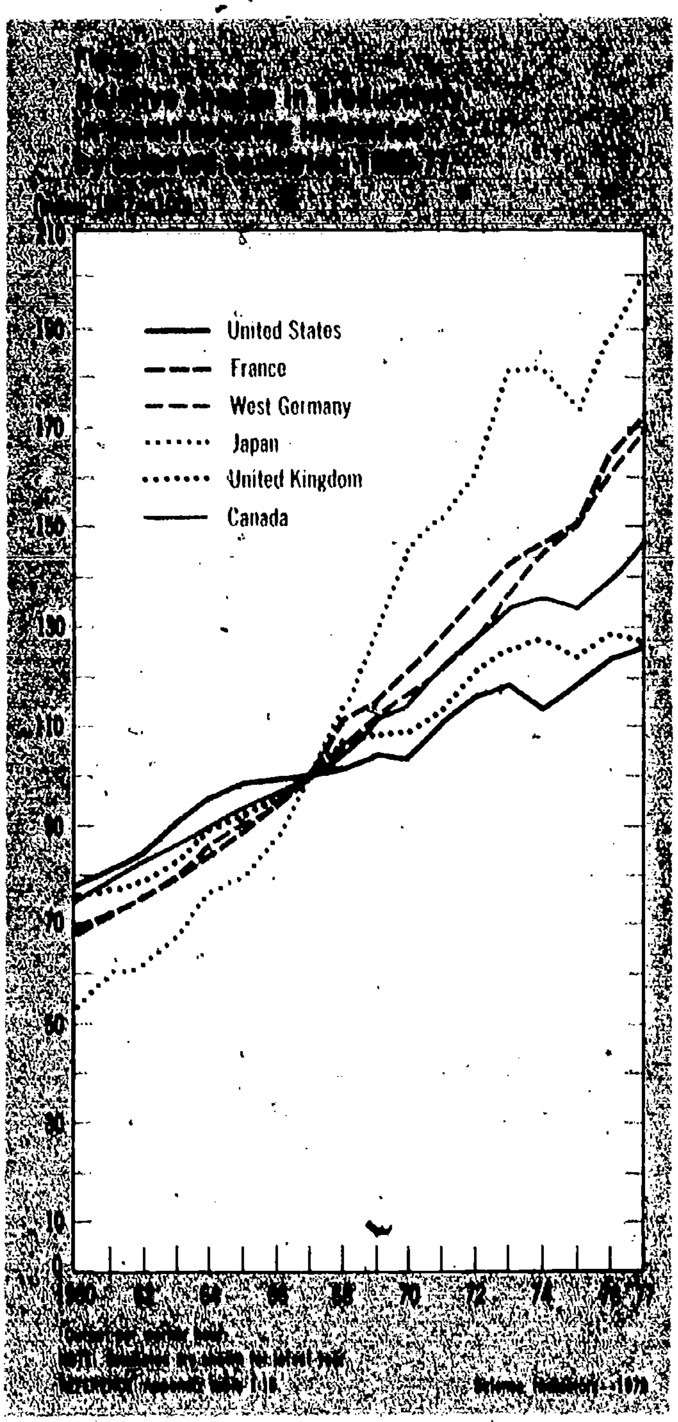
position and that this slowdown may be due in part to a waning U.S. ability to innovate.[62]

Productivity is commonly measured by output per worker-hour. Figure 1-11 shows trends of the relative changes in output per worker-hour for individual countries; it does not permit comparisons of actual productivity levels between countries. The United States had the smallest gains in productivity in the past decade among these countries (26 percent). Japan experienced the largest productivity gains over the same period (99 percent).

Productivity trends in the 1970's have been greatly affected by the 1974-75 worldwide recession when productivity fell and GNP growth slowed in most countries. The recent pattern exhibited by most countries has been typical of periods following recessions; productivity usually advances sharply in the early stages of recovery and then slows as existing capacity becomes more fully utilized.[63] Except for Canada, each of these countries experienced a substantial slowdown in productivity growth compared with 1976, the first full year of worldwide recovery from the recession. Most countries reduced employment hours as output slowed, thereby assisting their productivity growth rates. The United States was the only country to show solid gains in manufacturing employment and hours in 1976 and 1977.[64]

Part of the country differences in productivity gains may stem from the fact that the United States is at a much higher level of national production than other countries and thus may possibly be experiencing the diminishing rates of return effect often associated with an increasing scale of economic activity. Japan has the highest productivity growth rate, but its productivity level is still only about two-thirds the U.S. level.[65] In 1977, the U.S. productivity level was still greater than all other countries under comparison.

The current slowdown in U.S. productivity growth contrasts sharply to the impressive gains made in the two decades after World War II. However, the post-World War II growth rate is viewed by many as unusually high in U.S. historical terms and largely a result of the relatively good position in which the United States found itself after the war. Capital expenditures often embody new technologies and may be related to R&D advances. Reluctance of U.S. industry to invest in the latest technologies, new equipment, and plants (due in part to the pressures of inflation, interest rates, government



[62] *Technology, Trade, and the U.S. Economy*, (Washington, D.C.: National Research Council, 1978), pp. 49-70; and Statement by Elmer B. Staats, Comptroller General of the United States at hearings before the Subcommittee on Production and Stabilization of the Committee on Banking, Finance and Urban Affairs, U.S. House of Representatives, September 14, 1978

[63] Arthur Neef and Walter Larson, "International Comparisons of Productivity and Labor Costs Trends in Manufacturing," *News*, Department of Labor (USDL 78-443).

[64] Keith Daly and Arthur Neef, "Productivity and Unit Labor Costs in 11 Industrial Countries, 1977," *Monthly Labor Review*, vol 25 (November 1978), pp. 12-14.

[65] See Appendix table 1-16

regulation, and tax policies) is seen as a major cause of the U.S. productivity slowdown.[66]

Investments in R&D and technological innovation have positive, long-term effects on productivity and economic growth even though many other factors also influence productivity.[67] Many studies have tried to link R&D and economic growth from various aspects;[68] however, these studies face several formidable conceptual and empirical problems. These include insufficient understanding of the way in which research is translated into technological innovation and the way the resulting innovation then influences productivity or economic growth. The nature of this process is complicated by the long and variable time lags between stages. Other major problems include difficulties in measuring inputs and outputs in general; difficulties in isolating the positive and negative effects of specific factors on output growth; defining the appropriate time horizon to examine the expected effects; and difficultes in selecting payoff criteria.

It is difficult to quantify the contribution of research and development to productivity and economic growth. However, the conclusions of the studies that have focused on various levels of aggregation (e.g., innovation, firm, industry, and economy) together give strong evidence that the contribution of R&D is important and that the rate of return on investment in research and development is at least as high or higher than other types of investment.[69] The current slowdown in U.S. productivity growth is due to a variety of factors; one of them may be the fact that national R&D expenditures in constant dollars experienced little or no growth from 1968 to 1975.[70] If the United States had continued to devote at least the same fraction of national resources to R&D as it did in the 1960's, U.S. productivity gains might have been greater. It is likely that the increases in R&D investments in Japan and West Germany have been positive factors contributing to the large productivity gains in those countries.

International Technology Transfer and Trade

The international transfer of technology and its effects are presently being debated. International discussions have centered on the responsibilities of industrialized nations to developing countries. Domestic debate has centered on the type and amount of technology desirable to transfer, the probable overall impact on the U.S. economic and strategic position, and the need for restrictions. Another issue is whether technology transfer can and should be used as a tool for implementing broader foreign policy concerns.

The proponents of strict control of technology transfer claim that the United States is unnecessarily disseminating its technology, which they say has often resulted in loss of markets (both abroad and domestic). They argue that U.S. capital investments abroad result in the loss of job opportunities in the United States. These factors are felt to be detrimental to the U.S. economic position; in the case of trade with the Soviet Union, China, or Eastern Europe, the transfer of some technologies is considered to be harmful to the U.S. strategic position.[71]

Those favoring the unrestricted transfer of technology point out that it is virtually impossible to restrict technology, and that if the United States does not provide requested services and products, other countries will enter those markets and benefit from the sales.[72] Also, the growth of information and knowledge industries has made it increasingly possible to argue that the United States has a comparative advantage in exporting scientific and technical know-how in lieu of goods. Furthermore, sales abroad help to finance domestic R&D and the development of

[66] John W. Kendrick, "Productivity Trends and Prospects," *Technological Innovation and Economic Development: Has the U.S. Lost in the Initiative?* Proceedings on a Symposium on Technological Innovation (Washington, D.C.; Energy Research and Development Administration 1976), pp. 13-32.

[67] These factors include improved labor skills and education, increases in capital intensity, improved organization of production, imported technology, and changes in the social barriers to economic efficiency.

[68] For example, see *NSF Colloquium on the Relationship Between R&D Returns from Technology*, May 21, 1977, National Science Foundation (forthcoming).

[69] *NSF Colloquium on the Relationships between R&D and Economic Growth/Productivity*, November 9, 1977 (forthcoming).

[70] See figure 2-1.

[71] Elizabeth Jager, "Trends in the Industrial Sector," Session on International Trends in Applying Science and Technology: Problems, Opportunities and Policies, American Association for the Advancement of Science, Annual Meeting, Washington, D.C., February 14, 1978; and *U.S. Technology DOD Perspective: A Report of the Defense Science Board Task Force on Export of Technology*, Department of Defense, 1976.

[72] *Factors Affecting the International Transfer of Technology Among Developed Countries*, Department of Commerce, 1970; ~~Lowell W.~~ Steele, Statement before Joint Hearings of the Subcommittee on Banking, Housing and Urban Affairs and the Subcommittee on Science, Technology, and Space of the Committee on Commerce, Science and Transportation, U.S. Senate, May 16, 1978; and *Technology Transfer and the Developing Countries* (Washington, D.C.: U.S. Chamber of Commerce, 1977).

new products.[73] In addition, capital investments overseas often create new markets that are sometimes inaccessible to export trade due to import restrictions.

The extent of technology being transferred is difficult to measure. A recent ad hoc Meeting of Experts on the Measurement of International Technology, held in Geneva in February 1977, concluded that "Technology transfer is said to have taken place when the recipient applies effectively the technology supplied by the donor. Up to the point of effective application, only an information transfer has occurred."[74] The difficulty in determining the actual utilization of the technology further complicates efforts to quantify these activities and points out some of the uncertainties of technology transfer.[75]

Technology can be diffused or transferred in a variety of ways. The unobstructed exchange of scientific and technical literature is one of the main channels. Exchange of know-how through personal contacts—including training of personnel, permanent or temporary immigration and emigration of scientists and engineers, and attendance at technical meetings and conferences—is another important means of transfer.[76] Embodied technology is exchanged in the form of exported or imported goods and services. A holder of a patent or trademark may license the use of this intellectual property to another party; or a firm may make a direct capital investment in another country and transfer know-how to its subsidiary. Licensing and direct investment are major channels for the transfer of technology by American firms. This section describes technology flow indicators such as foreign direct investment, and receipts and payments of royalties and fees. The ability to assess completely the magnitude and significance of technology transfer is in an early stage of development. Thus, these measures are only rough indicators of the scope and direction of technology transfer because little is known about its entire magnitude and significance.

Royalties and Fees. U.S. receipts and payments of fees and royalties are commonly used as indicators of U.S. technology transferred through the sale and purchase of technical know-how—patents, licenses, manufacturing rights, and similar forms of intangible property. Royalties are payments for the use of copyrights or trademarks, and licensing fees are charges for the use of a patent or industrial process. U.S. transactions in these areas fall into two categories: those associated with U.S. direct investment (i.e., between U.S. firms and their overseas subsidiaries) and those between independent organizations, called "unaffiliated transactions." Unaffiliated receipts and payments are more likely to reflect the true value of the technology transferred because the terms of agreement between affiliated firms can be influenced by corporate considerations other than the actual value of the technology concerned; for example, multinational companies could use royalties and fees as a means of transferring profits. It is nonetheless essential to examine direct-investment-related receipts and payments because most license agreements are direct-investment related (over 80 percent). Also, it is necessary to look at both categories of transfers because the economic or technological development strategies of individual nations may influence the type and volume of transfer activity preferred. For instance, most Japanese business agreements occur in the unaffiliated category, but those of Canada are associated largely with direct investment.

Several caveats should be mentioned. Receipts and payments data do not indicate terms and conditions of license contractual agreements. Because payments are usually spread over time, data for any given year reflect returns on cumulative, as well as annual, transfers. However, because payments are usually proportional to use, current payments do provide some measure of the current use of transferred technology. These data reflect changes in both the value and number of technology transfer transactions, but the relative influences of these two factors cannot be determined because data on the number of transactions are not collected. The data include receipts and payments for transactions that do not strictly involve technology; for example, a considerable part of these royalties

[73] Edwin Mansfield, "Returns from Industrial Innovation, International Technology Transfer and Overseas Research and Development," *NSF Colloquium on the Relationship Between R&D and Returns from Technology*, May 21, 1977, National Science Foundation (forthcoming); and Edwin Mansfield, Anthony Romeo, and Samuel Wagner, "Foreign Trade and U.S. Research and Development," *The Review of Economics and Statistics*, vol. LXI (February 1979), pp. 49-57.

[74] *Report of the Ad Hoc Meeting of Experts on the Measurement of International Technology Flows*, United Nations Economic and Social Council (SC.TECH./AC.7/2:CES/AC.33/26) February 24, 1977, p. 2.

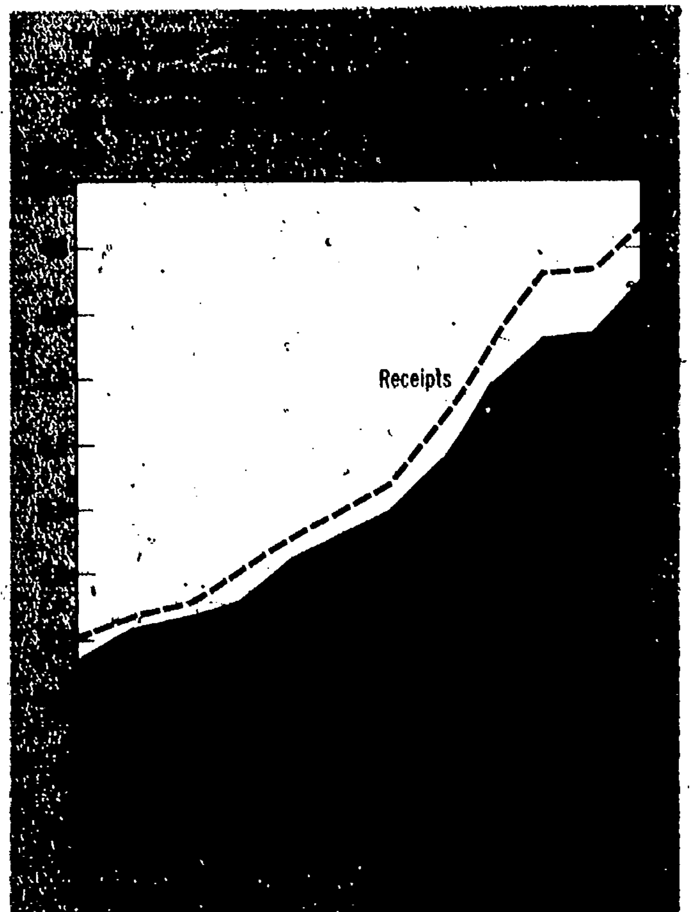
[75] What is generally termed "technology transfer" should be more appropriately labeled "technology flows." Nonetheless, since "technology transfer" has become a generalized term, we use it here.

[76] See the section of this chapter entitled "Cooperation and Interaction" for treatment of some of these types of people-oriented exchanges.

and fees are for access to trademarks (although trademark rights are usually tied to quality control restrictions on production processes and so are linked to technology).

On the whole, the United States sells more technical know-how than it buys (figure 1-12). Over the past decade the balance increased at an average annual rate of about 10.5 percent. This growth in the balance[77] of receipts of royalties and fees largely reflected transactions between U.S. firms and their subsidiaries abroad. Not only do about 80 percent of all such transactions take place between affiliated firms, but their net receipts of royalties and fees have expanded more rapidly than those from unaffiliated firms (11.3 percent average annual increase for affiliated receipts compared to about 9.5 percent per year for unaffiliated receipts). U.S. payments for transferred technology, although still only about one-tenth as large as receipts in 1977, have increased since 1966 at an annual rate of 11.1 percent. Much of the recent growth in U.S. payments for foreign technology is due to the increase in direct foreign investment in the United States.

[77] Receipts minus payments.



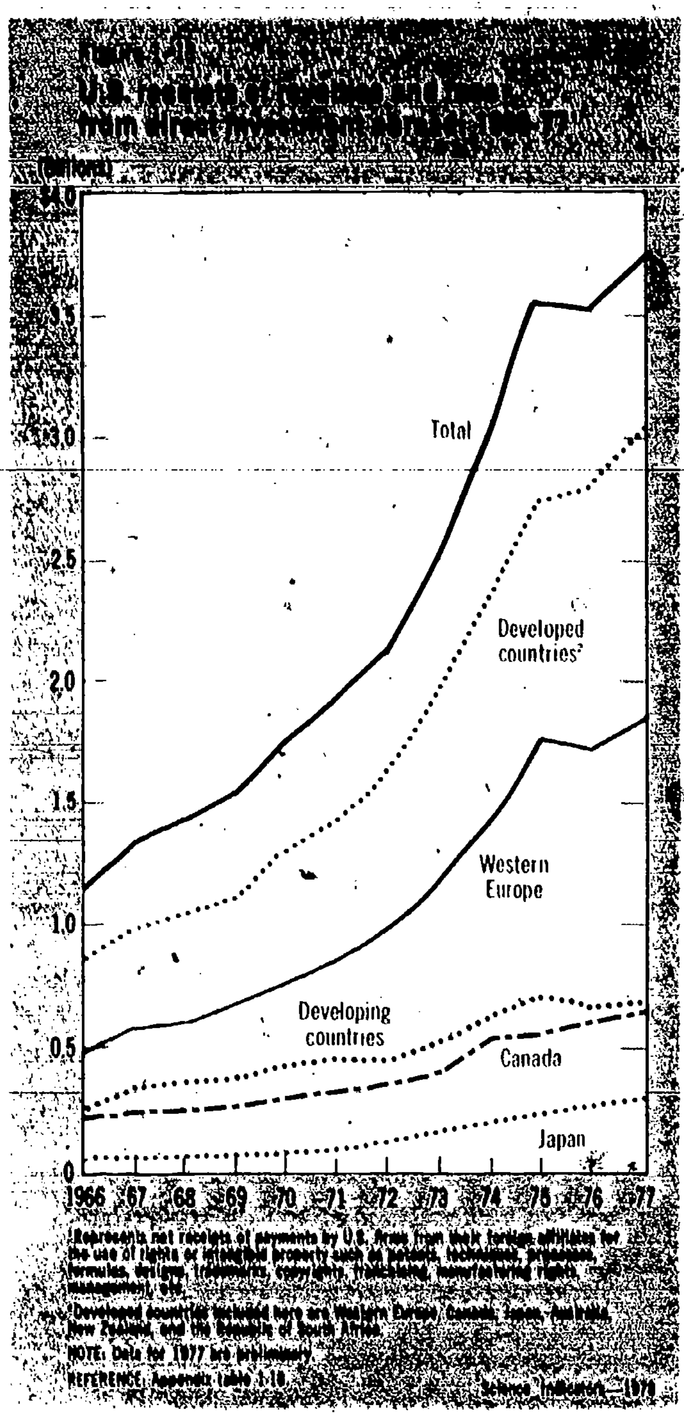
U.S. technology has been highly sought by, and transferred to, industrialized countries, particularly Western Europe (figures 1-13 and 1-14). In 1977, more than 80 percent of the affiliated and the unaffiliated purchases were made by industrialized countries. Almost half of all technology transfers went to Western Europe (about 49 percent of direct-investment-related royalties and fees and 43 percent of unaffiliated receipts).

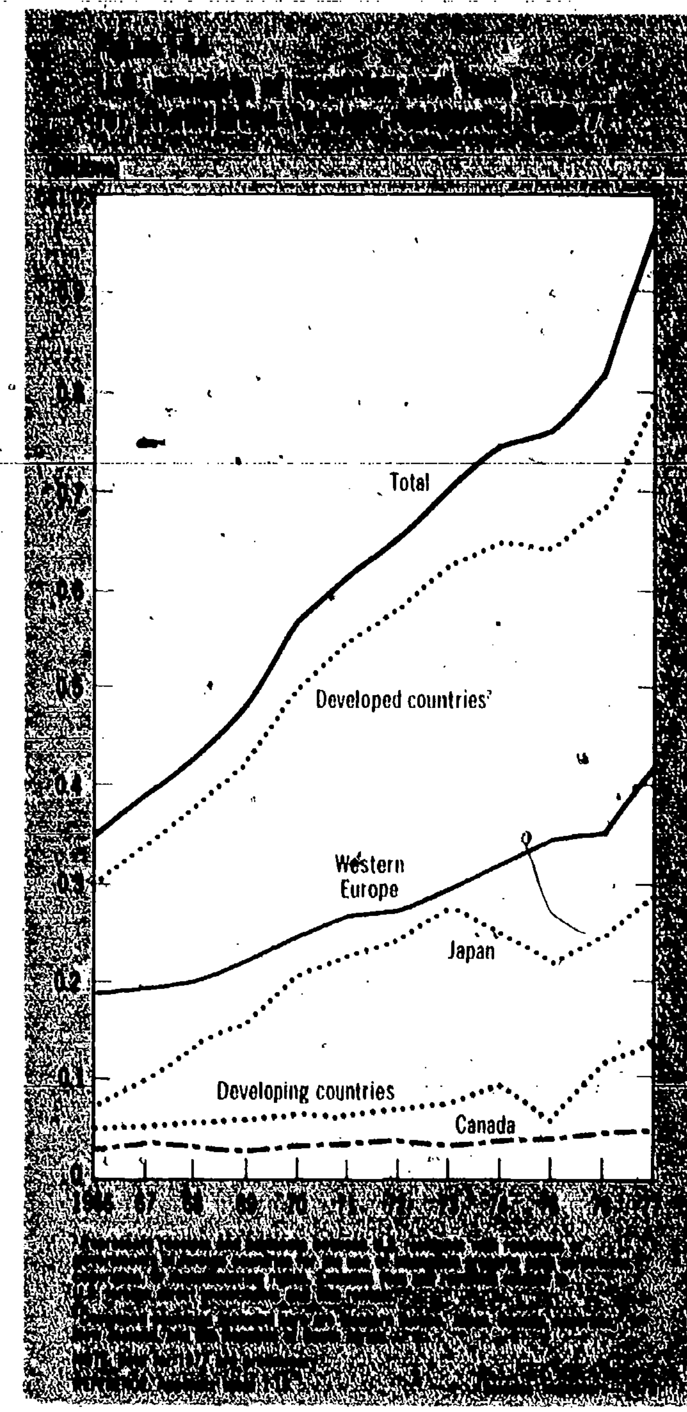
Japan has traditionally purchased U.S. know-how via unaffiliated sources, since direct foreign investment has been highly discouraged by the Japanese Government. In 1977, Japan was responsible for 30 percent of all unaffiliated U.S. receipts for royalties and fees as compared to only 8 percent of the U.S. direct-investment-related transactions. There has been a recent increase in the importance of direct-investment-related technology transfers in Japan. In 1971, direct-investment-related purchases of U.S. technology represented only about 30 percent of all technology transfers from the United States. In 1977, 51 percent of all Japanese purchases of U.S. technology through licensing agreements were related to direct investment. This reflects a liberalization of Japanese policy toward foreign capital inflow that occurred between 1971 and 1974.[78] However, a significant proportion of all unaffiliated U.S. technology transfers are to Japan; because there is likely to be less control over the utilization of technology transferred to an independent party than to a subsidiary, unaffiliated transfers to Japan may have lead to greater economic competition.

Most of the U.S. receipts of royalties and fees from Canada are direct-investment-related, indicating that U.S. firms transfer technology to Canada principally through their subsidiaries. Of total receipts from Canada in 1977, 93 percent were direct-investment-related and only 7 percent were unaffiliated. U.S. know-how is also most often transferred to developing countries via direct-investment-related transactions. In 1977, licensing agreements between U.S. firms and their subsidiaries accounted for 84 percent of total U.S. receipts from developing countries. Since 1970, unaffiliated receipts from developing countries have increased 106 percent and direct-investment-related receipts have increased 62 percent.

An overview of royalties and fees data shows that earnings from technology licensing

[78] Consultations with Dr. Terutomo Ozawa, Professor of International Economics, Colorado State University, and with representatives of the Japanese Embassy, Washington, D.C.





agreements by U.S. firms have been increasing, and U.S. technology transfers to other parts of the globe seem to be growing. If this indicator is viewed as a rough and partial measure of the value or salability of the total stock of U.S. technology, then there does not appear to be a decrease in U.S. technological earning power. Technology transfers are predominantly related to direct investment, a concentration that may suggest that U.S. firms prefer to retain equity interest in the use of their tangible property and thus maintain more control over its use. Arguments calling for restrictions of technology transfers often do not consider this equity control, nor the fact that technological improvements as a result of the transfer may flow back to the U.S. parent company. New export markets may also be created for U.S. firms through licensing agreements. This does not mean that negative effects on the U.S. economy cannot occur from technology transfers; in fact, U.S. technology is most often transferred to our economic competitors in Western Europe and Japan. The existence of a large proportion of unaffiliated license agreements with Japan may have been a contributing factor to our negative trade balance with Japan in R&D-intensive manufactured goods.

U.S. R&D Performed Abroad. Foreign direct investment frequently leads to technology transfer, although it is difficult to determine how much direct investment abroad can be considered technology transfer. Furthermore, the extent of direct investment abroad greatly affects the amount and value of licensing agreements (as discussed in the previous section) and the amount of U.S. R&D performed abroad.[79]

Steady growth has occurred in the U.S. direct investment position in manufacturing industries[80] since 1966 (11.0 percent average annual growth). In 1977, the U.S. direct investment position abroad in manufacturing industries totaled $65.6 billion and was concentrated in Canada, the United Kingdom, West Germany, and France. U.S. foreign investment in the chemical and machinery[81] industries accounts for almost half of total U.S. foreign investment abroad by manufacturing industries.[82]

A recent report describes the international spread of production of technology-intensive products that took place via U.S.-based multinational enterprises in the period from 1945 to 1975. Preliminary findings show that the rate of spread of these networks of subsidiaries and licensees reached a peak in the latter 1960's, but the spread of such networks continued at a high rate in the first half of the 1970's. Those firms considered to be R&D-intensive were found to be moving the production of their new products abroad more rapidly; these firms eventually introduced a higher percentage of their total products abroad and recorded a higher average annual transfer rate than other firms.[83]

[79] *Report of the Ad Hoc Meeting of Experts on the Measurement of International Technology Flows*, United Nations Economic and Social Council (SC.TECH./AC.7/2:CES/AC.33/26) February 26, 1977, p. 3.

[80] Since most R&D expenditures occur in the manufacturing industries, information on direct investment in these industries is provided rather than total direct investment data.

[81] Includes both electrical and nonelectrical machinery.

[82] See Appendix table 1-20.

[83] One set of data consists of a sample of 180 U.S.-based multinational enterprises. These data include a record of the specific product lines manufactured in each subsidiary. Another new set of data traces the spread of production of 406 innovations introduced in 1945 or thereafter by 57 U.S.-based multinational enterprises. In addition, 548 "immitations" (in the sense that they were new to the introducing firm but closely resembled the innovations of other firms) were also traced. See Raymond Vernon and W. H. Davidson, *Foreign Production of Technology-Intensive Products by U.S.-based Multinational Enterprises* (Boston: Harvard University), (forthcoming).

An examination of the R&D conducted by U.S. affiliates abroad shows that these expenditures have increased 41 percent between 1974 and 1977 (text table 1-4), while domestic industrial R&D expenditures and company-funded R&D expenditures increased only 31 percent over the same period. This may indicate that conditions exist that favor R&D investments abroad. However, between 1976 and 1977, R&D performed abroad by U.S. affiliates increased at about the same rate as domestic industrial R&D. Moreover, in absolute terms, domestic company-funded R&D expenditures were 13 times greater than the R&D expenditures of U.S. affiliates abroad; the foreign expenditures remained at about 7 percent of total U.S. company-funded R&D expenditures throughout the period 1974 to 1977.

The machinery, electrical equipment, and chemical industries were responsible for the largest amounts of R&D performed abroad. Research and development expenditures by the U.S. machinery affiliates increased 61 percent from 1974 to 1977; electrical equipment R&D expenditures abroad increased only 11 percent; and the chemical industry showed a substantial increase—an 81-percent increase in chemical R&D and a 105-percent increase in drug research and development.

Government regulation is often claimed to be one of the primary factors in the growth of chemical industry direct investment and R&D abroad and has been blamed for slowing the rate of introduction of new pharmaceutical products.[84] Changes in regulation do create uncertainty and inconsistency which can inhibit new capital investment and innovative activity. Excessive amounts of documentation required for compliance with some regulations can also be a deterrent.[85] It is thought that increases in the number and level of sophistication of federally mandated clinical tests have led to higher development costs. According to one estimate, the average cost of a typical new drug development overseas (United Kingdom, the Netherlands, Sweden, France, and West Germany) was only $7.5 million, compared to $11.5 million in the United States in 1972.[86] It should be noted, however, that it is very difficult to determine the costs of regulation. Not all clinical

[84] William M. Wardell and Louis Lasagna, *Regulation and Drug Development* (Washington, D.C.: American Enterprise Institute for Public Policy Research, 1976).

[85] *Technology, Trade, and the U.S. Economy*, (Washington, D.C.: National Research Council, 1978), pp. 63-68.

[86] Lewis H. Sarett, "FDA Regulations and Their Influence on Future R&D," *Research Management*, vol. 17 (March 1974), pp. 18-19.

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Table 1-4. Company R&D performed abroad by foreign affiliates of U.S. domestic companies by selected industry: 1974-77

[U.S. dollars in millions]

Industry	1974[1]	1975	1976	1977
Total	$1,064	$1,211	$1,377	$1,499
Food and kindred products	18	13	18	19
Chemicals and allied products	158	215	254	286
Drugs and medicines	76	130	146	156
Stone, clay, and glass products	7	7	(2)	(2)
Primary metals	3	9	12	11
Fabricated metals	(2)	(2)	22	25
Machinery	258	331	352	416
Electrical equipment and communication	228	232	263	253
Electronic components	4	7	9	9
Aircraft and missiles	9	5	5	6
Professional and scientific instruments	39	49	49	54
Other manufacturing industries	341	346	398	421
Nonmanufacturing industries	3	4	4	8

[1] 1974 data are based on data obtained only from the top 200 U.S. R&D-performing companies.

[2] Not separately available but included in the "Other manufacturing industries" group.

SOURCE: National Science Foundation, "U.S. Industrial R&D Spending Abroad," *Reviews of Data on Science Resources* (NSF 79-304), p 2.

tests are made merely to meet Government regulations; many would be done in the normal course of developing a new product. The costs of testing are in part trade offs which Government officials have determined are necessary to ensure increased safety and improved quality of products.

For these and other reasons, in recent years the drug industry increased foreign research and development at a higher rate than its domestic R&D investment.[37] However, costs of conducting R&D abroad have risen and Government regulations have been clarified and somewhat streamlined. Thus, between 1976 and 1977, domestic and foreign drug R&D expenditures increased at about the same rate. Other segments of the chemical industry (especially agricultural chemicals) increased their R&D programs abroad at a higher rate than their U.S. programs. Most R&D efforts abroad are generally aimed at developing products that meet local conditions and needs, market tastes, or use local inputs. For these reasons, it is anticipated that increases will generally continue in foreign R&D in many industries in the near future.[38]

Foreign R&D Carried Out in the United States. In recent years, the amount of foreign investment in the United States has accelerated, increasing at an average annual rate of about 13.5 percent since 1973 and reaching a total estimated value of $34.1 billion in 1977. In 1977, three countries contributed almost 60 percent of the total foreign investment in the United States: the Netherlands (21 percent), the United Kingdom (19 percent), and Canada (18 percent). West Germany and Switzerland each represented about 7 percent of the total, and Japanese and French direct investments in the United States were each only 5 percent of the total foreign investment. Foreign direct invest-

[37] In 1975, there was a large increase in foreign drug R&D corresponding with new Food and Drug Administration regulations which clarified which tests conducted abroad would be acceptable to meet U.S. regulations.

[38] "Industrial R&D Rises 11% Between 1976 and 1977," *Science Resources Studies Highlight*, National Science Foundation (NSF 79-302), p. 6, and "U.S. Industrial R&D Spending Abroad," *Reviews of Data on Science Resources*, National Science Foundation (NSF 79-304), pp. 1-2.

ment was concentrated in manufacturing (40 percent), trade (21 percent), and petroleum extraction (19 percent).[89]

One of the main questions raised by the sudden increase in foreign investment in the United States is whether or not the result would be an undesirable outflow of U.S. technology. Although some foreign investments have permitted the United States to take advantage of technology that originated abroad, there have also been cases in which foreign firms have purchased American companies and have thereby gained access to U.S. technology which was subsequently transferred or controlled from abroad. Although both inflows and outflows of technology occur, recent studies have concluded that foreign companies invest in the United States more often to take advantage of the large, politically unified, and stable market than to have access to U.S. technology.[90] These studies also suggest that the United States probably receives a net technological benefit from this phenomenon because foreign companies introduce their most sophisticated technologies and new management and marketing techniques in order to compete effectively in the U.S. market; foreign investment in the United States also often involves the acquisition or establishment of manufacturing facilities and R&D facilities.

U.S. subsidiaries of foreign companies spent $813 million on R&D in 1974 (text table 1-5). This figure is almost 80 percent of the amount that U.S. affiliates spent for R&D activities abroad (see text table 1-4). Three-quarters of this R&D was conducted by European-owned affiliates. About 70 percent of these R&D expenditures were made by manufacturing industries, primarily chemicals and metals.[91]

Foreign direct investment in the United States is playing an important role in R&D in the pharmaceutical industry. Foreign direct investment in the U.S. pharmaceutical industry is usually accompanied by a full range of R&D activity within the United States, largely to meet comprehensive Government regulations. In many cases, R&D conducted by U.S. subsidiaries of foreign pharmaceutical companies has contributed to the availability of many commonly used drugs (e.g., Valium, Lasix, Imuran, and Adriamycin). American-based companies often play an important role in testing foreign drugs. Today the pharmaceutical industry is international in scope, with the United States often the recipient of pharmaceutical product technology and a source of pharmaceutical testing technology.[92]

[illegible]

U.S. International Trade in R&D-Intensive Manufactured Products. The U.S. international trade position depends on a number of factors,

[89] William K. Chung and Gregory G. Fouch, "Foreign Direct Investment in the United States, 1977," *Survey of Current Business*, vol. 58 (August, 1978), pp. 39-52.

[90] *Technology Transfer from Foreign Direct Investment in the United States* (Washington, D.C.: National Research Council, 1976); and W. Halder Fisher, *Technology Transfer as a Motivation for United States Direct Investment by European Firms* (Columbus, Ohio: Battelle Memorial Institute, 1977).

[91] *Foreign Direct Investment in the United States*, Department of Commerce, vol. 1, 1976, pp. 53-55.

[92] *Technology Transfer from Foreign Direct Investment in the United States*, (Washington, D.C.: National Research Council, 1976), pp. 11-26.

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including the prices of its products determined by labor, capital and other input costs, factor productivity, exchange rates, tariffs, and quotas. Other factors include the effectiveness of its international marketing, trade arrangements with other countries, terms of delivery, insurance, credit, and seller reputation. Product characteristics and uniqueness are also important considerations; in the United States, these are major factors. R&D and innovation have assumed an important role in the U.S. trade position.[93] A recent study compared U.S. exports with those of other countries and concluded that the United States is the only country with an unusual concentration of its manufactured goods in exports that are "R&D-intensive."[94]

It is generally accepted that the role of technology in U.S. trade is quite important.[95] Nonetheless, it cannot necessarily be assumed that increased R&D expenditures will automatically improve the U.S. trade position. In fact, since industries are linked in various ways (e.g., through interconnected markets for productive factors, behavior of exchange rates, and endogenous elements of U.S. and foreign commercial policies), R&D activities may improve the competitive position of one industry while aggravating or causing economic problems in other industries; for example, by diverting capital and labor and forcing up the price of some productive factors. However, increased R&D in a certain industry can also have positive spillover effects by providing superior and/or lower cost inputs.[96] Increased R&D can also have a positive effect on the overall economy by generating new industries and forcing stagnant industries to become either more dynamic or to tighten their operations.

[93] Rachel McCulloch, *Research and Development as a Determinant of U.S. International Competitiveness* (Washington, D.C.: National Planning Association 1978), p. 20.

[94] Regina K. Kelly, "The Impact of Technological Innovation on International Trade Patterns," *Staff Economic Report*, Office of Economic Research, Department of Commerce, 1977. It should be noted that the levels of R&D associated with various products in the United States are not necessarily the same as those in other countries, and that the product group mix within product categories may not be comparable for all countries.

[95] Raymond Vernon, "International Investment and International Trade in the Product Cycle," *Quarterly Journal of Economics*, vol. 80 (May 1966), pp. 190-207; and Raymond Vernon (ed.), *The Technology Factor in International Trade* (New York: Columbia University Press, 1970).

[96] Rachel McCulloch, *Research and Development as a Determinant of U.S. International Competitiveness* (Washington, D.C.: National Planning Association, 1978), pp. 24-26.

The relationship between R&D and international trade can be analyzed in part by examining the U.S. trade balance in manufactured product categories classified in terms of the relative levels of R&D investment. R&D-intensive product fields are defined here as those corresponding to industries with an average of (a) 25 or more scientists and engineers engaged in R&D per 1,000 employees and (b) total R&D funding amounting to at least 3.5 percent of net sales.[97] The product groups designated as R&D-intensive[98] are (1) chemicals, (2) electrical machinery, (3) nonelectrical machinery,[99] (4) aircraft and parts, and (5) professional and scientific instruments. All other manufactured products are considered non-R&D-intensive by these criteria.

At a time when the overall trade balance of the United States is showing large deficits (-$26.5 billion in 1977), the importance of R&D-intensive trade in manufactured goods has greatly increased. The trade balance (exports minus imports) for R&D-intensive manufactured products has been positive for at least two decades (figure 1-15).[100] The most dramatic increase (166 percent) was between 1972 and

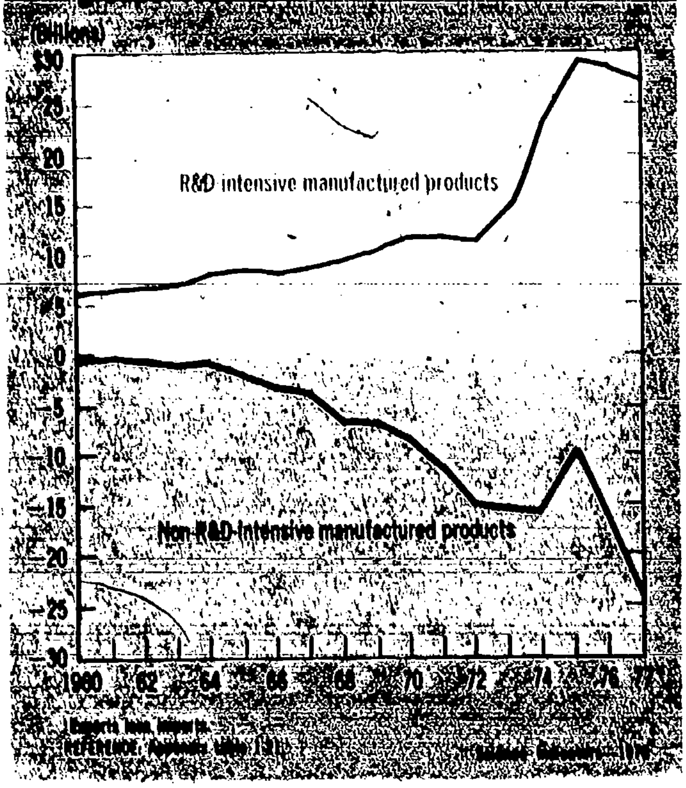
[97] Products and industries, although fairly closely correlated at the gross level, do not perfectly coincide, with the result that not all products manufactured by a high-R&D-performing industry can be considered R&D-intensive products. Examination of data on applied R&D by product field in manufacturing, however, shows that these fields are among the top recipients of applied R&D expenditures. See *R&D in Industry, 1976*, National Science Foundation (NSF 78-314), pp. 58-59. The Department of Commerce has developed two other classifications of R&D-intensive categories. One is more aggregated than the definition used here; the other is less aggregated since it is based on a product rather than industry basis, but it has the disadvantage of time delays in the availability of the data. An analysis and comparison of the three can be found in the *International Economic Report of the President*, Council on International Economic Policy, Executive Office of the President, 1977, pp. 120-124; and Regina K. Kelly, "Alternative Measurements of Technology-Intensive Trade," *Staff Economic Report*, Office of Economic Research, Department of Commerce, 1976.

[98] The U.S. industries associated with these products met both of these criteria during the 1961-76 period. From 71 to 90 percent of all R&D related to these products was conducted by the five corresponding industries.

[99] Computers are included in the nonelectrical machinery SIC code by the Department of Commerce and so are included in that product field in this report as well.

[100] It should be pointed out that petroleum imports, while a major cause for increasing deficits in the overall U.S. trade balance, are not considered manufactured goods and so are not responsible for the poor performance of non-R&D-intensive manufactured goods. For the same reason, agricultural products are not included in the trade indicators presented here but are briefly treated in the text following the discussion of figure 1-16.

Figure 1-15
U.S. trade balance in R&D-intensive and non-R&D-intensive manufactured product groups: 1960-77

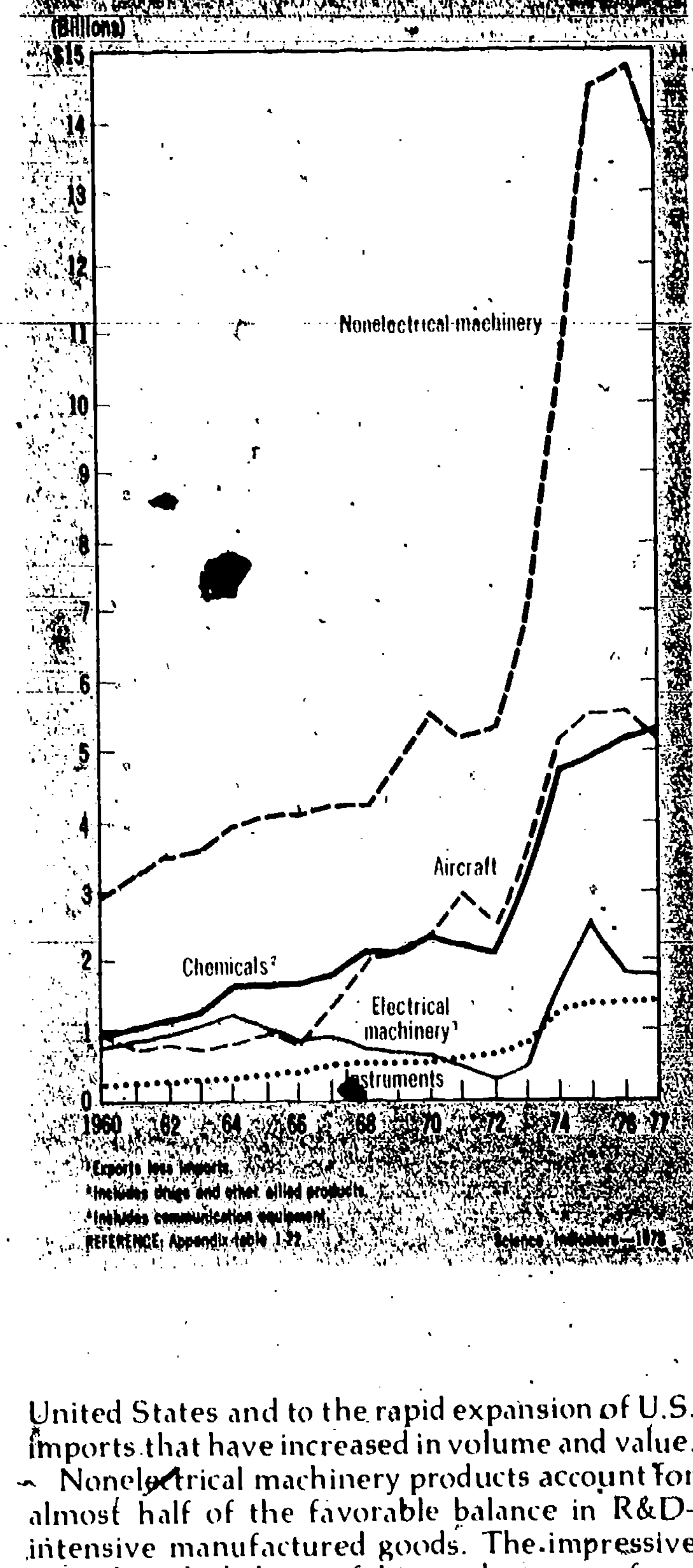


1975. The trends in U.S. foreign trade presented here were influenced by recent adjustments in the international monetary system. Since 1975, there has been a 6-percent decrease in this balance, largely due to increased imports of consumer electronic goods and the drop in value of the U.S. dollar, especially vis-a-vis the Japanese yen and West European currencies. Even so, the 1977 trade balance for R&D-intensive manufactured products was almost 5 times greater than that of 1960 and 2½ times the 1972 level.

In contrast, the trade balance for non-R&D-intensive manufactured goods was near zero in the early 1960's but declined from 1964 to 1977, when the deficit registered for these groups was $24.5 billion. Most of the recent increases in deficits of non-R&D-intensive trade were due to sharp increases in steel imports from Japan and Western Europe and importation of foreign automobiles.

The favorable U.S. trade balance in products from specific R&D-intensive industries is shown in figure 1-16. Many of these products have experienced no growth or actual decreases in their balance since 1975. This is due to both the slow and uneven economic growth outside the

Figure 1-16
U.S. trade balance[1] in selected product groups: 1960-77



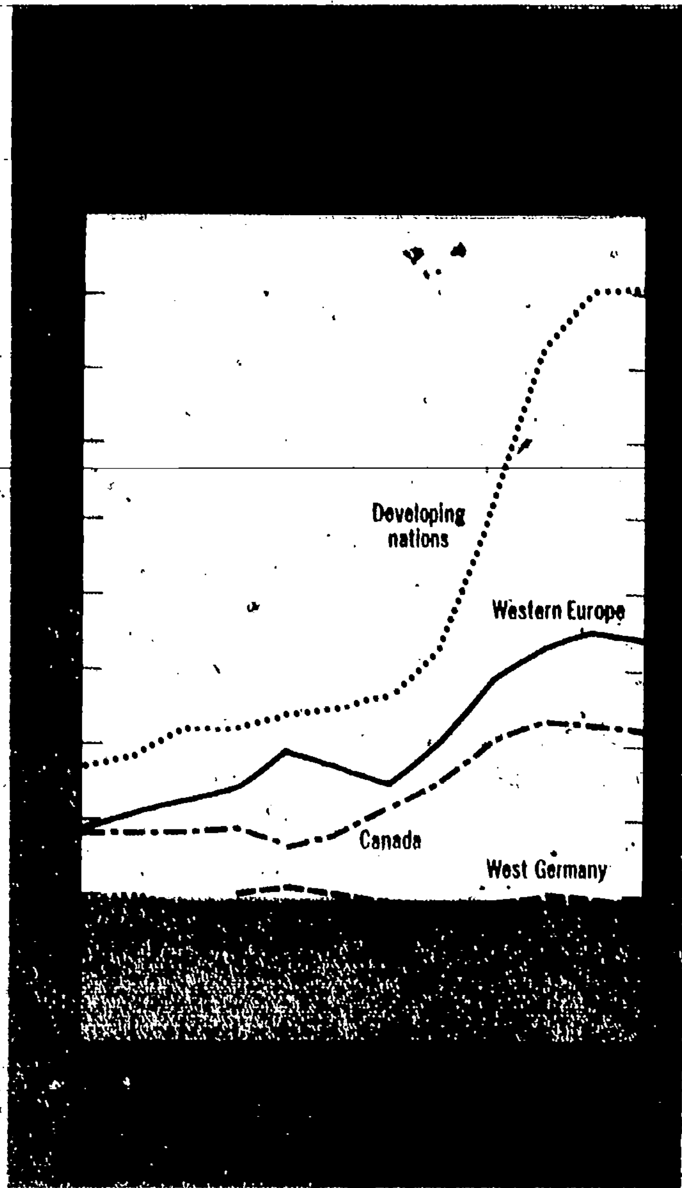
United States and to the rapid expansion of U.S. imports that have increased in volume and value.

Nonelectrical machinery products account for almost half of the favorable balance in R&D-intensive manufactured goods. The impressive growth in the balance of this product group from 1972 to 1975 (136 percent) was largely a result of increased exports of electronic computers, internal combustion engines, construction equipment, and mining and well-drilling machinery. This growth tapered off in 1976 and actually decreased 8 percent in 1977.

The chemicals and the aircraft and parts product groups each contribute about one-fifth of the positive balance in R&D-intensive manufactured products. Unlike most U.S. product groups, chemical exports continued to grow in 1977, largely as a result of increased volume rather than increased prices. The increase in net exports of chemicals since 1972 has been paced by exports of plastics and shipments of organic compounds, particularly those used in making drugs and agricultural chemicals.

U.S. agricultural productivity is highly influenced by R&D and technological advances, but because it is not a manufactured product, agriculture has not been included in the trade balance presented here. The leading role of U.S. agriculture is due at least in part to the contributions of science and technology in such areas as the development of new hybrids; the utilization of irrigation techniques; the improvement of fertilizers, pesticides, and herbicides; and the widespread mechanization of production.[101] Agricultural exports significantly affect the position of the U.S. trade balance. In 1977, the value of agricultural exports reached a record level of $14.2 billion, and agricultural commodities registered a $10.3 billion positive trade balance.[102]

The favorable position of the United States in R&D-intensive manufactured products is based primarily on net exports to all major U.S. markets with the exception of Japan and most recently, West Germany.[103] The U.S. trade balance in these products is shown in figure 1-17 for selected areas and countries. In 1977, the developing countries accounted for 58 percent of the positive R&D-intensive U.S. trade balance; nonelectrical machinery and chemicals were particularly large net exports for the United States in trade with these nations. In trade with Western Europe (25 percent of the positive balance), the United States registered its largest net exports in the areas of aircraft and nonelectrical machinery (particularly in computers). U.S. net exports to Canada were concentrated in the areas of electrical and nonelectrical machinery.



A trade deficit in R&D-intensive manufactured products developed with Japan in the mid-1960's and has persisted through the 1970's. From 1974 to 1977, this deficit increased 529 percent (84.6 percent average annual increase) and reached over $3.5 billion, largely due to a 76-percent increase in U.S. imports from Japan. The deficit occurred primarily in electrical machinery products (particularly consumer electronics) and to a lesser degree in professional and scientific instruments and nonelectrical machinery. Only in the areas of chemicals and aircraft is the United States a significant net exporter to Japan. Although the Japanese Government has agreed to encourage imports from the United States, the trend toward an increasing trade deficit with

[101] *Agricultural Production Efficiency* (Washington, D.C.: National Academy of Sciences, 1975).

[102] *Overseas Business Reports*, Department of Commerce, Domestic and International Business Administration, June 1978.

[103] For a more complete discussion of these relationships, see Keith Pavitt, " 'International' Technology and the U.S. Economy: Is There a Problem?" in *The Effects of International Technology Transfers on U.S. Economy*, National Science Foundation, Papers and Proceedings of a Colloquium (NSF 74-21), pp. 59-77.

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Japan is likely to continue in the near-term because of the high U.S. demand for Japanese goods, coupled with the sharp appreciation of the Japanese yen. However, since Japanese imports become increasingly expensive as the dollar depreciates, in the long run import substitution may occur, and if so, it would help the U.S. trade balance.

Summary of Outputs and Impacts

Although aggregate patent statistics are affected by many factors, they are often used to compare scientific and technological activity. Foreign patenting activity in the United States has increased from 20 percent in 1966 to 36 percent in 1977, with the largest numbers of foreign-origin U.S. patents being granted to inventors from West Germany, Japan, and the United Kingdom. During this same period, U.S. domestic patenting activity declined while domestic patenting substantially increased in Japan. Increased foreign patenting in the United States may be influenced by a variety of factors, including the commercial attraction of the U.S. market and the increased R&D and inventive capabilities of foreign nations.

The production of scientific and technical literature is one of the more direct outputs of research and development. The U.S. proportion of the world's influential journal literature remained steady between 1973 and 1977 at about 40 percent. In 1977, U.S. scientific and technical articles were cited 30 percent more than could be explained by their share of the world's literature; this indicates that U.S. research and development is relatively influential in world science.

R&D and technological innovation have positive long-term effects on productivity and economic growth. Relative productivity rates in turn affect the U.S. trade position. Aggregate U.S. productivity levels exceed those of most other countries. However, U.S. productivity gains over the past decade were the smallest of all the countries under consideration. Although productivity is affected by a variety of factors, it is possible that, had the United States continued to invest the same fraction of national resources in R&D as it did in the early and mid-1960's, U.S. productivity gains might have been greater.

Data on international technology transfer transactions and R&D-intensive trade indicate that U.S. output of R&D and technological innovation are highly competitive and are related to national economic strength. The positive contributions of science and technology to the U.S. trade balance are undeniable; however, since 1975, there has been a 6-percent decrease in this balance.

INTERNATIONAL INTERACTION AND COOPERATION

International scientific cooperation contributes to the advancement of world science, diffusion of knowledge, and improvement of human understanding and international relations. There are many tangible benefits to be gained from cooperative scientific activities. Direct economic value can result from cost-sharing scientific programs, task-sharing in solving problems, avoiding research duplication, obtaining access to unique foreign research facilities, and building on foreign research. Other benefits stem from concerted action in research to improve global or regional problems such as health and environmental conditions.

Time and resources can be conserved by early access to research data that point out promising areas of research and signal areas that may not currently be promising avenues of investigation. The direct exchange of methods and experimental results (e.g., through international meetings and the conduct of research abroad) can often act as a synergistic impetus to domestic scientific research by providing fresh outlooks and new perspectives. Nevertheless, possible drawbacks to international cooperation include security problems and time delays due to increased organizational complexities. Increased economic or scientific competition may also result, but competition also often encourages increased or intensified efforts.

In light of the benefits and costs, the question of whether or not the United States is appropriately engaged in international scientific activities should be continuously examined. As scientific capabilities of other nations grow and the costs of conducting research rise, the United States should and has encouraged international collaboration and division of labor in scientific research. Indeed, many scientific goals would be difficult or impossible to meet without the advantages of international cooperation. The United States has long been involved in a number of multinational efforts to meet large-scale scientific problems such as the International Geophysical Year (IGY) and the Global Atmospheric Research Project (GARP). Although there are numerous cooperative efforts between the United States and other countries, there are many areas in which expanded cooperation would be beneficial.[104] Plans are being made with the European Space Organization for a space mission to jointly examine solar regions of the sun and to increase cooperation in energy-related R&D. Fusion energy research facilities, high energy physics accelerators, and deep-ocean oil drilling are other areas which are candidates for further joint efforts.[105]

International scientific cooperation has traditionally helped to bridge political, cultural, and economic barriers between countries.[106] Scientific and technological relationships played a critical role in the normalization of our relations with the Peoples Republic of China. This is an example of how international cooperation can help achieve both diplomatic and scientific goals. The United States has been involved in assisting countries in building up their scientific and technological capabilities. Preparations for the forthcoming United Nations Conference on Science and Technology for Development have served to focus attention on the role of science and technology in meeting world problems and the ways in which the United States can redirect and intensify its efforts to bridge economic gaps through scientific and technical assistance.[107] The following section discusses some indicators of international scientific cooperation and interaction.

International Academic Cooperation

U.S. universities and colleges have contributed greatly to the building of the world's scientific and technological capabilities.[108] The types of interaction include institution building, cooperative R&D, developing U.S. capabilities in problem areas of concern to developing countries, and the education and training of students here and abroad.

Close to 60 percent of all the foreign students studying in the United States in 1975 were in scientific and technical fields (text table 1-6).

[104] Appendix table 1-24 identifies examples of possible areas of increased scientific cooperation with Western Europe. These are those in which Western Europe efforts are thought to be at a level of excellence comparable to that in the United States, or in which achievements were linked to the availability of unusual instrumentation or facilities. They were identified by a survey of National Science Foundation program officers (unpublished).

[105] "Presidential Message to the Congress on Science and Technology," March 27, 1979.

[106] For an extensive discussion of how science and technology create both opportunities and problems in the achievement of diplomatic goals see *Science Technology and American Diplomacy*, Committee on International Relations, U.S. House of Representatives, 1977.

[107] *U.S. National Paper prepared for the 1979 UN Conference on Science and Technology for Development*, Department of State, 1979; and *U.S. Science and Technology for Development: A Contribution to the 1979 UN Conference*. (Washington, D.C.: National Research Council, 1978).

[108] For a complete review of this involvement in developing countries, including possible future directions, see Robert P. Morgan, *The Role of U.S. Universities in Science and Technology for Development: Mechanism and Policy Options* (St. Louis, Mo.: Washington University, 1978).

More than half of these were from Asia, 16 percent from Latin America, and 14 percent from Africa, while students from Europe represented only 7 percent of all foreign students receiving training in science and technical fields in the United States.[109] The regional profiles show a variety of field concentrations. Within the science and technical fields, engineering had the highest percentage of students in four of the six regions.

The proportion of S&E doctoral degrees awarded annually in the United States to foreign citizens has increased from an estimated 7 to 9 percent before the 1960's to about 15 percent in the mid-1970's,[110] with the highest proportions appearing in the natural sciences and engineering (figure 1-18). The fields with the highest level and fastest growth of foreign doctoral recipients are agricultural sciences and engineering. Medical sciences have a high percentage of these foreign students, but growth in foreign participation has leveled off in the 1970's. Training in these three fields is an important factor in helping to meet the economic and basic needs of the world's population.

Data on postdoctoral students show that almost one-third of those working in science and engineering fields are from foreign countries. In engineering, more than half of all postdoctoral students training in the United States are foreign citizens, as are more than 40 percent of those in physical sciences (text table 1-7).

[109] See Appendix table 1-25.

[110] *A Century of Doctorates: Data Analysis of Growth and Change* (Washington, D.C.: National Academy of Sciences, 1978), p. 47.

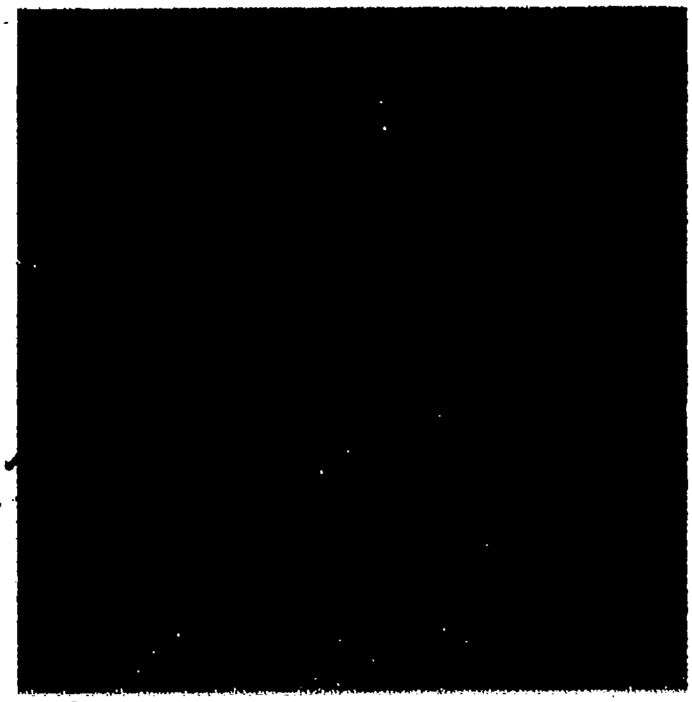
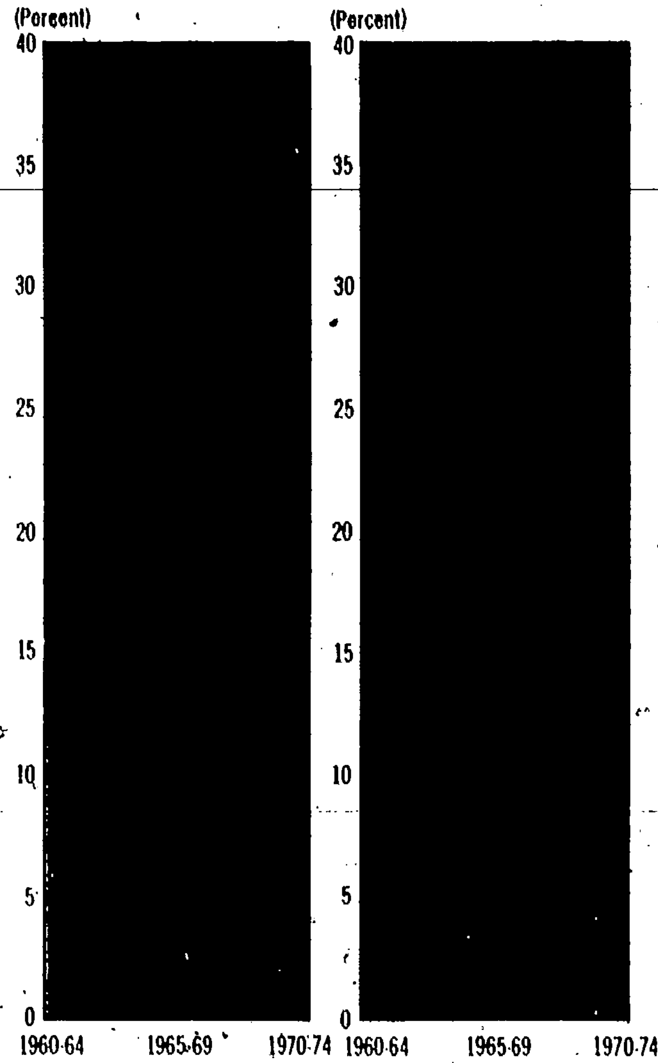


Figure 1-18

Doctoral degrees awarded to foreign students as a percent of all doctoral degrees from U.S. universities by field: 1960-74



REFERENCE Appendix table 1-26

Science Indicators—1978

U.S. universities are involved in a variety of internationally cooperative activities in addition to the training of foreign students in the United States. U.S. universities have contributed to the development of many foreign universities. A recent survey[111] of doctorate-granting colleges and universities found that of the 203 responding institutions, nearly two-thirds had at least some science and engineering faculty members who

[111] Irene L. Gomberg and Frank J. Atelsek, *International Scientific Activities at Selected Universities 1975-76 and 1976-77* (Washington, D.C.: American Council on Education, 1978), pp. 10-11.

had taught abroad during the past 2 years; three-fourths of the respondent institutions had faculty who collaborated on research with foreign counterparts; and three-fourths had faculty who traveled abroad for research purposes. Data from another survey showed that of those faculty members reporting collaborative scientific and engineering activities with developing countries, 24 percent taught abroad, 46 percent were engaged in collaborative research, and 30 percent were involved in consultation and scientific cooperation.[112]

In short, the U.S. role in the education and training of foreign students and assistance in the development of foreign universities has been one of this Nation's largest contributions to development of world scientific and technological capabilities and has led to the expansion and enhancement of the human resource capability of foreign countries.

Cooperation in Scientific and Technological Literature

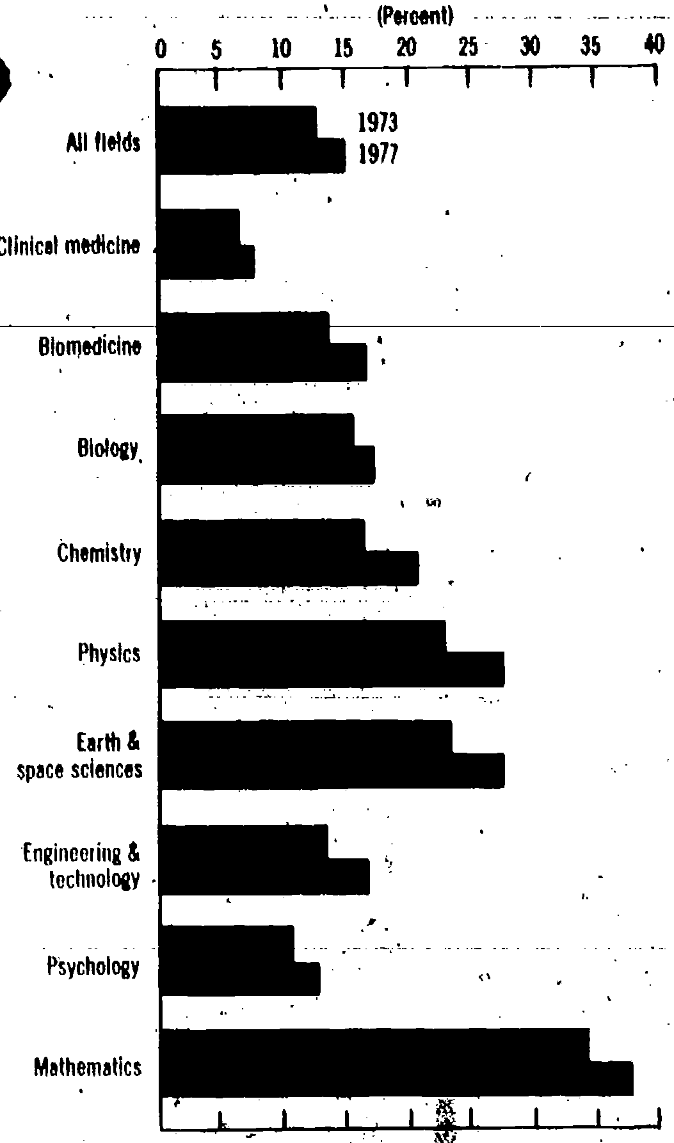
International cooperation in scientific research is reflected in the joint publication of research findings. While joint authorship is fairly common among authors in the same organization, it is less common for authors to represent different institutions or organizations.[113] Such joint research conducted by scientists and engineers of two different countries is even more rare. Collaboration in scientific research is encouraged by joint-country projects as well as the support of international or regional research centers. Inter-country joint authorship is also often facilitated by graduate study abroad and sometimes by attendance at international meetings.

Figure 1-19 provides a measure of the international cooperation, where "cooperative authorship" is defined as existing not simply when there is more than one author, but rather when authors are known to work either in different organizations or in different countries. It shows that for all fields as a group, internationally cooperative research has increased from 13 percent in 1973 to 15 percent in 1977. The greatest increases in international cooperative authorship occurred in the fields of physics, chemistry, and earth and space sciences. In terms of this measure, those fields which are most internationally cooperative are mathematics, physics and earth and space sciences, while psychology and clinical medicine have the lowest percent of internationally jointly authored articles.

Given some of the benefits of collaborative research activities, such as the conservation of time and resources, how much international cooperation is the United States involved in relative to other major research performing

Figure 1-19

Index[1] of international cooperative research by field: 1973 and 1977.



[1]Obtained by dividing the number of all scientific and technical articles which were written by scientists and engineers from more than one country by the total number of articles jointly written by S/E's from different organizations regardless of the country involved

NOTE: Based on 271,000 to 279,000 articles, notes, and reviews in over 2,100 of the influential journals of the *Science Citation Index* Corporate Tapes of the Institute for Scientific Information

REFERENCE: Appendix table 1-27

Science Indicators—1978

[112] Frank J. Atelsek and Irene L. Gomberg, *Scientific and Technical Cooperation with Developing Countries, 1977-78* (Washington, D.C.: American Council on Education, 1978), p. 12.

[113] See the discussion in the Resources for R&D chapter of an index of interorganizational cooperative research in the United States.

countries?[114] Figure 1-20 provides an index of international cooperative research based on the percentage of those articles jointly authored by S/E's whose authors are from different countries. This figure shows that West Germany, the United Kingdom and Canada have the highest levels of cooperative authorship (about 40 percent of their articles which are jointly authored across organizations are internationally cooperative in nature). The United States, Japan, and the Soviet Union have the lowest levels of internationally cooperative authorship—about half as much as the first three countries.

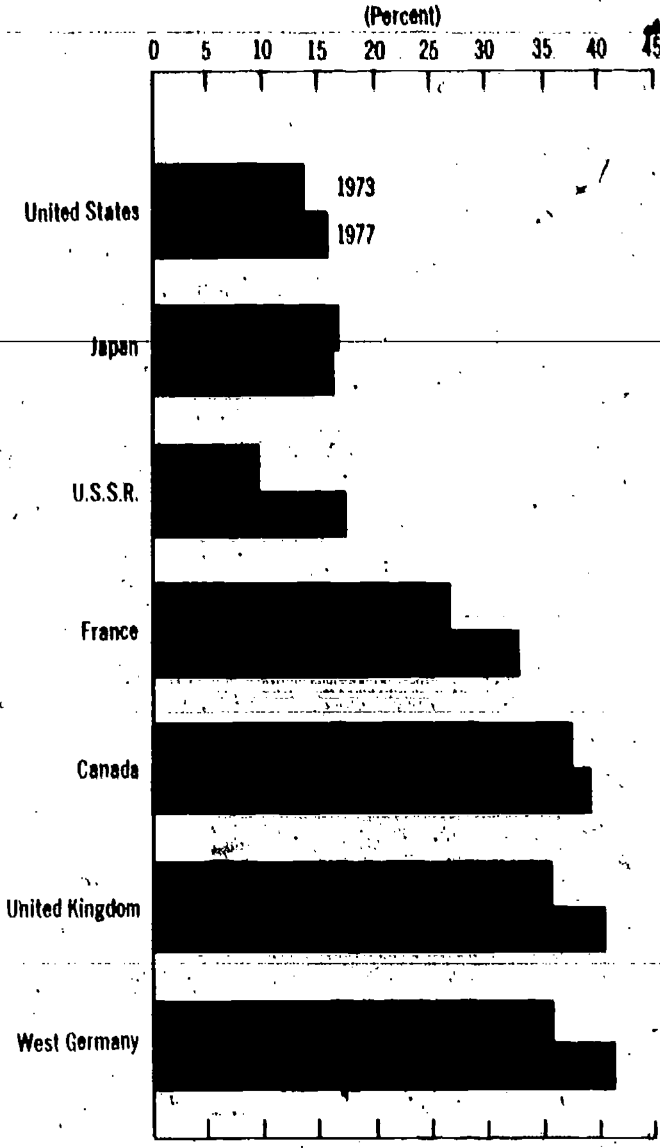
From 1973 to 1977, Japan was the only major country whose percentage of internationally jointly-authored articles decreased. The largest growth in international cooperation using this index was in the Soviet Union, almost all of which represented increased collaboration with East Germany. France, West Germany and the United Kingdom also experienced substantial growth in the amount of internationally cooperative research conducted from 1973 to 1977; most of this growth was due to increased collaborative efforts among themselves. During this same period, the United States increased international cooperation in the authorship of scientific articles, largely with West Germany and France.

International cooperation can take the form of publishing the scientific literature of one country in another nation's journals. By publishing the articles of foreign scientists and engineers, a nation provides a dissemination service for world science and simultaneously ensures easy access to the latest foreign research findings for its own research community. The extent that a nation publishes more foreign research findings than its own S/E's are publishing abroad is an index both of its capability to disseminate the world's scientific literature as well as its interest level in foreign research. The largest such balances for the United States occur in the fields of chemistry, clinical medicine, engineering and technology, and physics (see text table 1-8). In terms of actual numbers of articles, U.S. journals publish foreign research findings largely in the fields of clinical medicine, chemistry, biomedicine, and physics, while relatively fewer foreign articles are published in the United States in the fields of psychology and mathematics.

[114] Comparisons are made here with the seven countries which produce the greatest proportion of the world's scientific and technical literature: the United States, the United Kingdom, the Soviet Union, West Germany, Japan, France, and Canada. These seven countries together represented 77 percent of the world's influential scientific literature.

Figure 1-20

Index[1] of international cooperative research by country: 1973 and 1977



[1] Obtained by dividing the number of all articles which were written by scientists and engineers from more than one country by the total number of articles jointly written by S/E's from different organizations regardless of the country involved.

NOTE Based on 271,000 to 279,000 articles, notes, and reviews in over 2,100 of the influential journals of the *Science Citation Index* Corporate Tapes of the Institute for Scientific Information

REFERENCE Appendix table 1 28.

Science Indicators—1978

Participation in International Congresses

International meetings are a forum for the exchange of technical information and ideas and provide opportunities to report new findings of research and development. Contacts made at these meetings may lead to future working relationships or new sources of communication for keeping abreast of the latest developments in science in other countries.

Table 1-8. Distribution index of articles in U.S. and foreign journals[1] by field: 1973 and 1977

Field[2]	U.S. articles in non-U.S. journals 1973	U.S. articles in non-U.S. journals 1977	Non-U.S. articles in U.S. journals 1973	Non-U.S. articles in U.S. journals 1977	Balance[3] 1973	Balance[3] 1977
All fields	19,941	20,152	29,270	33,953	9,329	13,801
Clinical medicine	4,695	4,975	6,794	7,923	2,099	2,948
Biomedicine	4,124	4,306	4,148	5,377	24	1,071
Biology	1,660	2,049	2,013	1,971	353	-78
Chemistry	2,346	2,018	5,484	6,583	3,138	4,565
Physics	2,661	2,742	4,118	5,143	1,457	2,401
Earth and space sciences	1,200	1,126	1,284	1,146	84	20
Engineering and technology	1,382	1,302	8,723	3,848	2,341	2,546
Psychology	784	779	845	895	61	116
Mathematics	1,089	855	861	1,067	-228	212

[1] Based on the 271,000 to 279,000 articles, notes and reviews per year from over 2,100 of the influential journals of the *Science Citation Index* Corporate Tapes of the Institute for Scientific Information.

[2] See Appendix table 1-10 for a description of the subfields included in these fields.

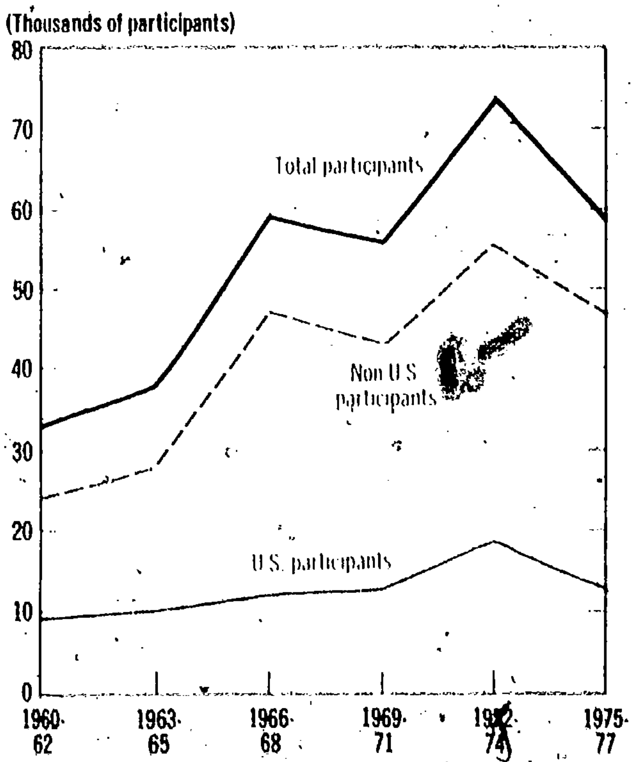
[3] When the balance is negative, it means that more U.S. scientific and technical articles are being published in journals abroad than foreign articles published in U.S. journals. When the balance is positive, the United States is publishing more foreign articles than U.S. authors are publishing abroad.

REFERENCE: Appendix table 1-29.

Figure 1-21 shows the participation in international congresses of those organizations constituting the International Council of Scientific Unions. Foreign participation in these meetings has grown rapidly since the early 1960's while U.S. participation has increased at a more moderate rate. Wide fluctuations in attendence exist from year to year depending on factors such as the number and location of meetings. For instance, non-U.S. participation experienced a dramatic increase in 1966, a year in which a number of large congresses were held overseas and virtually no major meetings took place in the United States. Many of these congresses are on a 3- or 4- year cycle. Peaks in attendance patterns also reflect the larger number of congresses held in certain years.

Since 1960, U.S. participation at international congresses has increased about 40 percent, while non-U.S. participants almost doubled; however, most of this growth occurred in the 1960's. In the 1970's, the U.S. share of total participation remained fairly steady, averaging about 23 percent. In the period 1972-74, total participation increased greatly because of the large growth in the number of congresses and meetings held. In addition, several congresses which have large memberships (e.g., UICC—the International

Figure 1-21
Participation in international scientific congresses: 1961-77



REFERENCE: Appendix table 1-30.

Science Indicators—1978

Union Against Cancer) met during this period. The most recent period shows a drop in total attendance because of a decrease in the number of congresses held.

The past growth in non-U.S. attendance at international meetings is an encouraging sign for worldwide scientific interaction and reflects in part the increased tendency to locate these meetings in a variety of regions outside of Western Europe and the United States. Thus, scientists of other countries can have a greater opportunity to participate, since the lack of adequate travel funds, particularly in developing countries, often limits attendence at meetings held abroad. However, this tendancy to vary the locations of the meetings may somewhat limit U.S. participation for the same reason.

Although the average number of meetings held per year in the 1970's increased about 75 percent over the previous decade, the average annual attendance per meeting has decreased about 17 percent. This is to be expected as new and more specialized unions are created to meet specific needs of expanding fields of science. Emphasis on the need for an interdisciplinary approach to problem areas such as science teaching, developing country needs, the environment, etc., has made the role of the interdisciplinary Inter-Union committees more important and increased their activity.[115]

[115] *Organization and Activities* (Paris: International Council of Scientific Unions, 1976), pp. 13-14

SUMMARY

The U.S. investment in research and development, in terms of both expenditures and scientific and technical personnel, is much greater than that of most countries and has shown increases since 1975. However, in terms of R&D per GNP and R&D scientists and engineers as a proportion of the labor force, West Germany, Japan, and the Soviet Union have been increasing their relative investments in R&D more rapidly than the United States. In addition, marked differences exist between these countries in the allocation of funds. In Japan and West Germany, industry provides a majority of the R&D funds, and Government funds are highly concentrated in areas directly related to economic growth. In the United States, over half of these Government funds are aimed at defense and space objectives.

In terms of R&D outputs and impacts, indicators of the U.S. position present a mixed picture. Data on R&D-intensive trade and international technology transfer indicate that U.S. technical know-how and R&D-intensive products are highly competitive and are a source of national economic strength. However, declining trends in U.S. productivity rates and in patenting activity are causes for concern because of their economic implications.

Although U.S. productivity levels exceed those of Canada, France, West Germany, the United Kingdom, and Japan, U.S. gains in productivity in the past decade were the smallest of all these countries. Productivity gains were the largest in Japan during this period.

Both U.S. domestic patenting and U.S. patenting activity abroad have decreased. Foreign patenting activity has increased in the United States during the 1970's, particularly due to the activity of West Germany and Japan. This is an indication of foreign interest in the U.S. market, but may also be related to increased foreign inventive activity.

Japan and West Germany are the two major foreign countries that have been increasing their R&D investments at the highest rates in terms of R&D expenditures and R&D scientists and engineers; their research and development has been largely provided by the industrial sector and highly concentrated in civilian areas. While the linkages between R&D, the innovation process, and economic growth are not completely understood, these countries have been enjoying some of the highest productivity growth rates, have been granted the largest numbers of U.S. foreign-origin patents, and have been highly successful in exporting R&D-intensive manufactured products to the United States.

It should be recognized that the world situation has been changing. Nations are becoming both more interdependent and more competitive. Other countries have and will continue to make economic and technological advances. Under these changing conditions, and because some problems require a more global approach, international scientific and technical interaction and cooperation have become increasingly important. Although there are numerous scientific cooperative efforts between the United States and other countries, there are many areas in which expanded cooperation could be beneficial.

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Chapter 2

Resources for Research and Development

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Resources for Research and Development

INDICATOR HIGHLIGHTS

- National R&D spending levels have begun to advance following a long period of reduced support. Constant-dollar R&D expenditures increased at an average annual rate of approximately 3.5 percent between 1975 and 1979, compared to an average annual decline of 1.0 percent over the previous seven years. The factors responsible for this advance include improved economic conditions conducive to private sector R&D investment. (See page 44.)

- Basic and applied research expenditures in real dollars began to rise again in 1976, but for different reasons. Basic research is supported primarily by Federal sources; the Government has taken the position that "prudent planning for the future demands a deliberate and continued commitment to basic research."[1] Applied research, supported substantially by industrial and Federal sources, also increased because of strong Federal interest and improved fiscal conditions in the private sector. Both basic research and applied research grew at an average annual rate of nearly 3.7 percent between 1975 and 1979. (See pages 52-53.)

[1] Presidential Message on Science and Technology, delivered to the Congress of the United States, March 27, 1979.

- In constant dollars, total basic research expenditures in 1979 are only slightly higher than the previous maximum, which was reached in 1968. However, national constant-dollar spending for applied research in 1979 is nearly 20 percent higher than it was in 1968. This apparent increased reliance on applied research may be a response to heightened concern about conducting research which may have relatively short-term economic and social benefits. (See pages 52-53.)

- Federal R&D spending in each of the major functional areas has grown steadily in recent years while the proportion of funds going to each area has stabilized. Spending for defense R&D is directed largely toward the development of tactical systems; increases for space reflect continued work on the space shuttle. In civilian areas, obligations for health, energy, and environment have continued to grow—but less rapidly than in some earlier years. The most dramatic changes have been seen in energy R&D, which grew at an average annual rate of 33.6 percent between 1974 and 1979. Expenditures for all civilian R&D as a percent of all R&D spending increased steadily throughout most of the 1970's. (See pages 55-60.)

Research and development activities fill a variety of cultural, social, and economic needs. R&D, like any other activity, operates under various constraints of time, personnel, and financial resources. Policymakers generally assess R&D activity in light of these constraints when allocating scarce resources to numerous activities. The information in this chapter points out some quantitative elements useful for the assessment of national R&D activity and rational resource allocation decisions.

This chapter describes some of the major mechanisms supporting U.S. scientific and technological activities, and it examines significant changes in levels of support and types of activity. It assesses aggregate national R&D spending and places R&D expenditures in perspective with the economy as a whole. Sources of support for R&D are identified as are the sectors receiving the funds. Research and development are looked at separately, and research itself is disaggregated into its components—basic research and applied research. Emphasis is also placed on examining the various functional areas of R&D, so that it is possible to see to which national goals and social needs Federal R&D dollars are applied and at what levels of support. Scientific and technical literature indicators are discussed as outputs of the R&D process, and information is presented on equipment for science and technology.

R&D resource allocation represents a special situation because of the nature of U.S. support for scientific and technological activities. R&D is a composite consisting of diverse activities of many performers funded by many public and private interests. Consequently, the national resource allocation process, rather than representing an overall master plan, reflects decisions made at various Federal and private levels. Factors that exert substantial influence on the allocation of resources to R&D activities include economic conditions; pressure from interests of citizens not directly involved with the "R&D community"; Federal policy toward science and technology; and social, economic, and technical opportunities.

A major influence on R&D resource allocation is Federal R&D policy. Some of the recent statements of this policy were made in connection with the FY 1979 Federal Budget, and the recent Presidential Message on Science and Technology[2] which called for growth of scientific research. The Budget also reflected a change in perspective, showing the need to view R&D not as the purchase of a commodity, but as an investment in the social and economic welfare of the country. In addition, the January 1978 State of the Union Message called for a strengthening of the Nation's research centers and a new surge of technological innovation by American industry.

Economic factors strongly influence R&D resource allocation in a number of ways. For example, under favorable economic conditions, industry may be able to provide more support for research than under other economic circumstances. Or, it may be apparent that R&D in a particular area, such as product or process improvement, may produce short-term economic benefit to an organization.

Another factor affecting resource allocation is citizen interest in scientific decisionmaking. Whether R&D activities involve DNA, nuclear power, or life on Mars, the public (which supports such work through taxes) increasingly demands a voice in the decisions affecting certain projects.

Note that dollars are used as a surrogate for R&D activity, and also, elsewhere in this report, data on scientific and technical personnel are used as measures of R&D activity. The use of dollars as a surrogate measure is particularly sensitive to distortion produced by inflation. Therefore, emphasis is placed on assessment in terms of constant dollars. In the absence of a specific R&D price deflator, the implicit price deflator for the gross national product (GNP) is used to convert current dollars to constant dollars; 1972 is used as the base or reference year. The GNP implicit price deflator, which applies to the economy at large, is general and is only approximately appropriate for use in connection with R&D as a whole or with specific R&D-performing sectors. Attempts to develop sectoral R&D deflators demonstrate that this GNP deflator is fairly similar to sectoral R&D deflators, at least in the United States.[3]

The existing indicators do not measure the extent to which the resources engage the Nation's full R&D capacity. There are no indicators for measuring either the general effectiveness of the use of R&D resources or of the efficiency with which these resources are translated into R&D activity (and, subsequently, into societal benefits). It is difficult to assess directly the quality of the resources directed to R&D, particularly the qualifications of the scientists and engineers involved. Complete data and information are not available regarding the objectives to which total R&D resources are directed; only in the case of Federal obligations are R&D resource data reported according to specific areas of national concern such as health, energy, and national defense. The Industry chapter of this report includes some data regarding funds for energy, pollution abatement, defense, and space.

[2] *The Budget of the United States Government, Fiscal Year 1979*, pp. 6, 91-98 and Presidential Message on Science and Technology, delivered to the Congress of the United States, March 27, 1979, p. 2.

[3] Additional information concerning R&D price deflators can be obtained in *A Price Index for Deflation of Academic R&D Expenditures*, National Science Foundation (NSF 72-310); D. Kent Halstead, *Higher Education Prices and Price Indexes, 1977 Supplement*, Department of Health, Education, and Welfare, National Institute of Education, 1977; and a paper produced by the Organisation for Economic Co-operation and Development entitled *Trends in Industrial R&D in Selected OECD Member Countries, 1967-1975*, September 18, 1978. The estimated rates of inflation in the U.S. economy for 1978 and 1979 are 7.3 percent and 7.0 percent, respectively. Changes in the rate of inflation would require appropriate adjustments to the estimates of "real" R&D growth reported here.

NATIONAL RESOURCES FOR R&D

Levels of Expenditure

Quantitative indicators assist in the study of relative changes in the allocation of resources to science and technology, and they pinpoint significant shifts in available resources, so that any needed program changes and policy actions can be initiated. Preferably, these adjustments to policy should be made after factors responsible for shifts in the allocation of resources are understood and alternative strategies have been explored. However, sometimes the available information is insufficient to permit such a rational strategic approach.

A broad measure of the fiscal commitment to R&D activity is the level of expenditure throughout the Nation. In 1979, this amount was $51.6 billion, or over $235 per capita (see figure 2-1).

Comparing R&D expenditures with expenditures for other areas provides perspective. All R&D costs amount to less than one-third of health expenditures. R&D expenditures are 28 percent less than national spending for recreational activities and about the same level as the annual expenditures for advertising.[4]

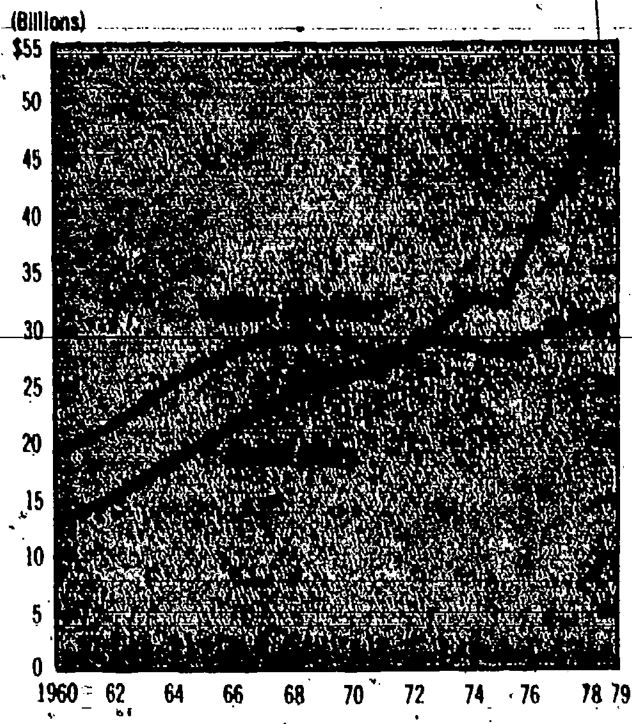
In the aggregate, R&D spending reflects actions by the Congress, governmental agencies, private industries, universities and colleges, and nonprofit organizations, concerning where to place a substantial amount of their financial resources. Such decisions are increasingly made unilaterally at lower levels of institutional aggregation.

In terms of current dollars, the level of funds provided to R&D by all these sectors has never been higher. However, R&D has been just as much affected by the forces of inflation as other activities. Following 7 years of little or no growth, constant dollar national R&D expenditures have been advancing. Such expenditures were approximately $31.8 billion in 1979, 7 percent over the $29.8 billion reached in 1968. They are estimated to rise at an average annual rate of approximately 3.5 percent between 1975 and 1979, compared to an average annual decline of 1.0 percent from 1968 to 1975.

Further growth is projected through 1985, with real expenditures expected to reach over $38 billion in that year.[5] Much of this growth is expected to result from major increases in R&D spending by the Federal Government and industry. The Federal sector will likely emphasize R&D spending for defense, health, and energy, whereas the industrial sector will probably emphasize R&D for energy, regulatory R&D, and environmental R&D. Universities, colleges, and other nonprofit institutions are expected to increase R&D funding only slightly.

These broad changes in overall national R&D activity provide little insight into changes in the nature of specific R&D work. R&D covers a vast spectrum of different types of activity, varying from basic investigations, such as exploring the nature of gravity, to specific applications, such as developing new nuclear reactors. This spectrum is somewhat continuous; nevertheless, some discrete groupings are helpful in assessing the variation of subcomponents and in evaluating the appropriateness of the activity balance. The most distinct activity difference is between research

Figure 2-1
National R&D expenditures: 1960-79



¹GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NOTE: Estimates are shown for 1977, 1978 and 1979.

REFERENCE: Appendix table 2-1.

Science Indicators—1978

[4] U.S. Bureau of the Census, *Statistical Abstract of the United States: 1977*, pages 235 and 844. Also, U.S. Department of Health, Education, and Welfare, *Health, United States 1976-1977*, DHEW Publication No. (HRA) 77-1232, page viii.

[5] See *1985 Funding Projections*, National Science Foundation (NSF 76-314), for technical details concerning this and other R&D funding projections.

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and development. Research expenditures are much smaller primarily because development usually involves high-cost hardware and technology. The section of this chapter entitled Character of R&D Activities analyzes the trends for research separately from those for development.

Expenditure figures alone do not show the viability of U.S. science and technology. There is no generally accepted model that can demonstrate that a certain level of expenditure is better than another, or that more dollars guarantee significant discovery. The value of science and technology in terms of their benefits to mankind cannot necessarily be correlated to spending.

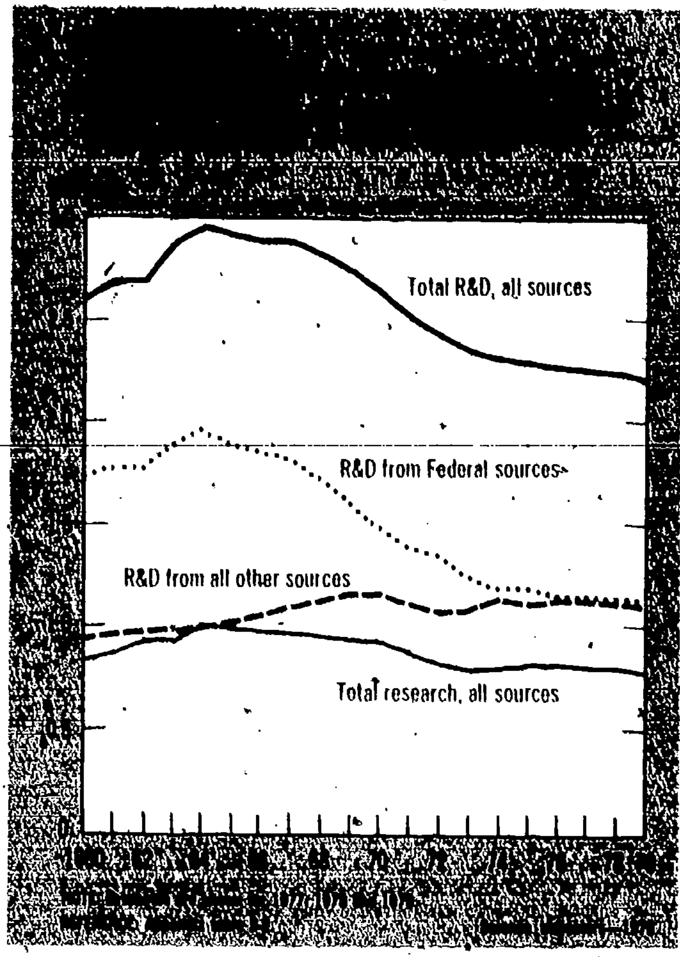
There are certain measurable outputs, such as patents and research publications. However, the relationship of these outputs to financial input is complex. Effective scientific and technical progress can benefit from a steady, long-term fiscal commitment, and, especially in the private sector, such commitment depends strongly on the minimization of uncertainties. But benefits can derive from a break in support; in some cases the regrouping that often follows can lead to new areas of activity.

R&D in the National Economy

The ratio of R&D spending to GNP was at an alltime high in 1964, when it reached 2.97 percent. This ratio has fallen steadily since then, to an estimated 2.21 percent in 1979 (see figure 2-2). The gradual decline in the ratio of R&D expenditures to the GNP is expected to continue through 1985, and the ratio in 1985 is projected to be about 2 percent.[6] The cause of past and projected changes is not a decline in R&D expenditures themselves, but rather that GNP has increased and is projected to increase faster than R&D expenditures. Comparable historical data for other major R&D-performing countries show that declines in R&D per GNP have occurred for the same reasons as in the U.S., except for Japan and West Germany whose R&D spending has grown faster than their GNP.

A similar pattern can be seen for the percentage of GNP accounted for by research expenditures only. This ratio has declined steadily since 1964. In that year, research spending amounted to 1.01 percent of the GNP, but in 1979 the ratio stands at an estimated 0.80 percent.

It is useful to study variations in R&D spending as compared to changes in GNP. Highlighting relationships between R&D spending in a major



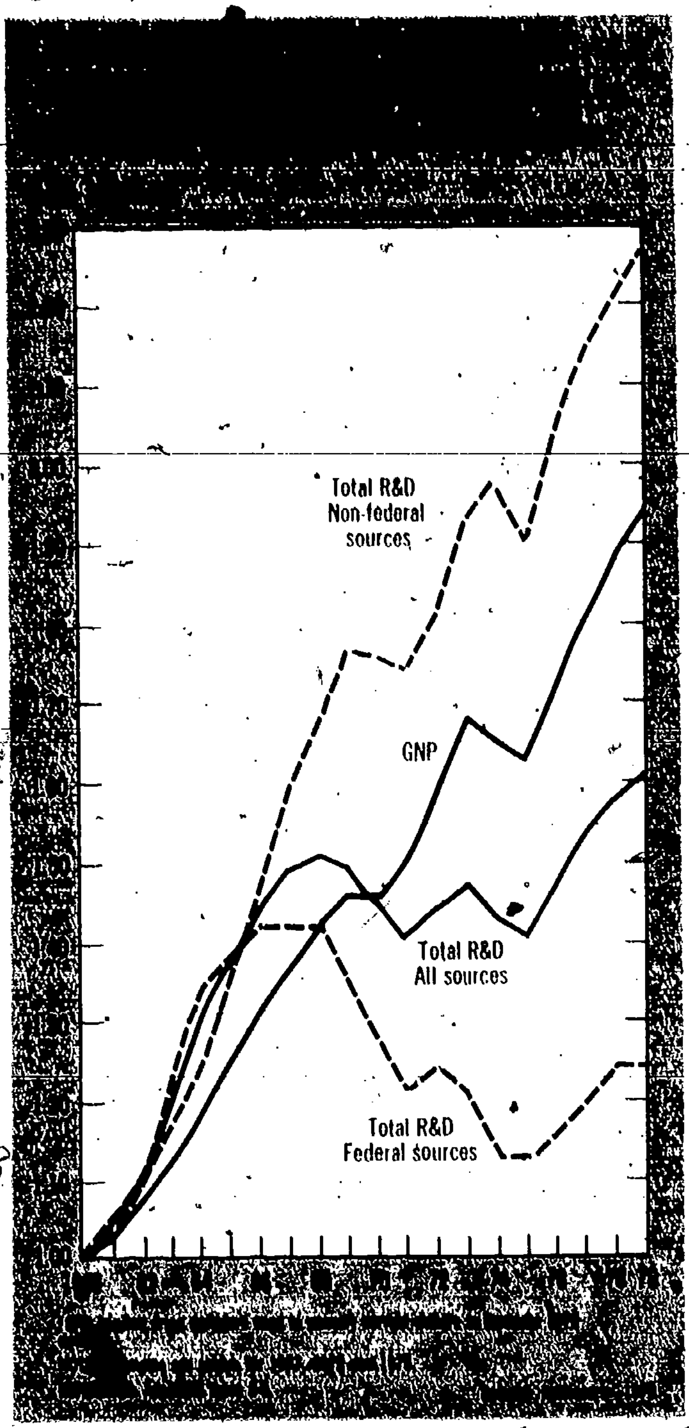
economic sector and spending in the economy as a whole may identify elements of R&D spending that are particularly sensitive to economic activity in general. For near years, non-Federal support for R&D has been highly correlated with the GNP[7] (see figure 2-3). The reasons for this correlation are not fully understood; possibly non-Federal supporters of R&D believe that they can deemphasize R&D (with its relatively long-term return) temporarily, in order to deal with short-term fiscal constraints.[8] Thus, variations in GNP may warn of impending shifts in R&D spending by the non-Federal sector. Since these sources account for approximately half of all R&D spending, they can have significant effects on national R&D spending levels.

The relationship between GNP and Federal R&D spending is very low, perhaps because long-term Federal R&D spending in general tries to deal with national problems, and in the short

[6] *Ibid.*

[7] The correlation coefficient for this data series is .99.

[8] Some of the reasons given for this phenomenon appear in Howard K. Nason, Joseph A. Steger, and George E. Manners, *Support of Basic Research by Industry* (St. Louis, Mo.: Industrial Research Institute Research Corporation, August 29, 1978).



term, Federal R&D spending is not a direct product of variations in national economic activity. However, on a long-term basis, both national objectives and the overall level of the national economy are considered. This belief was reiterated in the National Science and Technology Policy, Organization, and Priorities Act of 1976, which stated that there should be a "...continuing national investment in science, engineering and technology which is commensurate with national needs and the prevalent economic situation."[9]

Sources of R&D Funds

R&D is supported by private and public sectors of the economy. It has been a hallmark and strength of American R&D policy to have R&D supported by diverse sources. This multisource funding can be important to effective R&D because it prevents the unilateral control of R&D priorities and thus reduces the chances for neglect of important areas of exploration and exploitation. Multisource funding is characteristic of the role played by scientific and technological activity in the national economy. Each sector has its own needs and reasons for performing R&D, and these needs dictate the level of support provided, the type of work supported, and its duration. For example, industrial R&D programs often focus on work that has relatively low risk and provides sufficient opportunity for producing economic gain in a reasonable time. Federal R&D supporters focus more on programs of primarily national concern, which probably have little chance of producing direct financial benefits, which may carry a relatively high risk, and which may require a long time to produce useful results.

Federal R&D does deal with short-term solutions to problems. However, Federal R&D supporters recognize that industry is likely to undertake short-term work and not spend its limited financial resources in areas where payoff is either improbable or too far into the future.

Exactly where in the economy does money for R&D come from, and which sectors provide the most funds for R&D? What changes have taken place in the extent to which each of the sectors provides funds for science and technology? Answers to such questions are important to effective R&D policymaking, since knowledge of sectoral funding patterns assists development of policy initiatives. For example, shifts in industry support for R&D might be handled by changes in tax policy.

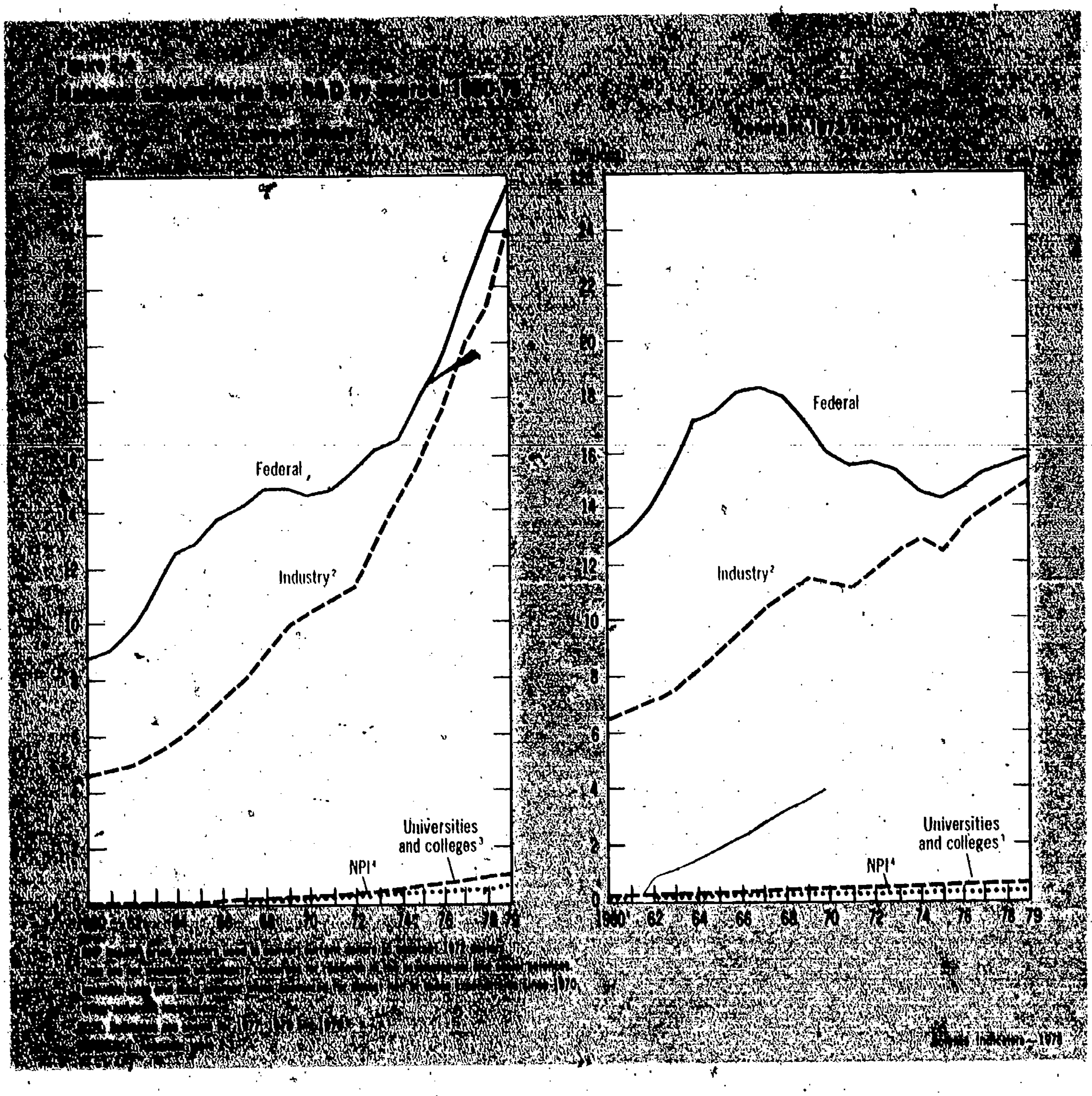
Four major sectors of the economy provide funds for research and development: the Federal Government, industry, universities and colleges, and nonprofit institutions. Most funds are provided by Federal and industrial sources.

Since World War II, funds from Federal sources have been larger than those from other sectors. However, changes have occurred, particularly

[9] The "National Science and Technology Policy, Organization, and Priorities Act of 1976," P.L. 94-282, 42 USC 6601, Sec. 101(a) (4).

after the early 1960's. Thus, from 1960 to 1965 the Federal Government provided approximately 65 percent of all R&D funds, while industry provided about 33 percent (see Appendix table 2-3). By 1979, the balance had shifted significantly, with Federal sources accounting for only 50 percent and industry approximately 46 percent. The shift resulted largely from a decline in Federal support, a decline attributable to termination of the manned space program and reductions in defense R&D spending. In addition, there were increases in industrially funded R&D that reflect growing reliance on research and development for the production of new products and processes; product improvements; and attempts to cope with safety, environmental, and other regulations from the Government.

Total spending in current dollars by each source has grown significantly over the 1960-1979 period (see figure 2-4). However, in constant dollars, the pattern of change in spending is quite different. For Federal sources, the growth period of the early 1960's was followed by substantial decreases starting in 1968 and persisting essentially unchecked through 1975. Over the 1968-1975 period, these declines



amounted to 21 percent, for an average annual drop of approximately 3.4 percent, resulting primarily from reductions in spending for manned space programs and defense.

Beginning in 1976, Federal R&D spending in constant dollars started to rise again, and it is estimated that expenditures will grow almost 8 percent between 1976 and 1979, for an average annual gain of approximately 2.5 percent. Increased support for the space shuttle program and overall increases in spending for defense and energy R&D have been significant factors in this increase. For the period 1979-1985,[10] continued growth in Federal support in constant dollars is projected, with spending in 1985 forecast to rise nearly 22 percent over the estimated 1979 level, for an average annual gain of over 3 percent. The main reason for this estimated growth is anticipated continuing increases in defense spending, which account for the bulk of Federal R&D spending.

Constant dollar expenditures of R&D funds by industrial sources also climbed steadily throughout most of the 1960's, growing 75 percent between 1960 and 1969 for an average annual growth of almost 6.5 percent. This growth was followed by alternating periods of advances and declines from 1970 to 1975, caused largely by variations in general economic conditions that affect corporate spending. Over the 1970 to 1975 period, constant dollar spending by industrial sources for R&D advanced more than 8 percent, at an average annual rate of about 1.6 percent. Since 1976, the corporate base for industrial R&D spending has experienced a more steady rise because of favorable economic conditions and satisfactory profitability following the recessionary periods of the early 1970's. It is estimated that industry-provided R&D funds, in real terms, will continue to grow through 1979. In 1979, expenditures are expected to have advanced by about 11 percent over the 1976 level, for an average annual change of 3.5 percent in constant dollars.

This rate of increase is expected to be maintained through 1985. A significant reason for the projected increase is the anticipated growth of R&D in the chemicals industry. Nonmanufacturing industries, although representing a small fraction of the total, are also expected to show substantial annual growth in R&D spending over this period.

[10] See *1985 Funding Projections*, National Science Foundation (NSF 76-314).

Performers of R&D

The preceding section shows that U.S. science and technology receive support from various sectors of the economy, each supporting R&D to fulfill its own needs and meet its own goals. However, knowledge of who pays for R&D imparts no information concerning who does the work. The performers of R&D have unique capabilities that permit them to engage in R&D programs to the advantage of themselves and their sponsors. For these reasons, it is important to track changes in the distribution of R&D funds to performers.

The Federal Government is the major provider of funds for R&D, but industry has traditionally performed the bulk of the Nation's R&D programs. The reasons for such reliance on industry vary, but they include the realization that industry, having its own R&D efforts related to its products and processes, is already prepared to take on additional R&D efforts. For example, industry has a comparative advantage in development, testing, and evaluation. There is considerable variability in the level of R&D activity among different industries.

The Government spends considerable sums of money on its in-house R&D efforts, but as a percentage of National R&D expenditures they represent one of the smaller sectoral components. In 1979, Government is expected to do $6.9 billion worth of R&D, only 13 percent of the total. Industrial performers are estimated to spend $36.8 billion in 1979, or 71 percent of the total (see figure 2-5). Universities and colleges will account for an estimated $5.0 billion or 10 percent (primarily in research). The university-administered Federally Funded Research and Development Centers and the nonprofit institutions will account for approximately $1.4 and $1.6 billion respectively, or about 3 percent apiece. The proportions held by these performers have been fairly consistent throughout the 1970's.

For industrial performers, 1975 marked the end of a decline in constant dollar spending that began in 1969. Much of this decline resulted from reduced Federal R&D support. In 1979, the industrial sector is expected to spend more on R&D, in constant dollars, than ever before, exceeding the 1969 peak year by about 7 percent. This growth is a product of strong spending of industry's own funds plus increased Federal support. It is estimated that 1979 industrial expenditures in constant dollars will rise 12 percent over the 1976 level, and spending by universities and colleges will climb 10 percent

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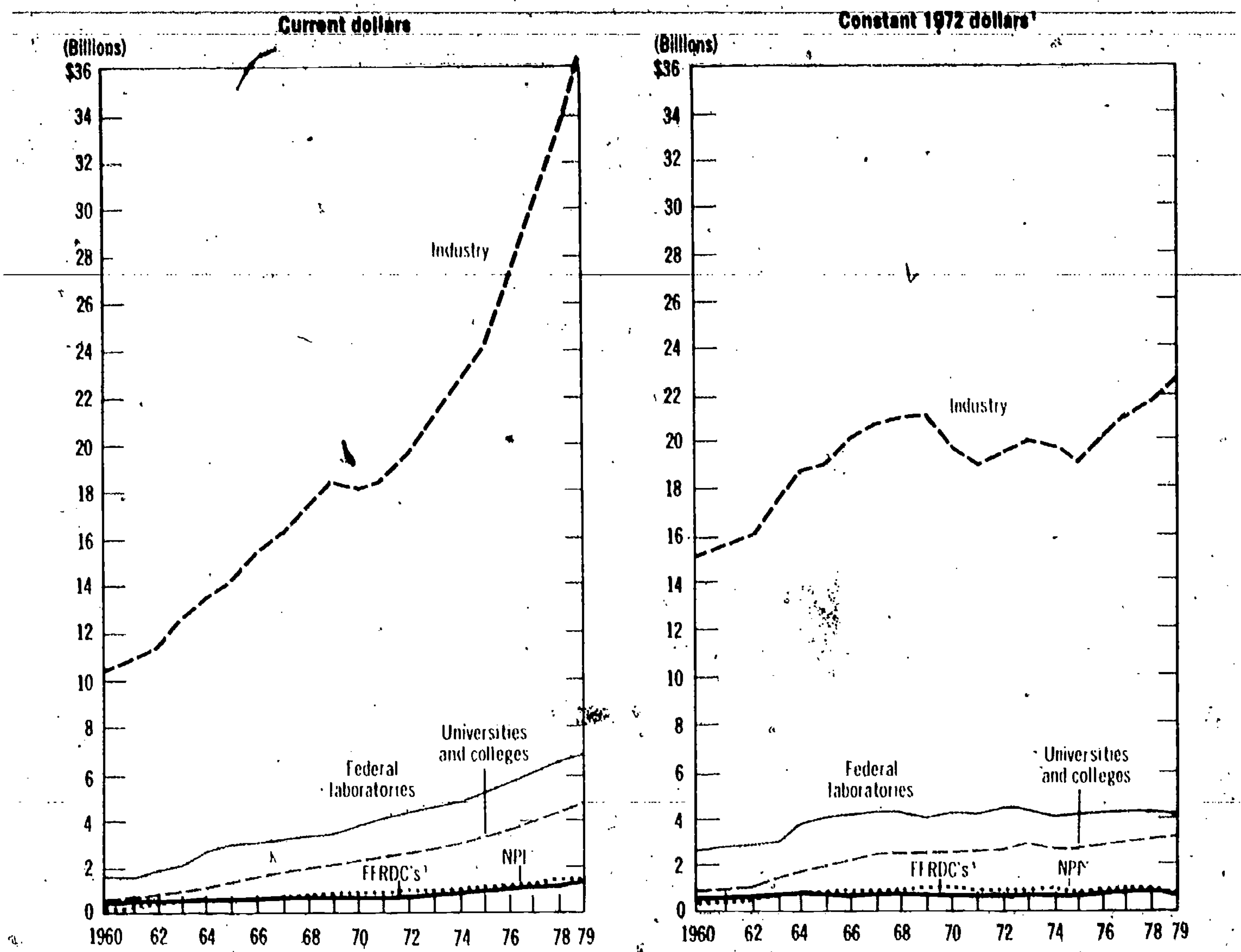
Figure 2-5
National expenditures for R&D by performer: 1960-79



[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.
[2] Other nonprofit institutions.
[3] Federally Funded Research and Development Centers administered by universities.
NOTE: Estimates are shown for 1977, 1978 and 1979.
REFERENCE: Appendix table 2-4.

Science Indicators—1978

over this 3-year period. Among university-administered FFRDC's, constant dollar spending is predicted to grow only 2 percent.

Scientists and Engineers

Thus far, expenditure level has been used as the primary surrogate measure for R&D activity. Possibly a more direct indicator of R&D activity is the number of people employed in R&D.[11] This measure is useful for validating general trends in expenditure data, because of the relation between overall expenditure levels and the

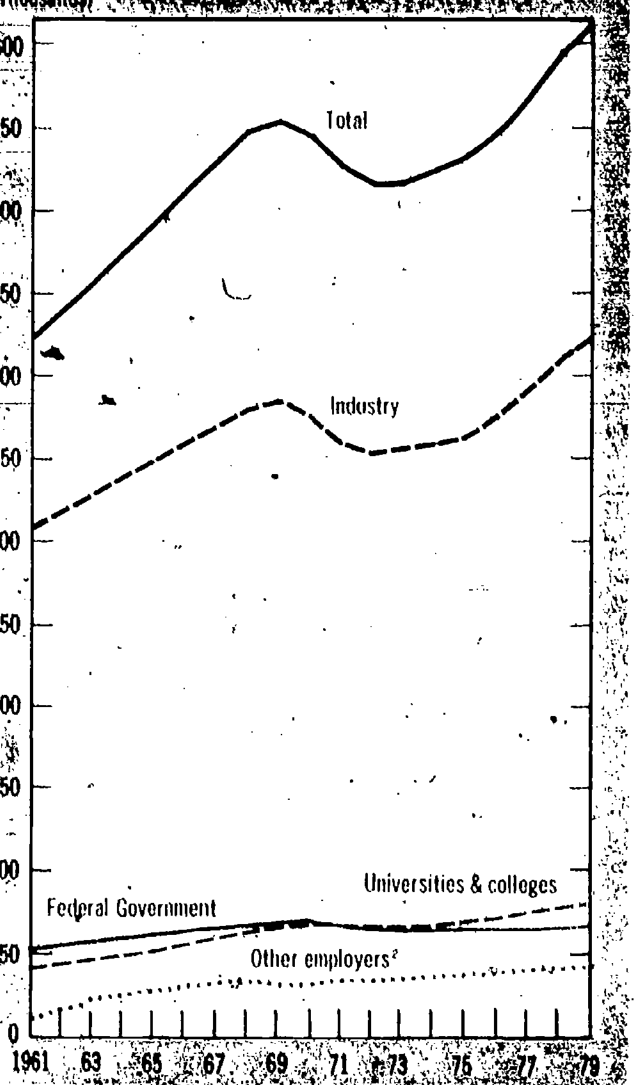
[11] Because many scientists and engineers work in R&D part-time (e.g., in universities and colleges), an approximate full time equivalent (FTE) figure is used exclusively in this discussion.

amount of personnel effort devoted to R&D. However, this relationship could be affected by rapid increases in personnel costs or variations in the mix of cost components. Since industry is the largest performer of R&D, it also accounts for more scientists and engineers in R&D activities than all other sectors (see figure 2-6). In 1979, industry represented nearly 70 percent of the total.

Beginning in 1974, employment of R&D scientists and engineers started to rise, after having declined steadily between 1969 and 1973. However, not until 1977 did employment levels pass the previous peak of 1969, but by 1979, the 1969 peak was exceeded by almost 10 percent.

Most increases in employment from 1974 to 1979 occurred among nongovernmental performers of R&D, three-fourths of which resulted from industrial growth of R&D activity. (For more comprehensive treatment of this topic, see the Scientific and Technical Personnel chapter of this report.)

Figure 2-6
Scientists and engineers[1] employed in R&D by sector, 1961-77



[1] Full-time-equivalent basis, excluding those employed in State and local agencies, calculated as the yearly average for the industry sector.
[2] Includes scientists and engineers employed in R&D in other nonprofit institutions and FFRDC's administered by universities.
NOTE: Estimates are shown for 1977, 1978 and 1979.
REFERENCE: Appendix table 2-5.
Science Indicators—1978

CHARACTER OF R&D ACTIVITIES

Research and development has thus far been treated as an entity, even though it incorporates diverse scientific and technical activities. However, policy decisions about science and technology can be improved when the level of available information is further disaggregated. What balance is being struck between expenditures for research as opposed to those for development, and what is the mix between the two major types of research—basic and applied? Equally important are questions about sources of support for each type of activity. The following sections analyze trends in support for research separately from development, as well as patterns of support for basic and applied research. Expenditure data for each type of activity reflect the Nation's emphasis on advancement of basic scientific knowledge, application of knowledge to solving national problems, and development of products and processes used by our society. Some of these efforts are designed to meet short-term goals, but others are not expected to produce immediately useful information or result in any economic gain for years to come.[12]

Development and Total Research Expenditures

Most R&D funds are spent on development, which typically accounts for about two-thirds of the total national R&D expenditures (see figure 2-7). In constant dollars, expenditures for development have grown substantially between 1975 and 1979 to an alltime high. Increases in Federal spending for development accounted for part of this increase; however, industrial support also played a significant role (see Appendix table 2-14). Constant dollar support by industry has

[12] The definitions of basic research, applied research, and development are provided on Appendix table 2-8 where data by character of work are presented.

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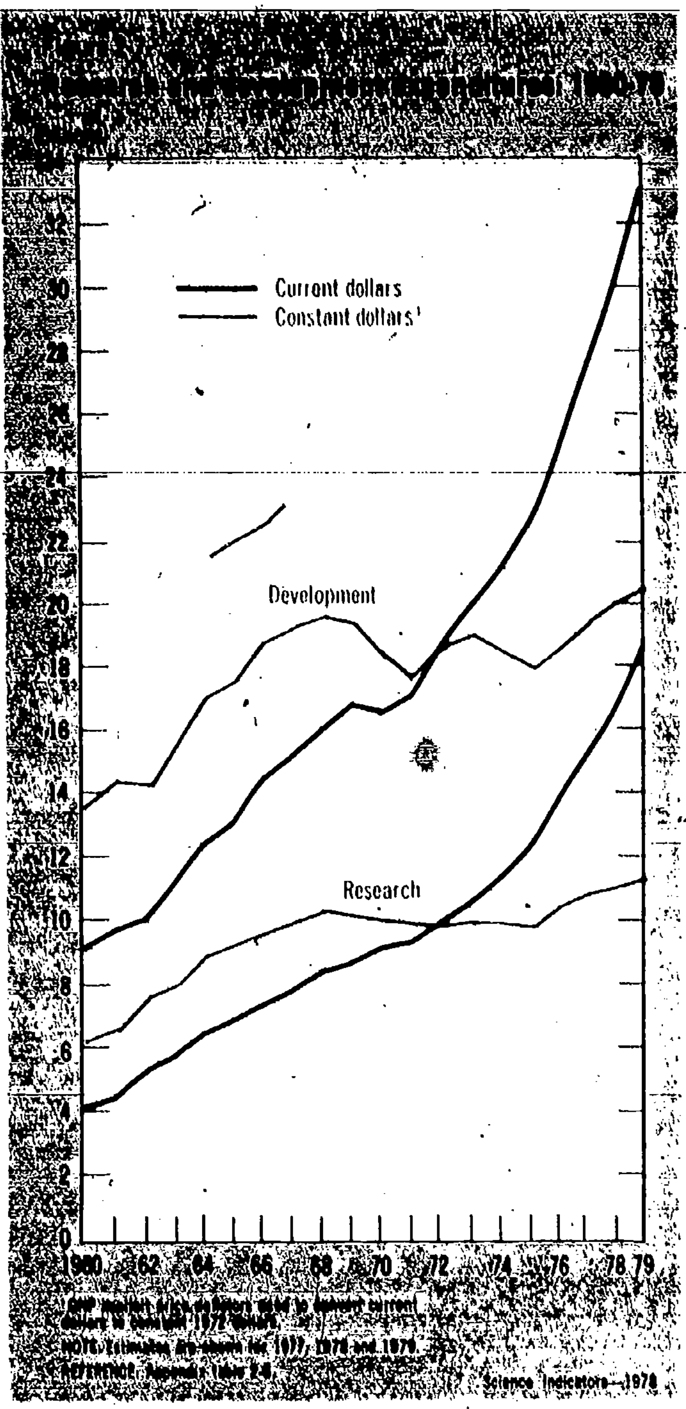

shown a strong overall growth pattern. The few declines it has experienced have, to some degree, resulted from economic conditions and general corporate profitability.

Development costs are generally much larger than research costs and, of course, represent a very different type of effort. Single research projects can vary widely in their costs, but expenditures of $50,000 to $100,000 are not uncommon. In contrast, the cost of developing a single large item of hardware or pilot operation can run into the millions.

In constant dollars, research spending has experienced a smoother pattern of change than has development. Research spending leveled off from 1968 through 1975. In 1976, research spending started upward once again reaching an alltime high in 1979. This growth resulted from increased support by both industry and the Federal Government (see figure 2-8).

Scientific and Technical Literature

The impact of the constant dollar declines in research spending through the early seventies was felt more heavily in some research areas than others. There has come to be a two- to four-year lag (depending on the field of science involved) between the performance of research and the publication of its findings.[13] From 1973 to 1977, seven of nine major fields saw declines ranging between 5 and 25 percent in the number of U.S. research articles published in the world's most influential journals (figure 2-9).[14] Only articles in clinical medicine and biomedicine continued to rise in number over this period. The greatest decline occurred in mathematics where publication rates for universities, the Federal Government, and industry each fell by 25-26 percent. In engineering and in chemistry, the industrial and Federal Government sector literature dropped the most, while in the earth and space sciences, the Federal Government accounted for almost all of the overall drop by the 29 percent decrease of its literature.

The distribution of scientific and technical articles by research-performing sector did not change significantly in the 1973-77 period (see Appendix table 2-9).

This considerable stability of input to the total corpus of scientific and technical articles was accompanied by an apparent increase in the extent of cooperative research[15] being performed. If one assumes that scientific and technical articles written by S/E's at different institutions or organizations reflect such joint

[13] This estimated lag is based on work done by Computer Horizons, Inc.

[14] See the Basic Research chapter for a discussion of the considerably different rates of change in the same field for basic and for applied research articles. The declines described here may be slightly overstated if less research is being conducted of the type that leads to publication, if there are increases in the effect of factors impeding the release of such research in articles, or if the U.S. articles are not as likely to be carried by this set of over 2,100 influential journals as in earlier years.

[15] Defined as articles which were written by scientists and engineers in a given organization with scientists and engineers from another organization.

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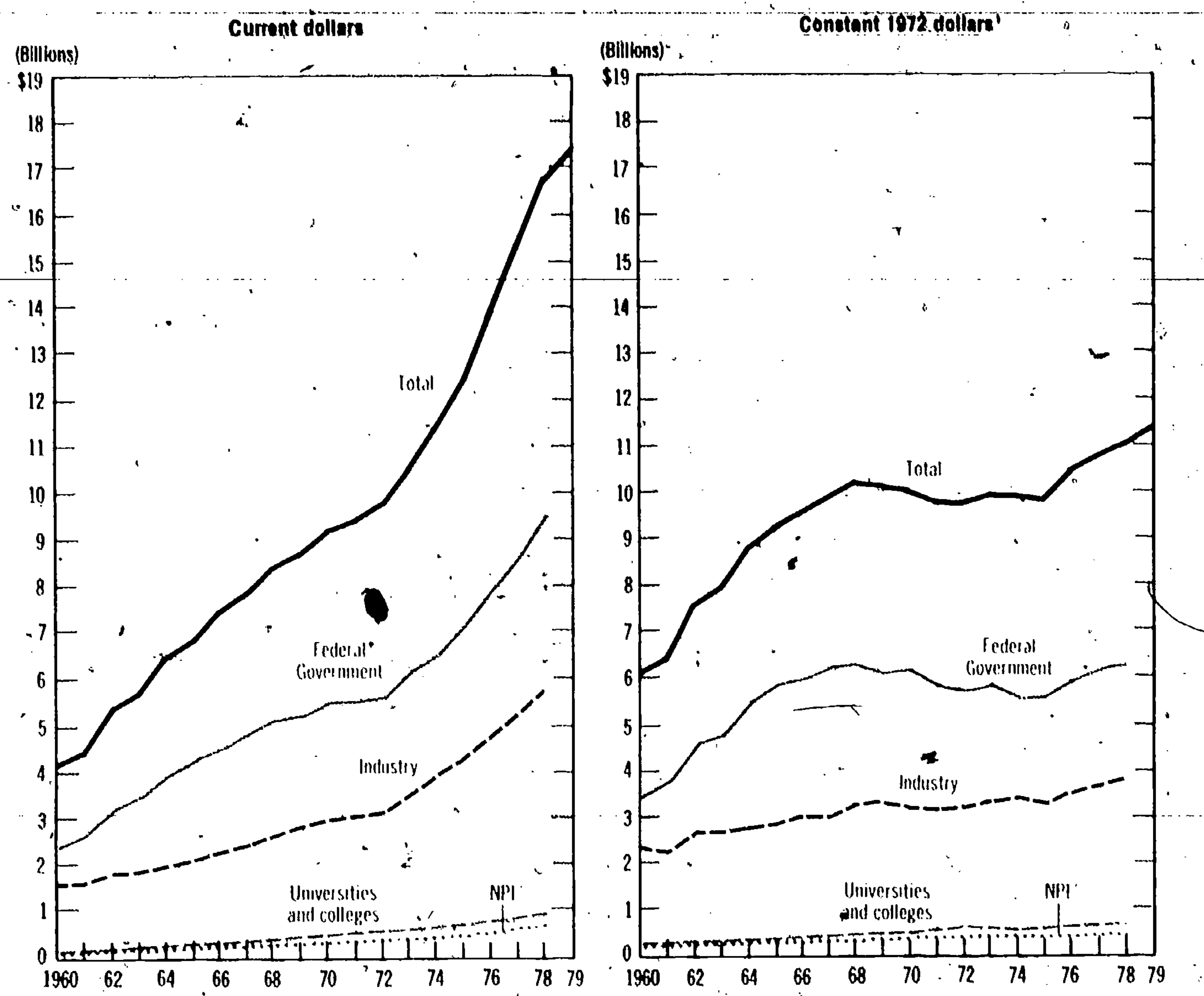
Figure 2-8
Total research expenditures by source: 1960-79



¹GNP implicit price deflators used to convert current dollars to constant 1972 dollars
Nonprofit institutions
NOTE Estimates are shown for 1977, 1978, and 1979
REFERENCE Appendix table 2-7

Science Indicators—1978

effort, it can be seen from figure 2-10 that increased cooperative authorship of this type occurred in many fields and sectors. If only changes greater than 5 percent are considered, six of the nine fields saw scientists and engineers in university-administered FFRDC's increase their use of this cooperative mode. On the other hand, university scientists and engineers and those from the other three sectors by and large showed increases less than 5 percent on this indicator of cooperative research activities. (See Appendix table 2-10).

Basic and Applied Research

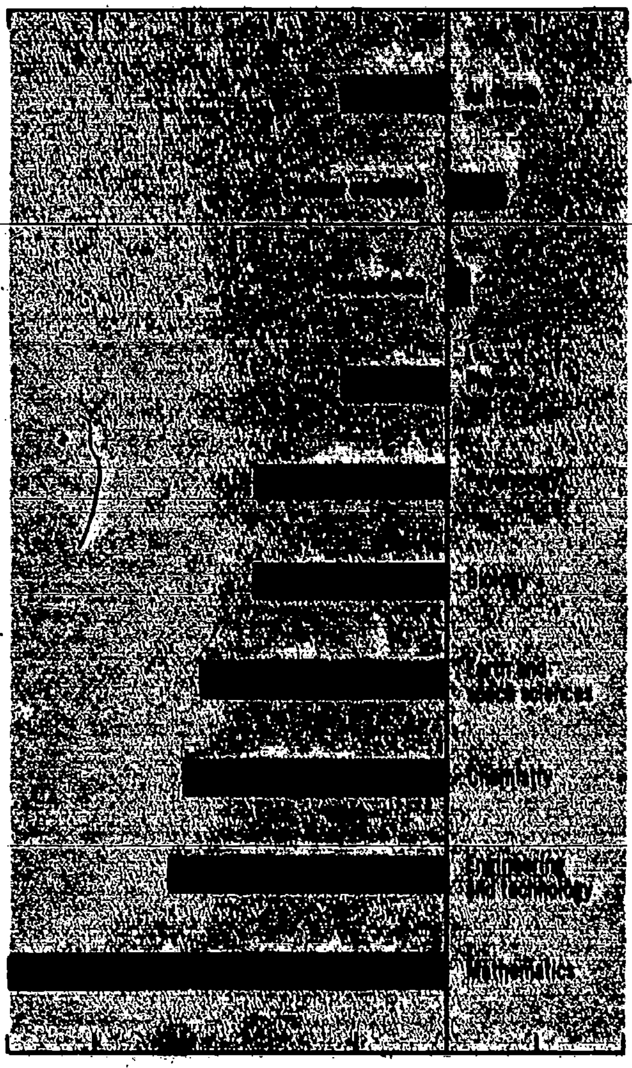
Expenditures for basic and applied research represent only one-third of the national R&D total, but the knowledge and advances gained often have social and economic impacts greater than the expenditures involved.[16] Therefore, the

Figure 2-9

Percent changes in the number of science and technology articles' by U.S. authors by field: 1973 to 1977

(Percent decrease) (Percent increase)

−25 −20 −15 −10 −5 0 5 10



'Based on the articles, notes and reviews in over 2,100 of the influential journals carried on the *Science Citation Index* Corporate Tapes of the Institute for Scientific Information

REFERENCE Appendix table 2 8 Science Indicators – 1978

overall level and the balance between these activities should be monitored so that shifts in levels of support can be identified and policy options for dealing with them can be examined. Review of historical patterns of support for each type of research activity pinpoints areas in which policy changes and shifts in emphasis have been made. Such was the case in 1976. Total national expenditures for basic research, in constant dollars, had been declining steadily since the late 1960's (see figure 2-11). Expenditures for applied research fell, then leveled off near the 1968 level through the mid-1970's before rising again. Further study shows some possible causes for these earlier declines (see figure 2-12). In the case of basic research, Federal support had fallen more than 13 percent from 1968 to 1975,[17] and this drop in Federal funding was primarily responsible for the overall decline of this activity. Over the same period, constant dollar basic research expenditures by industry fell 17 percent. Policy actions by the Federal Government were primarily responsible for the rise in funding levels for basic research: in 1979, an estimated 16 percent above the 1975 level. From 1975 to 1978, constant dollar support by Federal and industrial sources rose by 14 and 9 percent, respectively. Even with these increases, total constant dollar support for basic research in 1978 remained at about the 1968 level, though it rose almost 4 percent in 1979. Federal support in 1978 was at the level of the late 1960's, and industrial support was comparable to that provided in 1970.

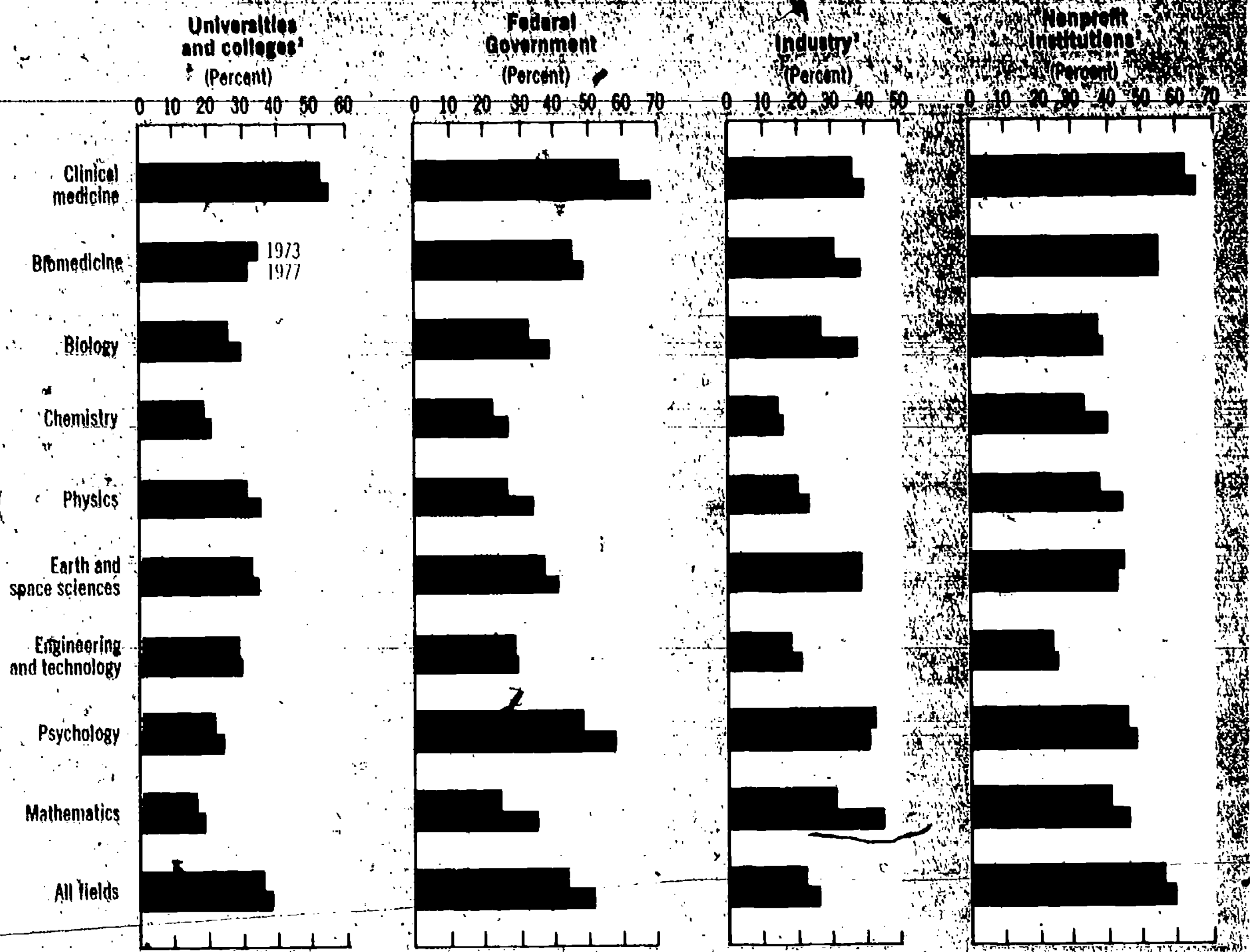
Applied research expenditures, in constant dollars, also began a sharp rise in 1976, climbing nearly 9 percent above the 1975 level. By 1979, total constant dollar expenditures for applied research were estimated to be almost 16 percent higher than they were in 1975. The largest two sources of funds for applied research were the Federal and industrial sectors, accounting in 1978 for about 50 and 45 percent of the total, respectively. Real dollar growth was significant from these sources between 1975 and 1978, with funds provided by Federal sources rising by nearly 10 percent in this period, and industrial support growing over 15 percent.

[16] Much significant work has been done with regard to the social and economic benefits of research. See *Selected Readings on Science, Technology and the Economy*, Subcommittee on Science, Research and Development, Committee on Science and Astronautics, U.S. House of Representatives, Ninety-Second Congress, First Session Oct. 1, 1971, for major references on this topic. See also the forthcoming reports on the NSF symposium on the *Relationship Between R&D and Returns from Technological Innovation*, May 21, 1977, and the NSF symposium on the *Relationship Between R&D, Economic Growth/Productivity*, November, 1977.

[17] The chapter "Resources for Basic Research" provides more complete coverage of indicators of basic research.

Figure 2-10

Index[1] of cooperative research based on scientific and technical articles, by field and selected research-performing sectors: 1973 and 1977

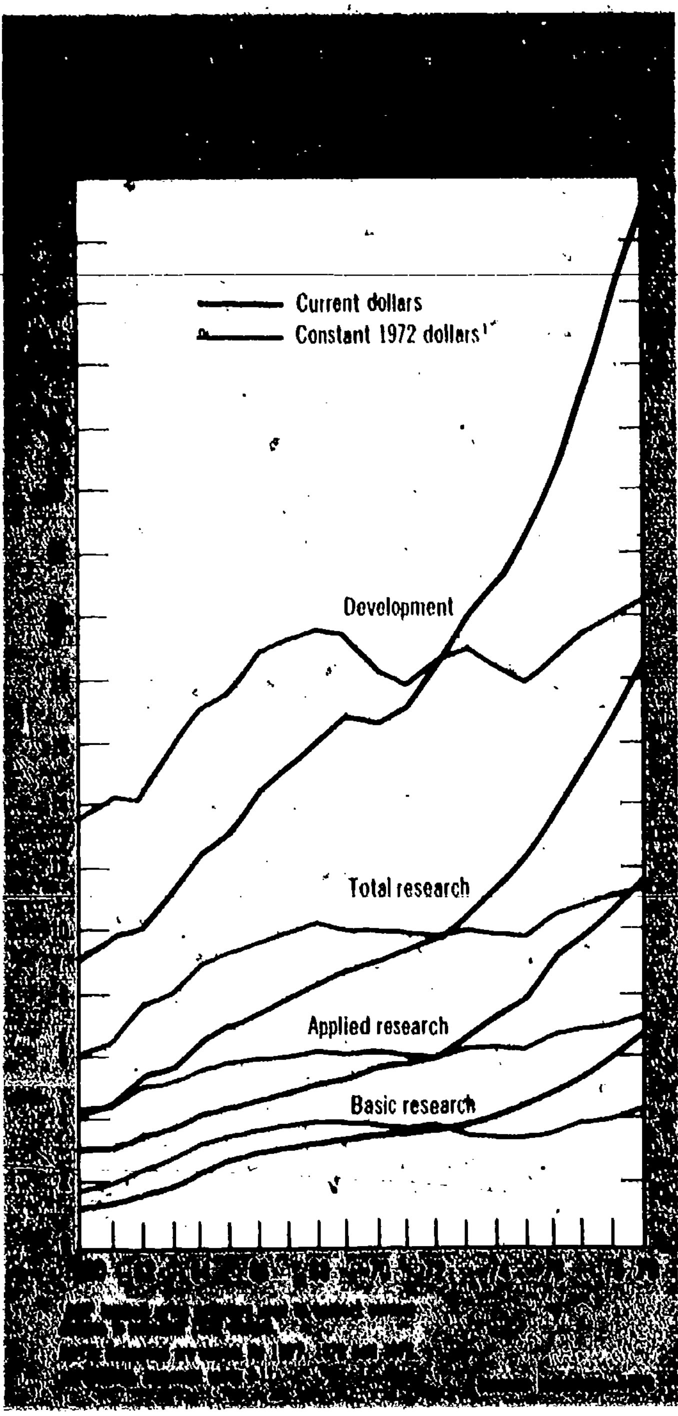


[1] Consisting of the percentage of all articles which were written by U.S. scientists and engineers in a given organization with S/E's from another organization, e.g., if S/E's from one university co-author an article with S/E's from another university or a corporation. It is assumed here that there was some degree of cooperative research performed. The data are from over 2,100 of the influential journals carried on the *Science Citation Index* Corporate Tapes of the Institute for Scientific Information.

[2] Excluding the Federally Funded Research and Development Centers administered by these sectors.

REFERENCE. Appendix table 2-10.

Science Indicators—1978



FUNCTIONAL AREAS OF FEDERALLY FUNDED R&D

Expenditure decisions concerning functional areas of R&D[18] are not usually made from the top down. Federal R&D expenditures in the aggregate rise or fall only after myriad decisions with regard to individual programs. Total R&D spending levels simply reflect the sum of many varied strategic decisions concerning specific science and technology efforts.

Identification of functional areas of major Federal scientific and technological activities provides a basis for assessing Federal R&D priorities, for deciding whether or not areas of great and immediate national concern (such as energy) are receiving sufficient support, and for deciding whether or not there is proper balance in support provided for all functions.

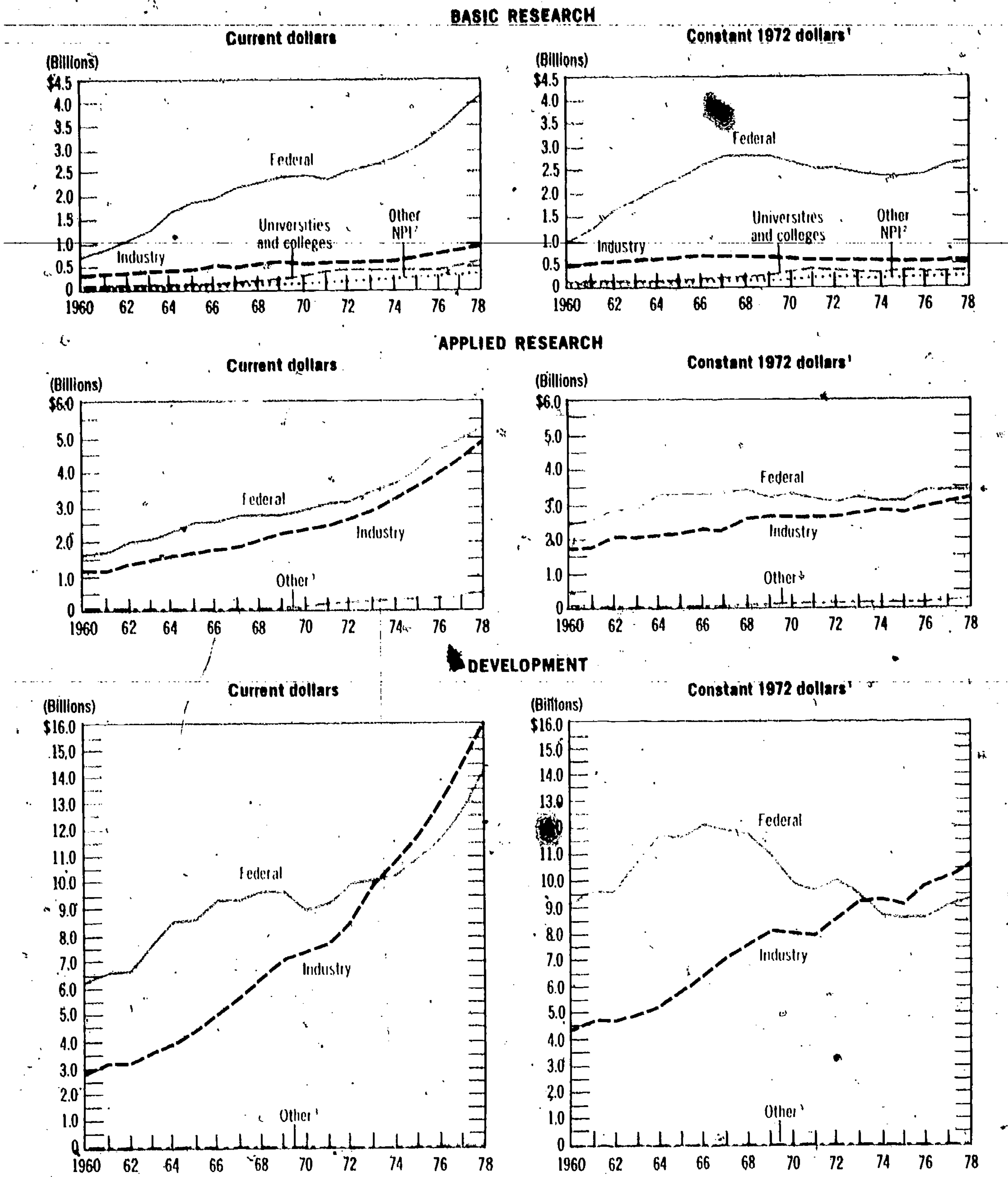
Federal support for the Nation's R&D activities is presented in figure 2-13 in terms of three major categories: national defense, space, and all civilian R&D. The largest of these categories, by far, is national defense, followed by all civilian R&D, and then space.

The data show that national R&D priorities have shifted considerably for these three major categories. Substantial changes have occurred in the space category, where the fraction of the total held in 1979 amounted to 12 percent—half of what it was a decade earlier. Civilian areas of R&D held 39 percent of the total in 1979, compared with 23 percent in 1969. This shift from space to civilian areas seems related to the deemphasis of the strong manned space program of the mid-1960's to late 1960's and the development of new initiatives in health, energy, and environmental areas. Smaller changes have taken place in the proportion of total R&D used for defense purposes. This proportion has stayed at the 48-50 percent level since 1976. Earlier trends can be found in Appendix table 2-15.

[18] Throughout the following discussion of Federal R&D functional areas, it should be noted that estimates given for 1979 may change significantly as a result of congressional action on agency budget requests. Data regarding the functions are presented in terms of Federal obligations. Obligations represent the amounts for orders placed, contracts awarded, professional services received, and similar liabilities incurred during a given period, regardless of when the funds were appropriated. Expenditures (outlays), which have been discussed in previous sections of this chapter, represent amounts for checks issued and cash payments made during a given period, regardless of when the funds were appropriated.

Figure 2-12

National R&D expenditures by character of work and source of funds: 1960-78



[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars

[2] Other nonprofit institutions

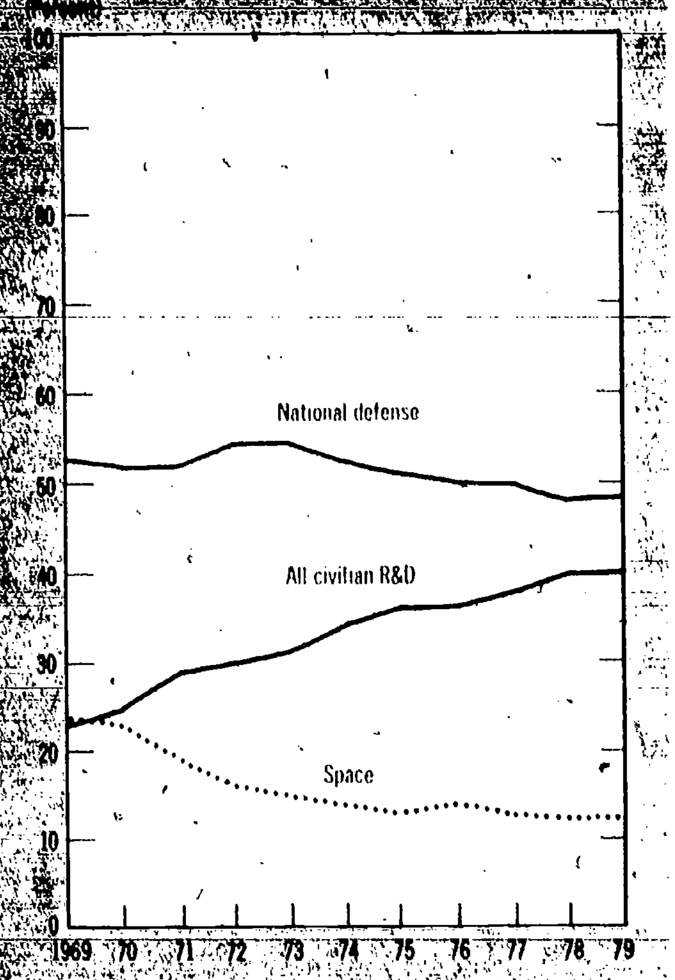
[3] Universities and colleges and other nonprofit institutions combined.

NOTE Estimates are shown for 1977 and 1978

REFERENCE. Appendix tables 2 12, 2 13, and 2 14

Science Indicators – 1978

Figure 2-13.
Percent of Federal obligations for R&D by major function: 1969-1979



NOTE: Estimates are shown for 1978 and 1979.
REFERENCE: Appendix table 2-15.
Science Indicators—1978

National Defense R&D

In 1976, U.S. expenditures for all military purposes amounted to $91 billion—54 percent of total world military spending for that year, and more than 5 percent of the U.S. GNP.[19] In that year, defense-related R&D obligations alone amounted to over $10 billion, or approximately 11 percent of all military spending. Defense R&D spending in current dollars appeared to level off somewhat in 1973 and 1974 but has continued to rise steadily since then. Obligations grew an estimated 12 percent between 1978 and 1979, with part of this increase slated for basic research efforts and advanced technology development. In addition, emphasis was placed on developing various strategic systems, including the intercontinental ballistic missile, strategic submarine systems, the air-launched cruise missile, and various tactical systems to improve early combat capability for U.S. forces in the defense of Western Europe. Continued defense support is also provided for the NASA space shuttle program.

[19] *World Military Expenditures and Arms Transfers, 1967-1976*, U.S. Arms Control and Disarmament Agency, Publication 98, p. 28.

Space R&D

Obligations for space R&D have varied considerably over the years. For example, the space race following the launch of the Soviet's Sputnik in 1957 led to rapid development of earth orbiters, followed later by the massive effort to put men on the moon. Priorities then shifted somewhat away from space, producing significant declines in space R&D spending. Recent initiatives relevant to the space shuttle have sparked moderate growth in space R&D. In current dollars, obligations rose an estimated 35 percent over the period 1975-1979, at an average annual rate of approximately 7.7 percent, compared to an average annual decline of 8.3 percent over the 1970-1974 period. Major emphasis in 1979 within this function includes continued development of the space shuttle system and procurement of four shuttle orbiters for operation from both the east coast and west coast areas of the United States; space telescope development; the Jupiter orbiter and probe; and development of a spacecraft to study, for the first time, the polar regions of the Sun.

Civilian R&D

This category, encompassing 13 functional areas of science and technology, includes the areas of R&D that most directly affect the lives of U.S. citizens. Policy decisions in these areas are reflected in the level of fiscal support for the individual functions (see figure 2-14).

As noted earlier, civilian R&D comprises about 39 percent of all Federal R&D obligations. Obligations for all civilian functions together have experienced rapid growth in each year between 1974 and 1978. For example, Federal R&D obligations for the functions in this group grew 21 percent between 1976 and 1977 and 16 percent between 1977 and 1978. However, between 1978 and 1979 this pattern of growth slowed somewhat because of a number of factors: attempts to avoid taking over activities more appropriate to the private sector, such as developing, producing, and marketing new

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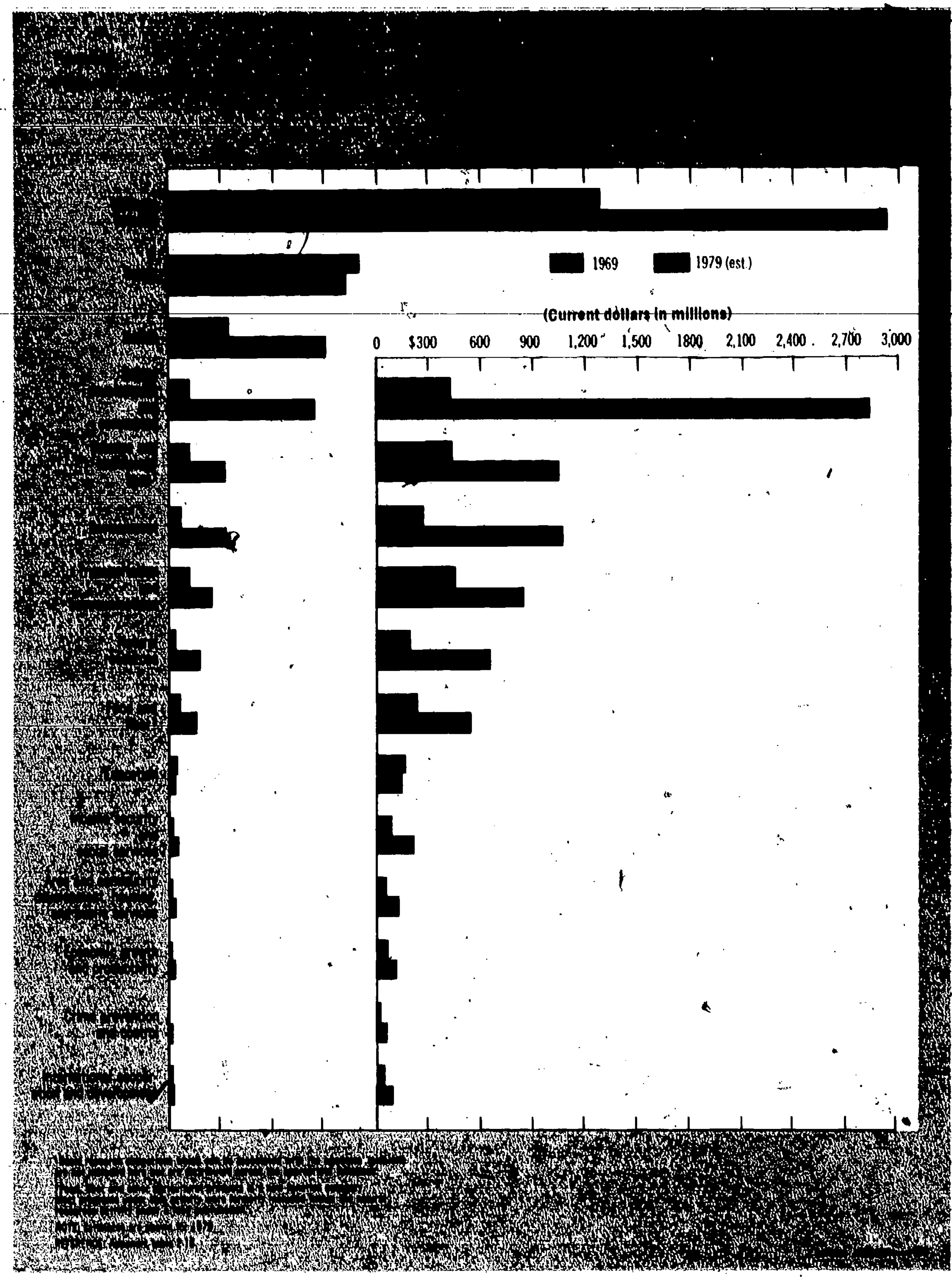

1969
1979 (est.)
(Current dollars in millions)
0 $300 600 900 1,200 1,500 1800 2,100 2,400 2,700 3,000

products and processes (as in the case of solar heating); the need to avoid public investment in technology where user demand or future economic viability and institutional acceptance is highly unlikely; and the need to avoid overinvesting in multiple demonstrations of somewhat similar technologies, or technologies that promise only marginal improvements, as in the case of coal gasification demonstration. The appropriate role of Government is to emphasize long-term (and relatively lower cost) research for the future and new technology options rather than major commercial-scale (and relatively higher cost) demonstrations.[20]

Health and energy R&D together have made up well over half the obligations in recent years. The fraction of total Federal R&D obligations held by each function is presented in table 2-1.

The Nation's health R&D activities have grown dramatically from relatively modest beginnings. In 1969, national obligations for health R&D were well over the $1 billion mark, and estimates show that health R&D will reach $3 billion in 1979. However, beginning in 1977, health R&D as a percentage of all civilian R&D spending decreased considerably, primarily because of reductions in funding of R&D programs for health care delivery.

Energy development and conversion involves R&D programs crucial to national goals of providing safe, economical, and plentiful energy sources; this component is one of the largest in civilian R&D; in 1979, it accounted for 26 percent of the total, more than twice the percentage it held in 1969. It is also an area which recently has experienced extremely rapid growth—current dollar obligations have advanced at an average annual rate of 33.6 percent between 1974 (the year just preceding new energy R&D initiatives) and 1979.

Main energy R&D programs include the development of technologies for increasing domestic oil and gas production; mining and burning coal more efficiently and cleanly; producing high Btu synthetic pipeline gas; pursuing better means to extract oil and gas from shale; advancing geothermal power production; supporting the development of a broad range of solar energy options; attempting to develop acceptable alternative fuel cycles that may preclude the potential problems with liquid-metal-cooled, fast-breeder reactors; and controlled thermonuclear fusion.

[20] These factors are described in *Special Analyses: Budget of the United States Government, Fiscal Year 1979*, p. 307.

[illegible]

Environmental R&D activities encompass pollution control; environmental protection; and understanding, describing, and predicting the environment. The growing awareness of the relationship between environmental quality and human health has led to emphasis on environmental health and safety. Environmental R&D programs recently accounted for about 10 percent of the civilian R&D total. This proportion has not varied significantly since 1976. The cost of environmental R&D initiatives is high—in 1978, obligations exceeded the $1 billion mark for the first time, and estimates for 1979 show that obligations will surpass the 1978 level (but not by enough to overcome the effects of inflation). However, these support levels are directed toward ameliorating a problem which carries far greater social and financial costs.

FEDERALLY FUNDED RESEARCH FACILITIES AND EQUIPMENT

Continued advancement in all areas of science and technology requires appropriate facilities and tools of the trade. Progress cannot occur unless such tools as nuclear reactors, telescopes, computers, high-energy accelerators, and wind tunnels are adequate to the work at hand. High costs of purchasing, operating and maintaining many types of devices have impact on persons in all R&D-performing sectors. This section discusses the past and present patterns of spending for facilities and for equipment purchased through Governmental sources, and it presents some policies, planned as well as functioning, for providing adequate research equipment.

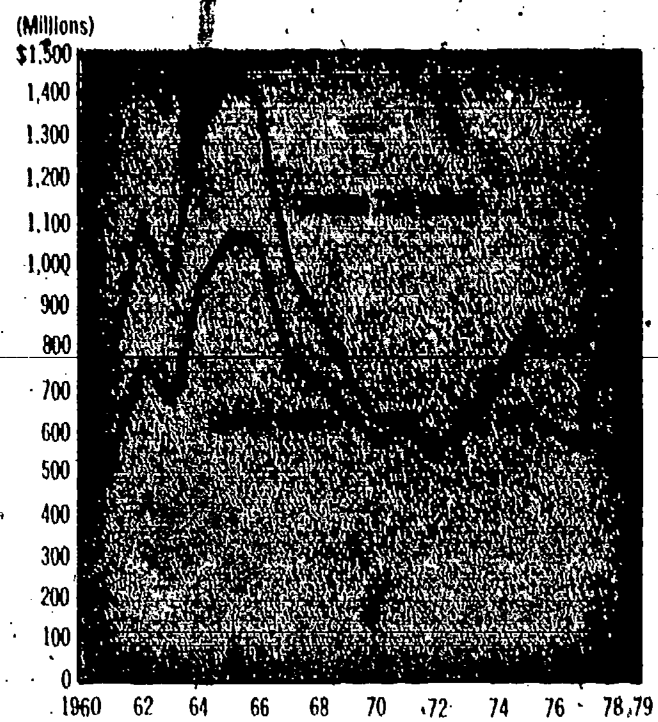
R&D Plant

Federal funding of R&D plant plays a significant part of the total investment in this area. Such funds cover acquisition, construction, and major repair of R&D facilities, as well as purchases of large fixed equipment such as reactors, wind tunnels, and radio telescopes.

Federal outlays for R&D plant have fluctuated widely (see figure 2-15). The rapid growth of constant dollar expenditures during the early 1960's was chiefly due to the expansion of NASA's intramural facilities and the decline in the late 1960's largely reflects the completion of these facilities. The upturn in expenditures after 1972 reflects increased spending for energy-related facilities, particularly for equipment to support work in fusion power research and high energy physics, the support of space shuttle facilities by NASA, and the construction of three

Figure 2-15

Federal expenditures for R&D plant: 1960-79



¹GNP-implicit price deflators used to convert current dollars to constant 1972 dollars

NOTE: Estimates are shown for 1977, 1978 and 1979

REFERENCE: Appendix table 2-17

Science Indicators—1978

major research facilities by the National Institutes of Health.

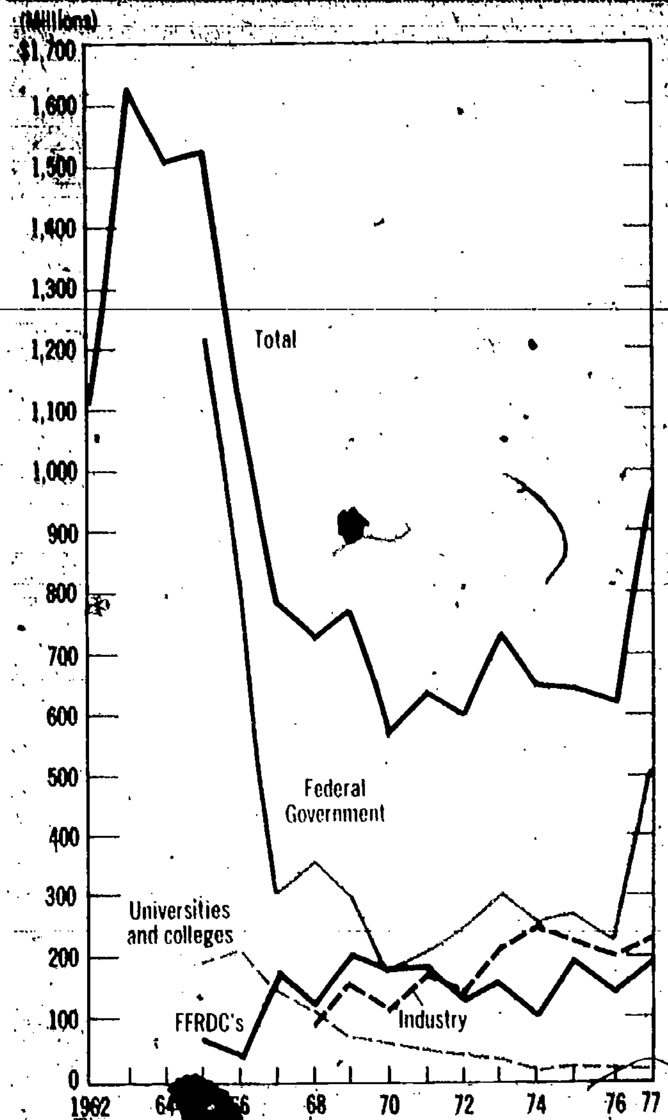
Federal intramural laboratories, industry, and FFRDC's administered by universities account for most obligations for R&D plant (see figure 2-16). In 1977, these performers accounted for 52 percent, 23 percent, and 20 percent, respectively, of the total. These performers gained increased support in 1977, but it probably was not sufficient to make up for the steep declines experienced throughout the late 1960's.

Equipment for Scientific Research

With today's equipment and computational resources, many R&D tasks can be performed in a fraction of the time required a few years ago. As the frontiers of science advance, the devices required for measurement or for more detailed analysis must be increasingly more sophisticated, and can be more costly than ever before. This expense obviously is not only a function of increased sophistication, but also of rapidly rising costs affecting all sectors of the economy.

The availability of adequate equipment in universities has implications beyond the need for

Figure 2-16
Federal obligations for R&D plant in constant dollars¹ by performer: 1962-77



¹GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

REFERENCE: Appendix table 2-18.

Science Indicators—1978

scientific advancement. Because advanced equipment is not always available, there is concern that students are not being properly educated in the state-of-the-art of their own disciplines. Funds for equipment are provided to academic researchers in a variety of ways, but one of the most important is that which is provided either as part of a Federal research grant, or that granted specifically for equipment purchase. The two major sources of these Federal funds are the National Science Foundation and the National Institutes of Health; together, these two agencies granted individual investigators approximately $98.8 million in 1977 for equipment for scientific research (see table 2-2).

Table 2-2. NSF and NIH funds for permanent equipment provided through research grants or grants specifically for equipment: 1974-77

(Dollars in millions)

Year	Current dollars	Constant 1972 dollars¹
1974	$76.6	$66.0
1975	78.1	61.4
1976	90.8	67.8
1977	98.8	70.0

¹GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NOTE: These figures do not include equipment provided through Biomedical Research Support Grants of NIH. Equipment support provided through these NIH grants, in constant dollars, accounted for $8.4 million in 1974, $10.2 million in 1975, and $9.6 million in 1976. All figures are estimates.

SOURCE: National Science Foundation and National Institutes of Health, unpublished data.

This figure is approximately 29 percent higher than funds granted in 1974 and is nearly 9 percent above the 1976 level. Even in constant dollars, equipment grant support has been advancing in recent years.

In addition to programs of increased financial support for equipment, other initiatives have been developed; these include plans to encourage sharing of equipment within university laboratories, and the establishment of regional instrumentation facilities where investigators could perform research programs.

In the equipment-sharing program, universities establish inventory systems of equipment available for sharing; these inventories are available to university researchers.[21] Regional instrumentation facilities are being established by the National Science Foundation and serve as central sources of unusually expensive equip-

[21] For further information concerning guidelines for such inventories, see *Minimum Requirements are Needed for Colleges and Universities to Justify Research Equipment Purchases*, General Accounting Office, HRD-78-52, May 11, 1978.

ment otherwise not readily available to scientists and engineers. The types of equipment considered under this program include devices for nuclear magnetic resonance spectroscopy, mass spectrometry, X-ray crystallography, lasers, and photoelectron spectroscopy.

OVERVIEW

The general picture which emerges is an encouraging one. R&D activity had been declining following the rapid growth of the early 1960's. Well-founded concerns were expressed regarding the erosion of the necessary resource base upon which the next generation of scientists and engineers must build and upon which the future welfare of the Nation will depend. However, national expenditures for R&D activity are advancing. Once again, Federal support for R&D is increasing in constant dollar terms, and the private sector is providing resources at levels higher than ever. The United States Government has explicitly adopted the idea that R&D is an investment in the future—not simply the purchase of a commodity—and therefore should receive appropriate support.

Among the two major types of research activity—basic and applied—a period of modest real growth has persisted for longer than any time since the late 1960's. This pattern is significant, because it means that the groundwork is being laid for increased long-term scientific and technological advances through basic research, and more short-term progress through applied research. Development expenditures, which fluctuated considerably from the late 1960's to the mid-1970's, now seem to be growing steadily. Such growth is particularly important in terms of short-term economic and social benefits.

National defense accounts for the largest proportion of Federal R&D spending and continues to grow. Spending for space R&D also requires substantial Federal resources. Increased spending in recent years for the space shuttle reflects the desire to capitalize on the practical value of the gravity-free environment and simultaneously advance man's understanding of the universe. The space shuttle program is expected to permit advances in manufacturing drugs and devices to a degree not possible within the confines of the Earth's gravity.[22]

In civilian areas other than space, health R&D and energy R&D together comprise well over half the total. Obligations in both these areas remain strong. However, the phenomenal growth in the energy areas since 1974 has slowed, perhaps temporarily. This change reflects the view on the part of the Federal Government that because of increased incentive for private investment in energy R&D, less reliance needs to be placed on the Federal budget to meet this national need.[23] As a percent of all Federal R&D spending, total expenditures in civilian areas had been growing during the 1970's, but in recent years this trend seems to have been reversed.

[22] Some questions have been raised concerning the potential for certain manufacturing operations in a space environment. For additional information concerning this topic, see *Materials Processing in Space* (Washington, D.C.: Committee on Scientific and Technological Aspects of Materials Processing in Space, Space Applications Board, Assembly of Engineering, National Research Council, 1978).

[23] *Special Analyses: Budget of the United States Government, Fiscal Year 1980*, p. 296.

ERIC

Chapter 3

Resources for Basic Research

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Resources for Basic Research

INDICATOR HIGHLIGHTS

- Total national expenditures for basic research have grown during the period from 1976 to 1979 in constant dollar terms following a period of reduced spending between the late 1960's and mid-1970's. This growth resulted primarily from Federal increases based on the realization that basic research represents an investment for the future. (See p. 65.)

- Universities and colleges perform the largest percentage of basic research in the United States. The share accounted for by this sector has increased in recent years. In 1960 this sector spent 36 percent of the Nation's expenditures for basic research, but by 1978 it had risen to 52 percent. Reasons for this change include reduced basic research activity in the industrial sector. (See pp. 67-68.)

- Beginning in 1976, constant dollar basic research spending by industry, which accounted for approximately 16 percent of the total, has advanced slightly, following a period of declining support that began in the middle-to-late 1960's. This relatively recent, modest growth is significant because it may signal the end of the longstanding trend of decreased industrial basic research activity. (See pp. 74-75.)

Basic research plays a special role in R&D. It is sometimes thought of primarily as an intellectual endeavor, and, as such, it aims to advance man's understanding of himself and his environment. However, basic research serves other purposes as well. It is relied on by the academic community as a way to educate students and by the Federal Government and industry to accomplish social and economic objectives.

This chapter discusses the national resources provided to achieve these goals. As discussed in the previous chapter, resources for basic research are measured primarily in terms of the funds available, although some indicators dealing with scientific and technical literature as an output of basic research are presented. This chapter will not attempt to quantify the total output of basic research; however, the economic and social benefits from basic research projects are substantial.[1]

The indicators presented here have a number of limitations. They do not cover the substantive aspects of basic research, such as advances in knowledge achieved in the various scientific disciplines.[2] The indicators do not include measures of the effectiveness or productivity of basic research activity.

There are also limitations to the data used in describing some of the trends presented here. For example, it is difficult to distinguish "basic" research from "applied" research. A particular research effort may be identified as basic or applied, depending on whether the classification is made by the research sponsor or by the performing organization or individual. Despite these limitations, the definitions provided when data are gathered have been comparable over time, and interviews of survey respondents show that interpretations, while varied, seem to be fairly consistent over time. Therefore, the trends presented can serve as reasonable measures of change.

[1] Information regarding specific discoveries in basic science that have had major, long term effects on society appears in Eugene H. Kone and Helene J. Jordan (eds.), *The Greatest Adventure* (New York: The Rockefeller University Press, 1974), as well as in the National Science Foundation's TRACES Study, *Technology in Retrospect and Critical Events in Science* (Chicago: Illinois Institute of Technology Research Institute, 1968).

[2] For illustrations of specific scientific breakthroughs, see *Frontiers of Science*, National Science Foundation (NSF 76-48), and *Status of Science Reviews 1979*, National Science Board (NSB 79-3).

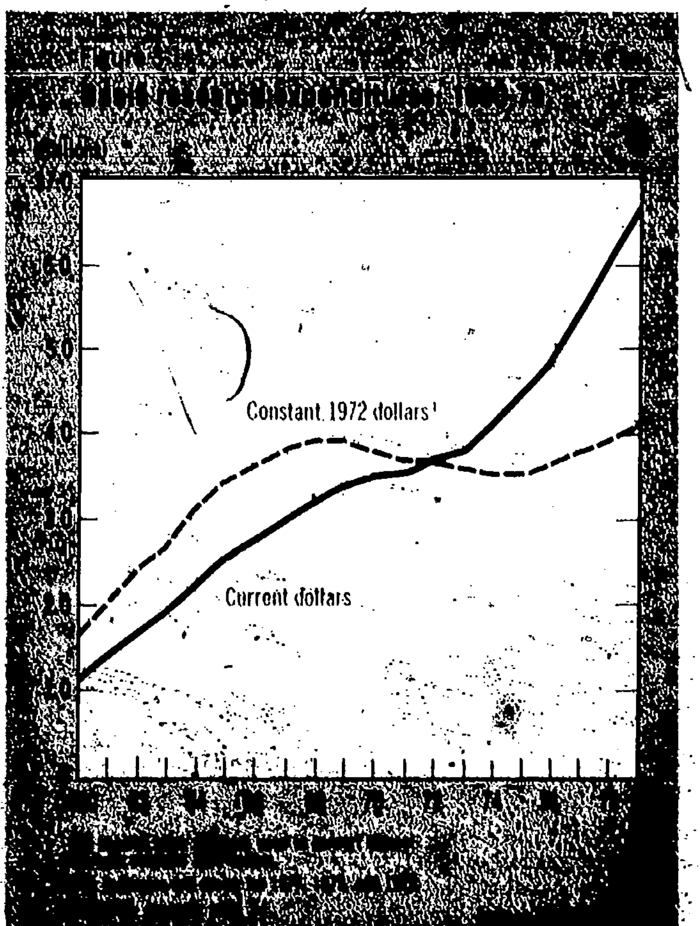
NATIONAL RESOURCES FOR BASIC RESEARCH

It is very difficult to measure the changes in knowledge or economic productivity that result from basic research activities. The indicators that follow, however, reflect the level of these activities in the United States. As with total R&D activity, dollars are used as approximate measures of the level of the national basic research effort.

Basic research receives about 13 percent of all R&D funds. This fraction has been relatively stable since the mid-1960's. Constant dollar[3] support for basic research has fluctuated somewhat during the last 10 years, but has advanced in recent years; expenditures increased at an estimated average annual rate of 3.7 percent between 1975 and 1979. Although it is estimated that constant dollar support for basic research will reach a new high in 1979 (see figure 3-1), this amount is only slightly higher than the previous peak that occurred in 1968.

The increase in funding stems primarily from an effort by the Federal Government to provide for strong growth in basic research. The Presidential budgets for Fiscal Years 1977, 1978, and 1979, and the recent Presidential Message on Science and Technology[4] have all carried clear statements concerning the importance of basic research and the need to provide adequate Federal support. Intensified Federal interest in supporting basic research has a major impact on national support levels because Federal sources provide approximately 70 percent of all funds for basic research.

[3] Here and elsewhere in this report, the GNP implicit price deflator is used to convert current dollars to constant 1972 dollars. This deflation method is only approximately appropriate for use in connection with R&D as a whole or with specific R&D-performing sectors. Attempts have been made to develop sectoral R&D deflators. References to this work are provided in the Resources for Research and Development chapter. See Appendix table 3-1 for the actual GNP implicit price deflators used in this report.



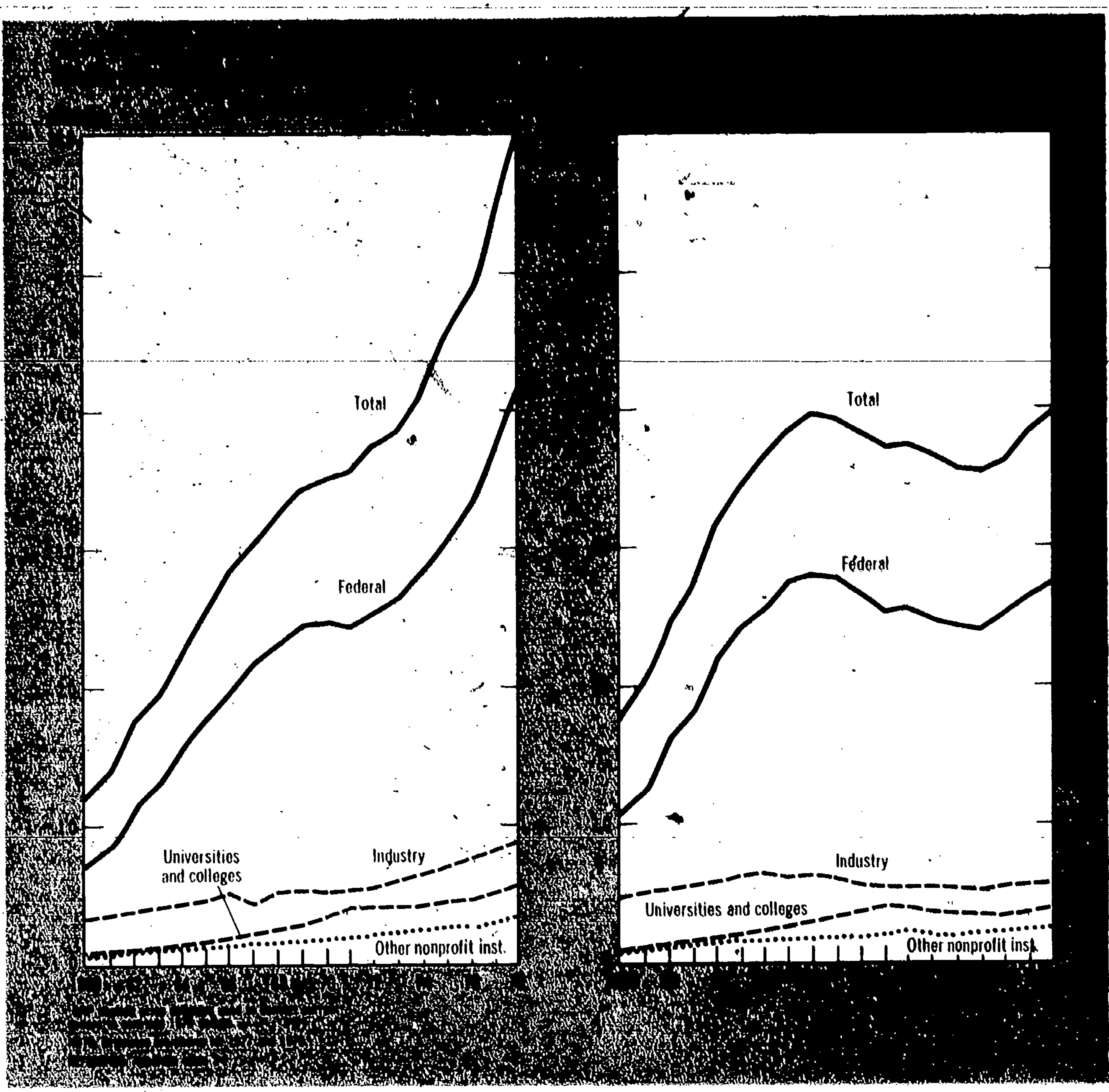
Sources of Funds for Basic Research

The Federal Government is the primary supplier of funds for basic research. One reason for this strong Federal role is the desire to support basic research in areas directly related to the Government's own needs. In this way, the Nation can maintain strong capabilities in critical areas such as national defense and health. Other reasons relate directly to the nature of basic research activity. Basic research may not produce short-term economic payoff even though long-range economic benefits may be significant. Therefore, non-Federal economic sectors are not likely to invest in basic research unless the potential payoff is high enough and certain enough. Benefits of basic research often do not accrue primarily to the sponsor, and their nature and incidence are unpredictable. Therefore, the incentives for private support are insufficient. In addition, the results of basic research are usually public goods whose production cannot be supported by the private market. Because of these inherent problems, the Federal Government attempts to help meet the need for basic research through its support.[5]

To compensate for the gradual decline in constant dollar basic research support during the period from 1969 to 1975, the Federal Government began to commit funds in increasing amounts in 1976 (see figure 3-2). Between 1976

[4] Presidential Message on Science and Technology delivered to the Congress of the United States, March 27, 1979, p. 3.

[5] For further information on this topic see *Basic Research and National Goals* (Washington, D.C.: National Academy of Sciences, 1965), pp. 148-149.



and 1978, Federal basic research funds in constant dollars grew at an average annual rate of 4.9 percent.

Constant dollar support for basic research by the industrial sector[6] also grew over the 1976 to 1978 period, but by a very small amount—an average annual rate of 1.8 percent. This period's increase, however, was preceded by an average annual decline of approximately 2.4 percent between the peak year of 1966 and 1975. Reasons for these recent increases in industrial basic research spending include increased corporate profitability and improved general economic conditions.

Estimated constant dollar support for basic research provided by universities and colleges increased in 1977 and 1978, following a period of decline in the mid-1970's. Expenditures for basic research by nonprofit institutions showed a comparable pattern to that of universities and colleges, with moderate real dollar growth in 1977 and 1978.

[6] Fuller treatment of certain aspects of industrial basic research is provided later in this chapter.

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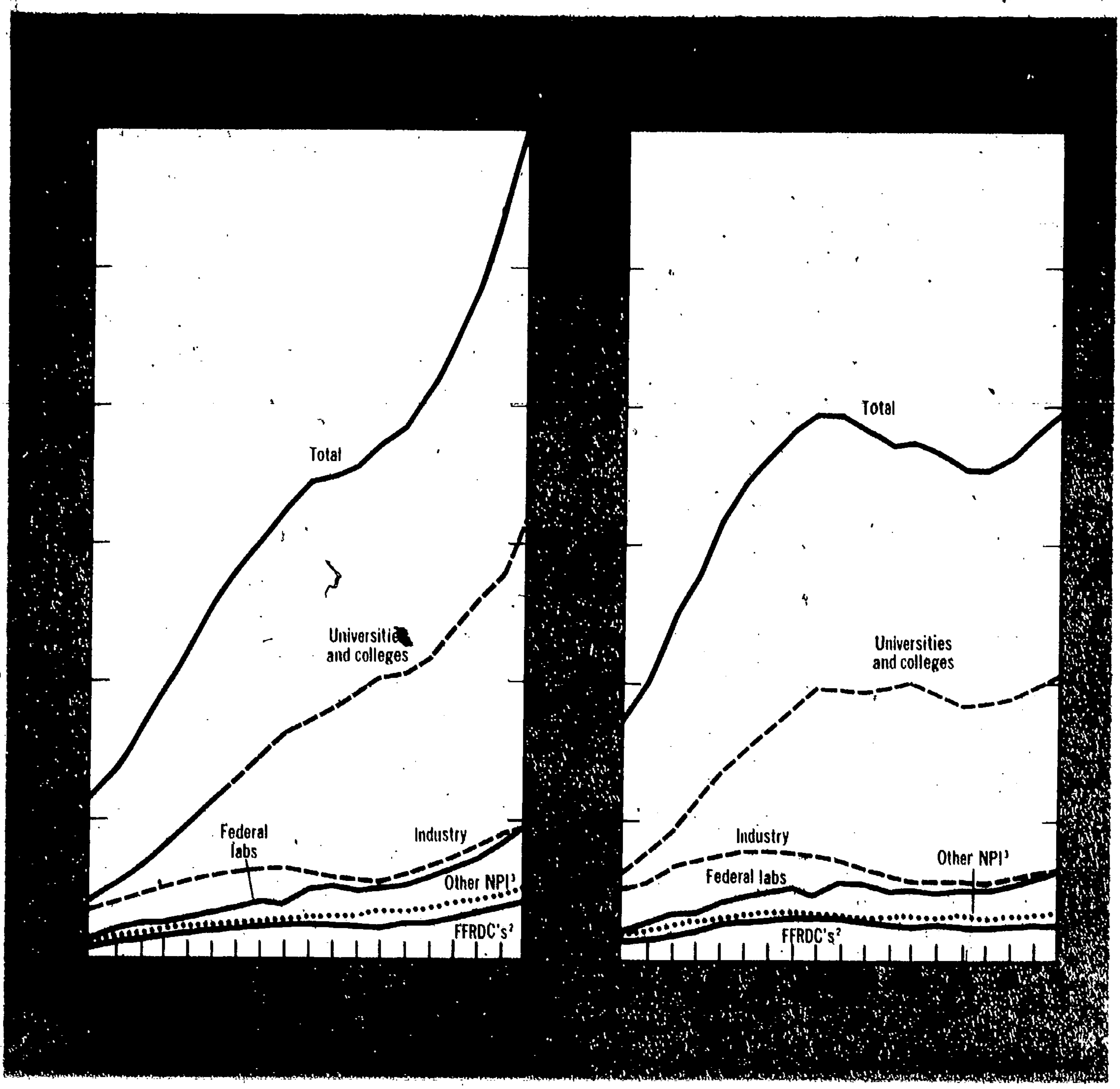
Performers of Basic Research

To understand more fully the institutional structures through which basic research is conducted in the United States, trends in terms of the sectors actually performing the research must be followed. Through such analyses one can determine, for example, the extent to which basic research is concentrated in universities and colleges and the change in patterns over the years. Such information is important because of the relationship between Federal agencies supporting basic research and the universities and colleges that receive substantial portions of these funds. The information also reveals the role of the Government as a performer of basic research, as opposed to a supplier of basic research funds.

Significant changes concerning the performers of basic research have occurred since 1960. In the university and college sector, constant dollar expenditures rose steadily from 1960 until 1968 and remained at about the 1968 level through 1972; however, by 1974 constant dollar expenditures had fallen by more than 8 percent and remained below the 1972 level until 1978, when expenditures reached a new peak (see figure 3-3).



Constant dollar spending in the industrial sector peaked in 1966 and then fell steadily throughout the early and mid-1970's. Some constant dollar growth occurred between 1975 and 1978, during which time estimated spending advanced at an average annual rate of 4.4 percent. As discussed later in this chapter, the earlier expenditure pattern for basic research by industry reflects industry's interest in emphasizing research programs expected to produce short-term gain.

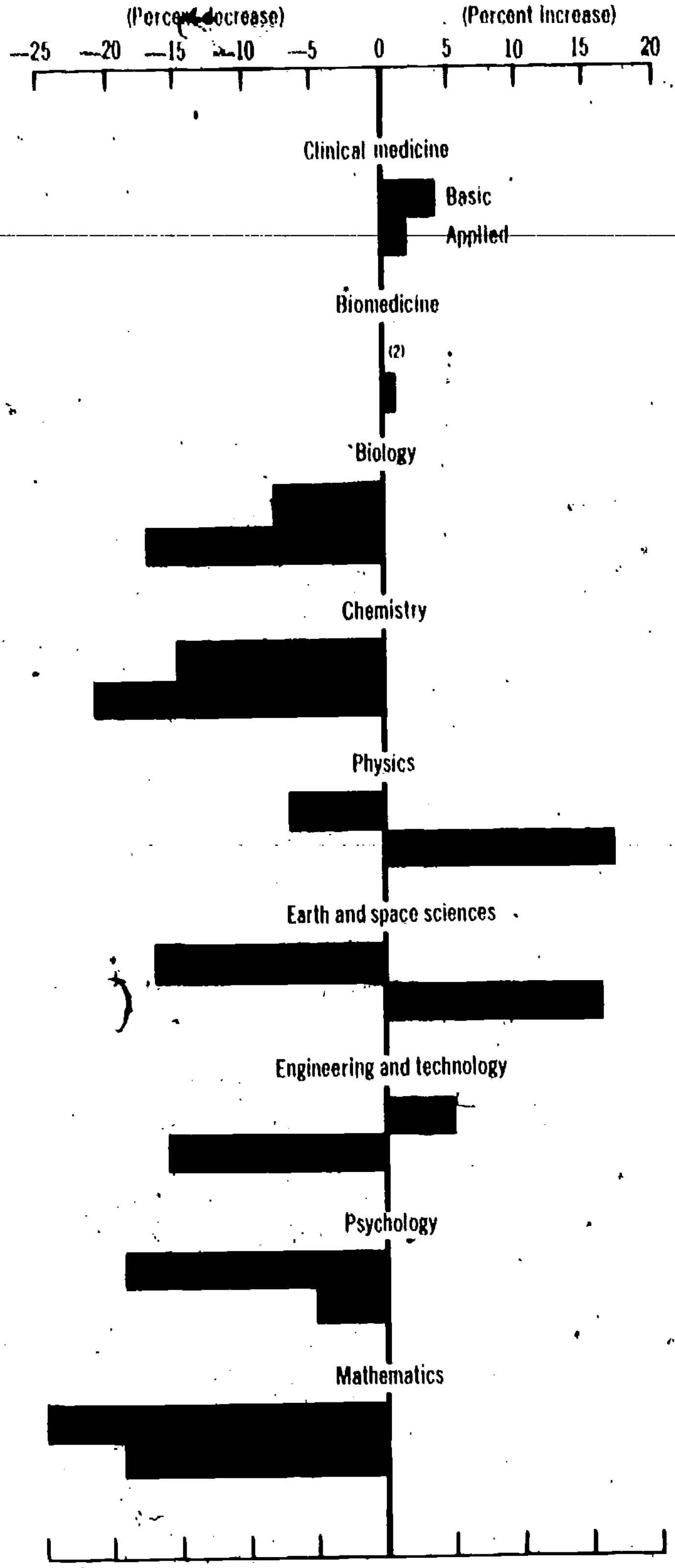
In 1960, based on expenditure data, universities and colleges performed approximately 36 percent of the Nation's basic research; industry performed 31 percent;[7] and the Federal Government, 13 percent. In 1978, however, universities and colleges performed an estimated 52 percent of all basic research, while industry's fraction fell to 16 percent. The Federal Government's portion remained the same over this period—approximately 16 percent. One reason for the increased role of universities and colleges is the reduction in industry's own support of basic research activity. Another reason is the rapid growth in the size of universities and colleges since the 1960's. With industry's deemphasis of basic research in favor of applied research, the proportion of basic research performed by universities and colleges rose, thus increasing the dependence on university basic research and increasing to a lesser extent the role of Federal laboratories, university-administered FFRDC's, and nonprofit institutions.

BASIC RESEARCH LITERATURE OUTPUT

The decline in real expenditures for basic research from 1968 to 1975 appears to have had a negative effect on some fields of science, while for a few fields, the number of basic research[8] articles published by U.S. scientists and engineers actually increased. National data on basic research expenditures are not available by field, but changes in the number of basic research articles may be used to identify shifts in the type of research performed. Figure 3-4 shows how the

Figure 3-4

Percent changes in the number of scientific and technical articles[1] by U.S. scientists and engineers by field and level of research: 1973 to 1977



[1] Based on 103,000 to 109,000 articles, notes, and reviews by U.S. scientists and engineers in over 2,100 of the influential journals of the *Science Citation Index* Corporate Tapes of the Institute for Scientific Information

[2] Less than 0.5 percent   REFERENCE Appendix table 3-4

Science Indicators - 1978

[7] This includes Federally Funded R&D Centers (FFRDC's) administered by industry; the university and college figure does not include funds for FFRDC's administered by universities.

[8] From field to field, the assignment of journals to the "more basic" or "more applied" categories may vary in concept, though for each field the same approach was used for both 1973 and 1977. For further information, see Francis Narin, *Bibliometrics: The Use of Publication and Citation Analysis in the Evaluation of Scientific Activity* (Cherry Hill, N.J.: Computer Horizons, Inc., 1976), pp. 198-199.

number of U.S. basic research articles changed from 1973 to 1977.[9] Clinical medical articles rose, regardless of the level of research involved (basic or applied). However, both types of biology, chemistry, psychology, and mathematics articles declined in this period.

The shifts between basic and applied research articles for physics and the earth and space sciences were seen in the increases of applied research articles, coupled with decreases in basic research articles. Although engineering basic research articles became more numerous, there was a considerable decrease of the engineering applied research literature. Scientists and engineers who were affiliated with the Federal Government accounted for much of this change. For articles in mathematics, the university and college sector accounted for most of the decline. Scientists and engineers in this sector authored 92-93 percent of all mathematics articles in both years (see Appendix table 3-5).

It is important to note, in view of the known biases of respondents who are asked to determine whether activities are "basic" or "applied" research, that the approach used here can demonstrate basic/applied shifts without input from individual respondents whose judgments on this category can vary over time.

University and college scientists and engineers wrote proportionately more of the basic research articles in 1977 than they did in 1973 in all fields except engineering, which experienced slight increases in the industrial and "other" categories[10] (see Appendix table 3-5). Changes in the distribution of applied research articles were not so noticeably directed toward universities and colleges.

As discussed in the Resources chapter, interorganizational cooperative authorship by scientists and engineers may be an indicator of the level of actual cooperative research that has occurred. In 1977, for most fields and most sectors, basic research articles had higher indexes of cooperation than did applied research (see table 3-1), especially in the fields of physics, earth and space sciences, and chemistry. For clinical medicine, however, a greater degree of cooperative research, as defined here, is found in applied research. Nonprofit organizations, the Federal Government, and industry appear to use this

[9] The literature base chosen for this analysis is the *Science Citation Index* Corporate Tape, from which the articles from a fixed set of 1973 journals are described for 1973 and 1977. See the Resources chapter for similar treatment of basic and applied articles combined.

[10] "Other" includes all Federally Funded Research and Development Centers.

Table 3-1. Fields and research-performing sectors whose index of cooperative research[1] is higher for the more basic research articles than for the more applied articles: 1977

All fields[2]	Universities and colleges	Federal Government	Industry	Nonprofit institutions[3]	FFRDC's[4]
Clinical medicine					
Biomedicine		X	X		
Biology			X	[illegible]	
Chemistry		X	X	X	X
Physics	X	X	X	X	X
Earth and space sciences	X	X	X	X	X
Engineering and technology				X	
Psychology		X		X	[illegible]
Mathematics		X		X	[illegible]

[1] This index is the percentage of all articles which were written by S/E's in a given organization with S/E's from another organization; e.g., if S/E's from one university coauthor an article with S/E's from another university or corporation, it is assumed here that there was some degree of cooperative research performed.
[2] See Appendix table 1-10 for the subfields included in these fields.
[3] Excluding the Federally Funded Research and Development Centers affiliated with these sectors.
[4] Those administered by universities.
[5] Too few articles on which to determine the comparative cooperative indexes for basic and applied research.

NOTE: Based on 103,000 articles, notes and reviews by U.S. scientists and engineers from the *Science Citation Index* Corporate Tape of the Institute for Scientific Information.

REFERENCE: Appendix table 3-6.

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mode of cooperative publishing for basic research more than do the other sectors.

FEDERAL SUPPORT FOR BASIC RESEARCH

The major role of Federal sponsors in basic research developed relatively recently and from rather modest beginnings. In 1901, total appropriations for Federal scientific agencies totaled $8 million, an estimated $2 million of which could be regarded as expended for scientific and research work and in the interests of higher education.[11] Clearly, not all of this support was for basic research. Since then, methods for classifying and accounting for Federal basic research expenditures have advanced considerably. By the early 1960's, basic research funds obligated by Federal scientific agencies had grown substantially, surpassing the $1 billion mark.

Given this major Federal role in basic science, questions emerge concerning how basic research funds are allocated by this sector. Which agencies are primarily responsible for basic research support? Have there been significant shifts over time in terms of which agencies provide the bulk of the funds? What fields of science receive Federal basic research support, and how have such support patterns changed? Answers to these questions can indicate, to a degree, the scientific priorities of the Federal Government and perhaps point to areas of science where future activity of a more applied nature is likely.

As a result of concerted efforts by successive administrations, Federal budgets for Fiscal Years 1977, 1978, and 1979 have sought increases in basic research obligations that would compensate for reduced spending in previous years and also provide for the effects of inflation. These efforts are clearly reflected in the basic research obligations by the agencies discussed below. In each of the agencies mentioned, constant dollar obligations[12] in 1979 are significantly higher than those for 1976; the total for all agencies increased approximately 26 percent during those three years.

The National Aeronautics and Space Administration (NASA) has experienced the largest increase in terms of constant dollar basic research obligations between 1976 and 1979—48 percent. The major reasons for this high rate of growth are substantial increases in NASA's physics and astronomy programs, including the space telescope program, and the changing emphasis within the lunar and planetary program toward more support for investigations, studies, and analysis of data and less support for spacecraft and related development costs.

Estimated constant dollar basic research obligations by the Department of Agriculture (USDA), the Department of Defense (DOD), the Department of Health, Education, and Welfare (HEW), the National Science Foundation (NSF), and the Department of Energy (DOE) also have advanced considerably during the 1976 to 1979 period, growing at 30 percent, 25 percent, 26 percent, 21 percent, and 13 percent, respectively. Of these agencies, estimated constant dollar obligations for basic research in Fiscal Year 1979 are at a new peak for all but DOD and DOE.

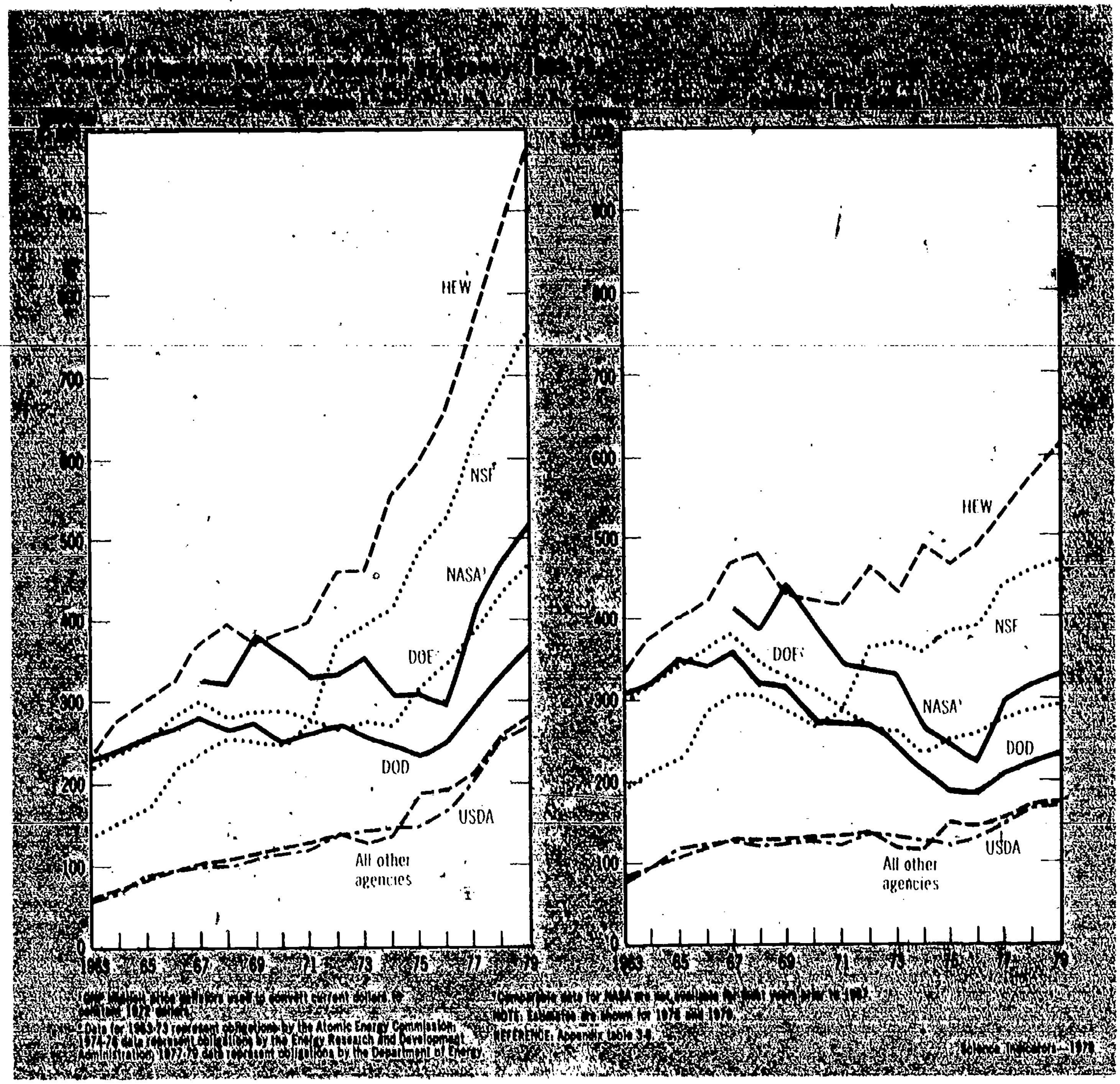
Since the early 1960's, the largest proportion of the Federal Government's funds for basic research has been provided by HEW (see figure 3-5). In 1979, this agency accounts for 27 percent of all Federal basic research funds. The basic research activities of HEW focus almost exclusively on health; approximately 87 percent of its obligations are accounted for by the National Institutes of Health (NIH) and nearly 9 percent by the Alcohol, Drug Abuse, and Mental Health Administration (ADAMHA).

The National Science Foundation, created to support scientific research and strengthen the Nation's capability in science, provides 21 percent of the Government's basic research funds in 1979. Its second-place ranking, in terms of share of Federal basic research obligations, is considerably higher than in 1963, when it was fifth and provided only 12 percent of the total Federal support.

In 1972, NSF began a period of substantial growth in current dollar obligations for basic research which has continued through 1979. During this period, obligations in current dollars increased at an average annual rate of approximately 10.8 percent. A major reason for this growth in the early 1970's was the "drop-out" of basic research support by other Federal agencies, which began about the time of the Mansfield amendment to the DOD appropriation in 1970. As a result, NSF served as the vehicle for partially picking up basic research formerly sponsored by other agencies.

[11] Dael Wolfle, *The Home of Science: The Role of the University* (New York: McGraw-Hill Book Company, 1972), p. 21.

[12] Federal obligations for basic research may differ from Federal expenditures reported in the same year for a number of reasons. A sector that performs research, for example, may report expenditures for research projects that it regards as basic research, whereas the Federal agency providing the support may report those same projects as applied research. In addition, obligations made in a given year may actually be spent over several later years.



Obligations by NASA account for 14 percent of the total in 1979 and have been at that point since the mid-1970's. In 1979, DOE, DOD, and USDA provided 13 percent, 10 percent, and 7 percent, respectively.

The relative importance an agency attaches to basic rather than applied research or development may reflect how it perceives the potential of a particular knowledge base to fulfill its mission (figure 3-6). The agency providing the greatest proportion of its R&D financial resources to basic research is NSF. This ratio dropped to 75 percent in 1974 but by 1977 had returned to the 90 percent level. Many shifts throughout the late 1960's and early 1970's have been the result of the introduction of new applied research programs. The increased percentage of basic research beginning in the mid-1970's resulted from the transfer of programs—many of which were applied research in energy areas—to the Energy Research and Development Administration (ERDA), now subsumed under the Department of Energy. However, the increase also resulted from increased obligations for basic research at NSF. As noted previously, the fraction of all Federal basic research obligations contributed by

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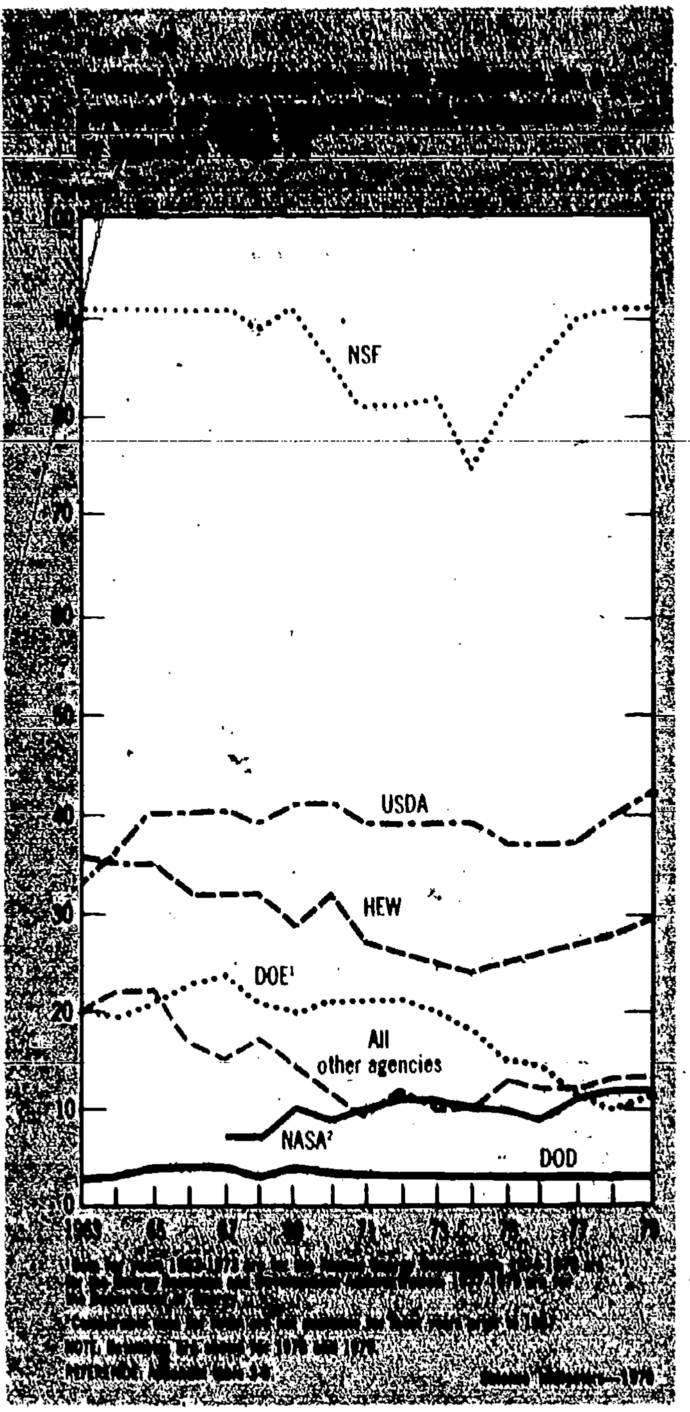
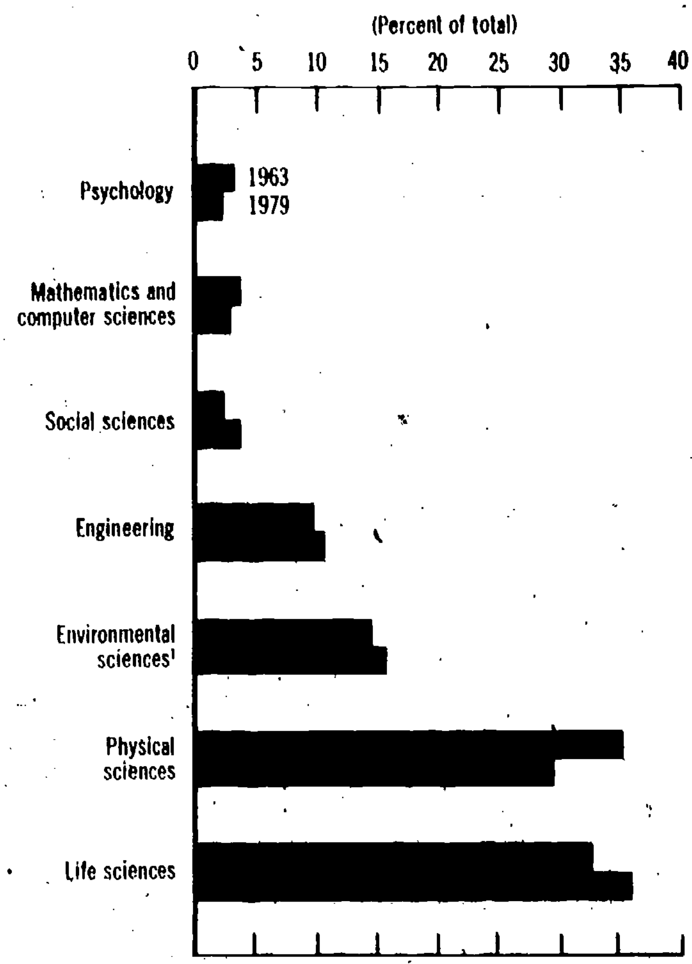


USDA is relatively low, amounting to about 7 percent in 1979. However, in terms of the agency's total R&D obligations, basic research receives rather high priority. For 1979, USDA continues support for its extramural competitive grants program, with emphasis on basic research on crop genetics and physiology, integrated pest management and human nutrition. Basic research obligations by HEW also constitute a significant fraction of that agency's R&D activity; the estimated proportion of such funds amounts to 30 percent of the total in 1979.[13]

By analyzing the pattern of Federal support to major fields of science, it is possible to determine those areas which seem to command highest priority. There has been considerable stability since 1963 in terms of the proportion of Federal basic research obligations to the fields of science presented in figure 3-7. Life sciences have received the greatest share of Federal basic research support. Most support for work in this field is provided by HEW, principally through

[13] The topic of basic research in Federal agencies has been reported on extensively in the 1978 annual report of the National Science Board, *Basic Research in the Mission Agencies: Agency Perspectives on the Conduct and Support of Basic Research* (NSB 78-1).

Figure 3-7
Distribution of federal basic research obligations by major field of science: 1963 and 1979



¹ Includes atmospheric sciences, geological sciences and oceanography

REFERENCE: Appendix tables 3-10 and 3-11.

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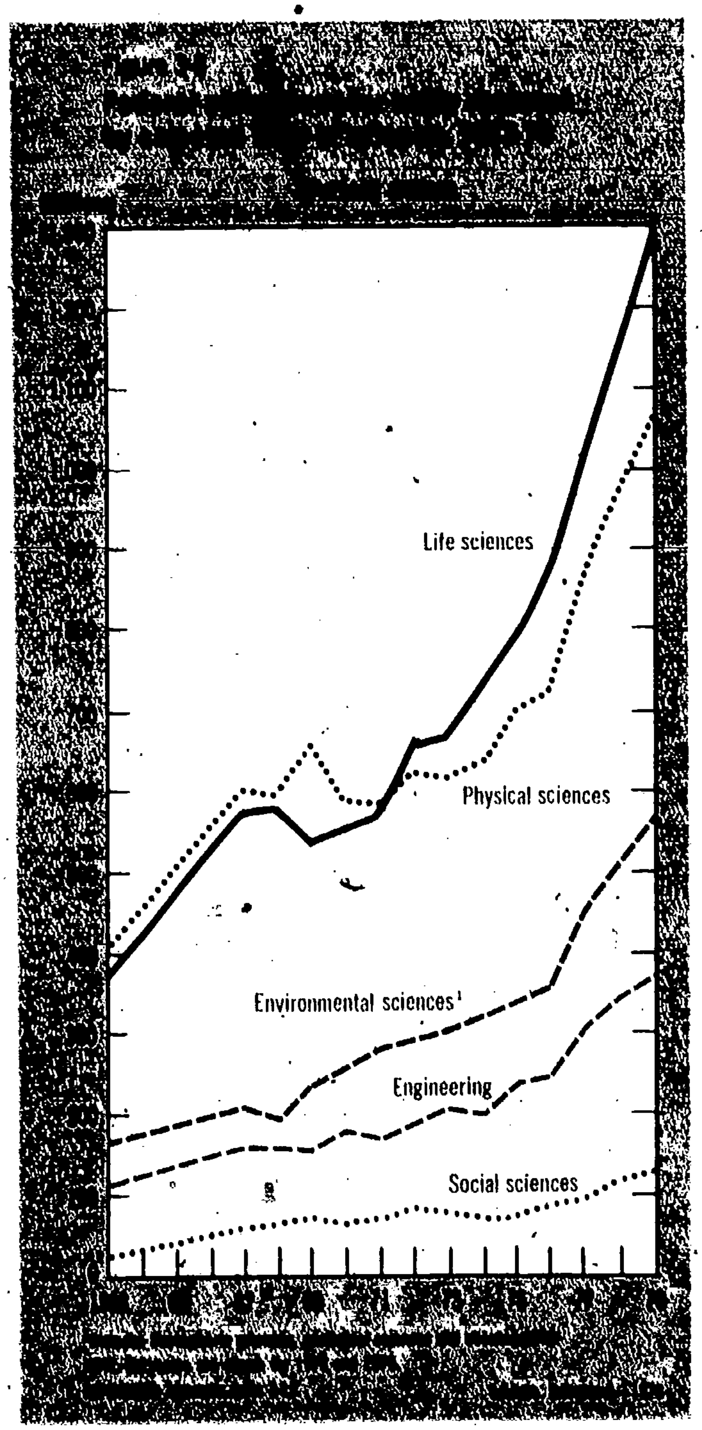
NIH. In the physical sciences, there is more diversity of support, with substantial funds provided by DOE, NSF, and NASA. Together, these two fields accounted for approximately two-thirds of all Federal basic research obligations in 1979, about the same portion that was held in 1963. As shown in figure 3-8, current dollar obligations for basic research in both fields have grown significantly, particularly since 1976, when Federal support for all basic research began to receive special attention.



BASIC RESEARCH IN UNIVERSITIES AND COLLEGES

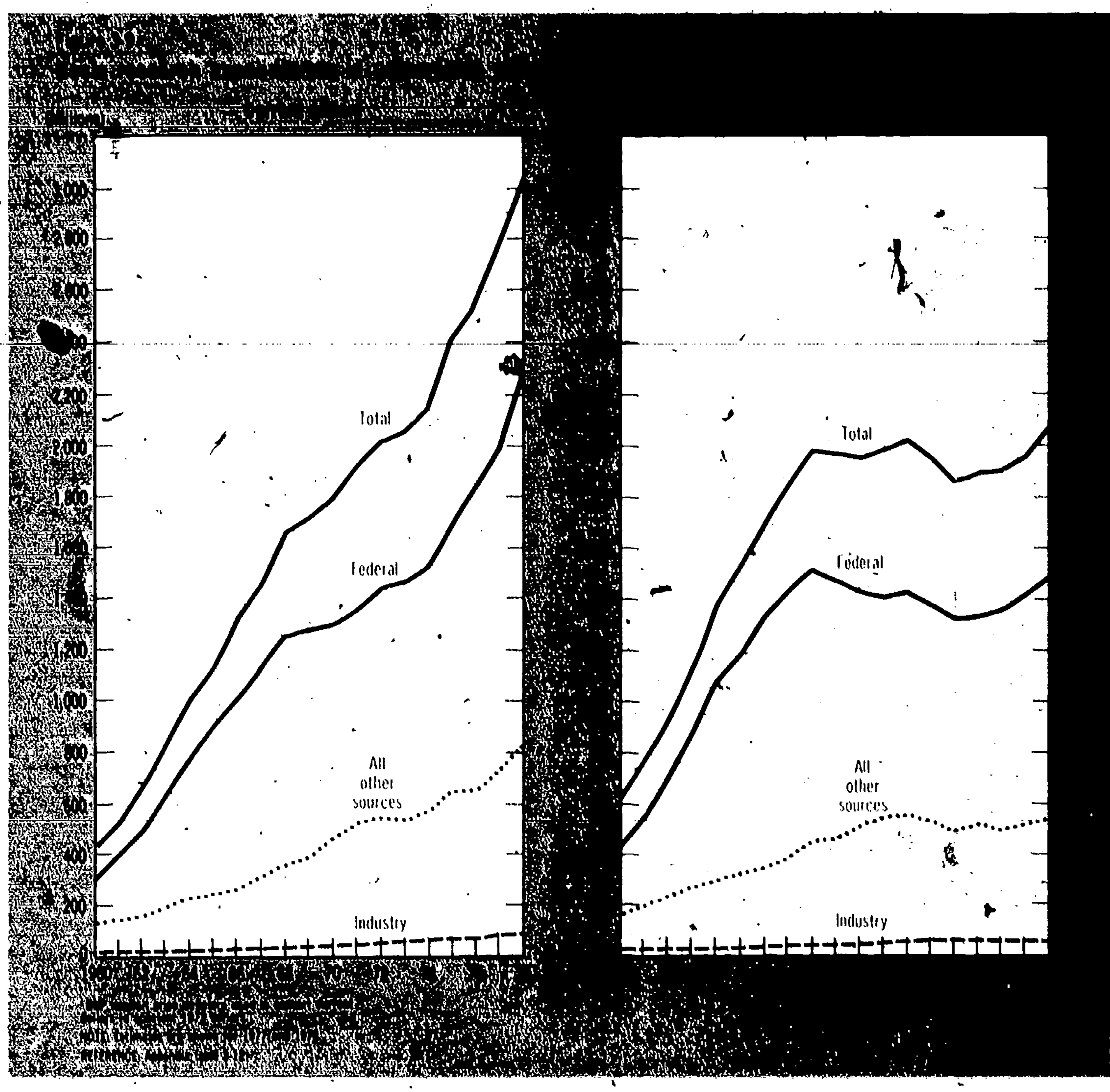
As the Nation's primary centers for scholarly inquiry, universities and colleges are the principal vehicles through which basic scientific research activities are conducted in the United States.[14] As a proportion of all R&D expenditures in the academic sector, funds for basic research accounted for between 68-70 percent during the period 1973 to 1978.

In constant dollars, overall support for basic research in universities and colleges grew rapidly from 1960 to 1968, primarily because of strong Federal support for all types of basic scientific activity (see figure 3-9). However, in 1969 total support began to level off, and between 1972 and 1974, support for basic research in universities and colleges fell more than 8 percent in constant dollars. Beginning in 1975, constant dollar support again turned upward and has continued to gain each year through 1978, when an alltime high in support for university basic research was reached.

Universities and colleges rely heavily on Federal support for basic research. In 1978, for example, more than 70 percent of the basic research funds received by these institutions came from Federal sources, and Federal sponsors have provided approximately the same proportion of basic research funds since 1970.

It was shown in figure 3-7 that there has been considerable stability in the field distribution of all Federal basic research funds over the period 1963 to 1979. The university and college sector has experienced a similar continuation of the distribution of Federal basic research funds by field. However, there have been substantial differences in the rates at which support has grown in particular fields. The most rapid growth can be seen for the environmental sciences in which obligations have advanced at an average annual rate of 15.7 percent between 1973 and 1977, with most of this growth taking place since 1975 (see figure 3-10). Basic research obligations in engineering have also grown rapidly, increasing at an average rate of 13.1 percent per year between 1973 and 1977. The least rapid growth has taken place in psychology and the

[14] Virtually all (98 percent) of the basic research conducted in colleges and universities is performed in institutions which grant doctoral degrees. This has been the case since at least the mid-1960's, and is true for non-Federal as well as Federal sources of support.



social sciences, advancing 3.0 and 3.2 percent per year respectively from 1973 to 1977. However, in the social sciences obligations declined at an average annual rate of 6.4 percent between 1973 and 1975, then grew 13.8 percent per year over the 1975-1977 period. These differences in growth rates reflect recent policy initiatives by the Federal Government to provide support for those fields of science in which additional attention may be required to meet national needs.

BASIC RESEARCH IN INDUSTRY

Although universities and colleges are the primary performers of basic research in the United States, the participation of the non-Federal sector in basic research activities is important to the economic and social welfare of the Nation. Industry plays a substantial role in translating the findings of basic research into the satisfaction of society's needs.[15]

Industry accounted for 16 percent of all U.S. basic research expenditures in 1978. However,

[15] The President has underscored the importance of basic research through budget messages, and there have been intensive policy research efforts in this area. For example, the Office of Science and Technology Policy in the Executive Office of the President has initiated a domestic policy review on industrial innovation which includes the topic of basic research in industry.

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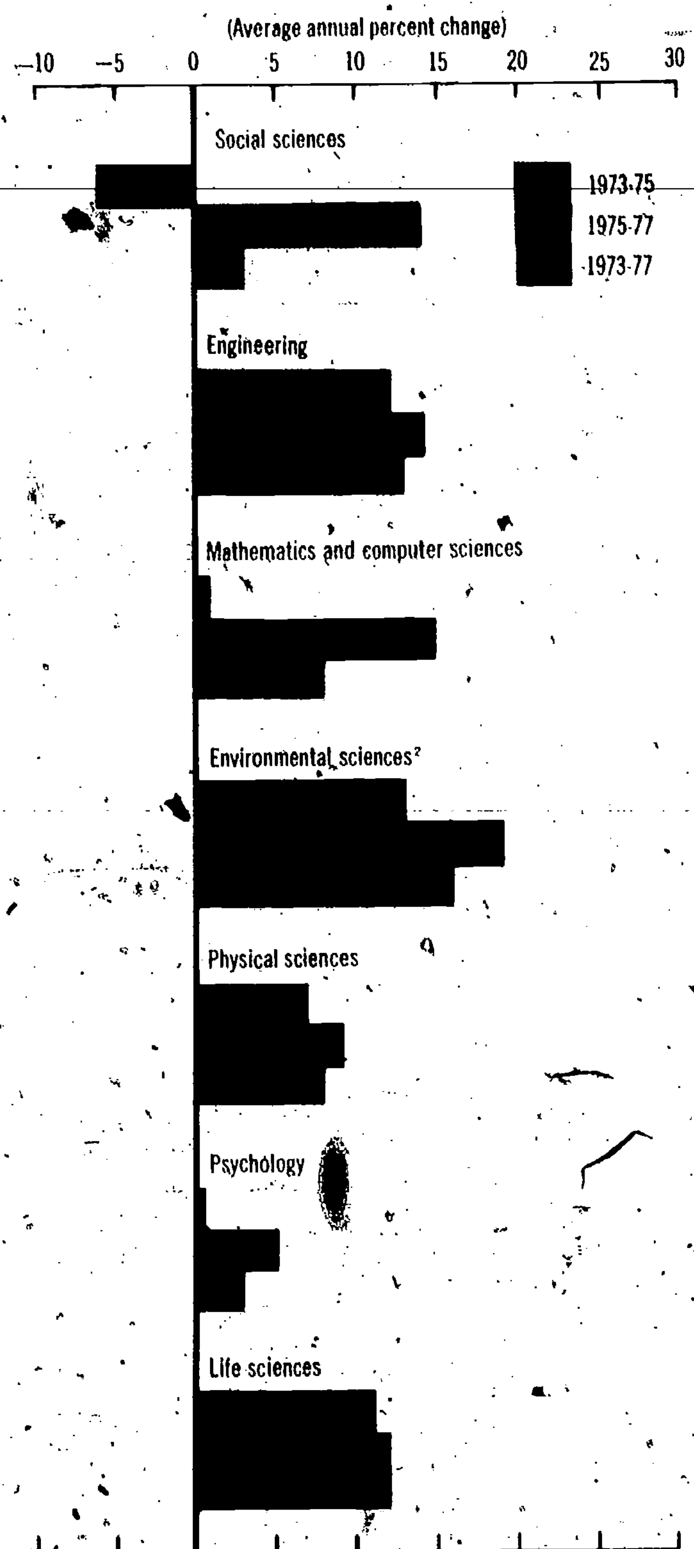
Figure 3-10

Federal obligations for basic research in universities and colleges, by field of science, for selected agencies[1]: 1973-77



[1] The agencies included here are the Department of Agriculture, Department of Defense, Department of Health, Education and Welfare, Department of Energy and its predecessor agencies, and the National Science Foundation

[2] Includes atmospheric sciences, geological sciences, oceanography, and environmental sciences not elsewhere classified.

REFERENCE: Appendix table 3-13

Science Indicators—1978

this fraction has fallen since 1960 when it was approximately 31 percent. As seen in figure 3-11, constant dollar spending declined after the mid-1960's, with only slight growth taking place after 1975. Funds provided by both industrial and Federal sources fell at approximately the same rate. A study by the Industrial Research Institute Research Corporation[16] used interviews and mail surveys to determine the reasons for this trend. Respondents most frequently offered the explanation that industrial R&D managers have changed their methods for managing basic research. In particular, during the mid-1960's, the industrial research process was evolving into a corporate function with a goal-directed emphasis. New organizational forms were being developed, and there was increasing control and formality in project selection. The expectation of business-related, short-term results became a dominant theme. In addition, decreased Government support and increased Government regulation occurred. Industry saw the opportunity for more development work and was reluctant to invest in work that apparently did not have an immediate payoff. Some corporate leaders believed that returns from R&D activity in general were diminishing. The energy crisis also accelerated or perpetuated the downward trend in basic research funding by industry because emphasis was placed on development, not research, as a way to cope with energy shortages.

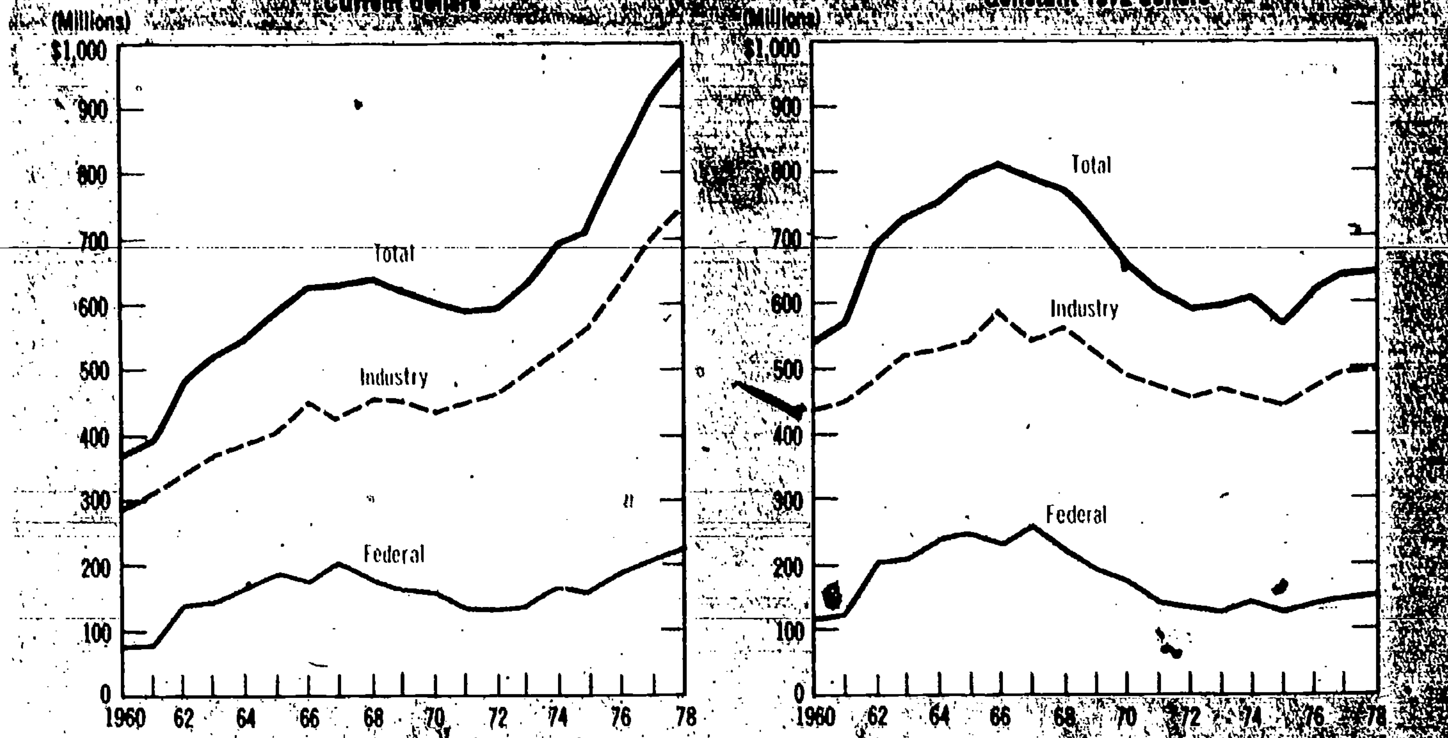
Another possible factor in declining industry support of basic research may be the feeling in industry that as university research expands and diversifies, industry does not need to support as much research; it can rely more on academic advances. Another factor may be that industry-supported basic research to attract the most talented people in a tight market. The opportunity to engage in basic research programs was a noneconomic fringe benefit that industry felt was needed to attract talent. As the market for technical manpower changed to a buyer's market, the need to use basic research as a recruiting inducement declined.

OVERVIEW

Although basic research declined in constant dollar terms between the late 1960's and mid-1970's, spending levels now appear to be growing. This growth seems particularly strong in the case

[16] Howard K. Nason, Joseph A. Steger, and George E. Manners, *Support of Basic Research by Industry* (St. Louis, Mo.: Industrial Research Institute Research Corporation, 1978), p. 17.

Figure 3-11
Basic research expenditures in industry by source: 1960-78



[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NOTE: Estimates are shown for 1977 and 1978.

REFERENCE: Appendix table 3-14.

Science Indicators—1978

of Federal basic research funding since basic research, perhaps more than ever before, is being viewed as an investment in the Nation's future. This concept has been enunciated in recent Federal budgets, and reinforced in a Presidential Message to the Congress which noted that new technologies depend upon a supply of knowledge derived from basic research. The funding activity by the Federal Government is particularly important because it provides more than two-thirds of all funds for basic research. The Nation relies on universities and colleges to perform more basic research than any other sector. Considerable concern has been expressed regarding the level of basic research activity in industry because of the declines in spending, in constant dollar terms, that occurred from the mid-1960's to the mid-1970's. Since 1975, however, basic research spending in this sector has grown slightly. The reasons for the earlier decline are reported to include greater interest in short-term returns from research activities, Government regulations, reductions in governmental funds for basic research, the availability of a storehouse of knowledge from previous basic research programs now ready for further development, and the need for research to protect and improve existing product lines. In addition, industry may be relying more than previously on university basic research.

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Chapter 4

Industrial Research and Development

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Industrial Research and Development

INDICATOR HIGHLIGHTS

- Industrial R&D expenditures from all sources were 69 percent of all U.S. R&D expenditures in 1977 and were above the low point, in constant dollars, that occurred in 1975. Growth is expected to continue through 1979, surpassing the previous high experienced in 1969. This return to previous high funding levels should relieve some of the concern that has been expressed about a decline in industrial R&D. (See pp. 80-81.)

- The Federal Government's constant dollar support for R&D in industry began to increase in 1976 after reaching in 1975 its lowest level since 1964. This was largely because of increased interest in energy and in the space program. However, Federal support is not expected to return soon to the high levels of the 1960's. The Federal component of R&D expenditure in industry dropped from more than half in the early 1960's to 35 percent in 1977, mainly because of decreases in military and aerospace programs. Declines in Federal support led to a 26 percent drop in the R&D-to-net-sales ratio for all manufacturing industry from 1967 to 1977. (See pp. 80-81, 82-84.)

- Company funds for R&D have increased almost every year from 1960 to 1977, at an average annual rate of 4.6 percent in constant dollars. Fluctuations in this investment seem to be parallel to fluctuations in the manufacturing industry component of the GDP. The ratio of company-generated R&D funds to net sales remained virtually the same, at 2 percent, from 1967 to 1977. This took place while net sales and R&D expenditures both increased significantly. (See pp. 80-81.)

- About 85 percent of Federal R&D funds to industry have consistently gone to development. The share of company R&D funding going to development has risen from 66 percent in the early 1960's to 74 percent in 1977. Since the mid-1960's, there has been a drop in company support for basic research, in constant dollars, though there has been a partial recovery since 1975. Company officials claim that the decline is due in part to a new management emphasis on shorter-term and safer investments. Much concern has been expressed over the decrease in industrial basic research, because such a drop may imply a weakening in the Nation's long-term capability for significant technological innovation. Although industry's support for basic research in other sectors has increased since the mid-1960's, 83 percent of industry's basic research funding was spent within the industry sector in 1977. (See pp. 88-89, 92-93.)

- In response to the energy crisis, industrial R&D expenditures related to energy grew by 92 percent in current dollars from 1973 to 1977. Increased Federal funding is going to long-term and untried technologies, such as coal liquefaction and gasification and geothermal energy. Solar energy is attracting large expenditure increases from both Government and private industry as a technically and economically attractive alternative energy source. R&D related to oil and gas and to energy conservation and utilization is mainly company-supported. Both solar and geothermal sources are expected to continue their sharp year-to-year increases in total R&D funding, but the principal expenditures will remain in the areas of nuclear energy and fossil fuels. (See pp. 96-98.)

- R&D costs devoted to meeting the problem of pollution abatement are mainly borne by private industry. In constant dollars, spending declined from 1973 to 1975, but sharp increases occurred in 1976 and 1977. Most of the activity concerned air pollution, specifically automotive emissions. (See pp. 98-99.)

- The total number of patents granted annually to U.S. inventors generally increased from 1960 to the early 1970's but showed a steady decline from 1971 to 1977 because of a decline in new patents owned by U.S. corporations. Complex influences on the level of patenting make analysis of patent data difficult; consideration of the caveats described in the text is important. In the present case, since patenting has dropped in almost all product fields, the trends seem to indicate a real decline in the rate of production of inventions by U.S. industry from 1971 to 1977. Such a decline could be attributed to a diminished need or desire for new inventions in industry because of a backlog of inventions produced in the 1960's, a large commitment by industry of capital to existing products and processes that reduced industry's interest in new inventions, or in adequate profit margins that may have made it unattractive to expand product lines through new inventions. (See pp. 99-103.)

Industry holds a place of special importance in any consideration of research and development in the United States. Most U.S. R&D expenditures take place in industry. Also, technology generated by industry is the principal means by which scientific research reaches the public in the form of new or improved products, processes, and services. Industry generates much new technical information within its own laboratories, but it also receives information from outside sources such as the published literature, contractors' reports, academic and private consultants, and the hiring of skilled personnel. These transfers of knowledge are vital to the improvement of industrial technology, particularly in high technology industries.

Within industry, R&D produces technical improvements in products, processes, and services. However, major improvements developed through R&D require the subsequent steps of engineering design, production engineering, prototype testing, manufacturing start-up, and marketing start-up and financing before they reach the public on a commercial scale. These steps nearly always cost much more than the original invention. Technical innovations in turn are the source of the economic and social benefits that industrial R&D brings to the public. Innovation is of considerable interest to the Federal Government. There is concern that the United States may not be sustaining a sufficiently high rate of technological innovation or that the direction of innovative activity may not be appropriate to national needs.

The input indicators shown in this chapter are all levels of R&D funding. Funding levels are attractive as input indicators because they are comparatively easy to measure and directly controllable by decisionmakers. However, it can be argued that it is not R&D funding as such that produces scientific and technological output but rather individuals with their associated salaries, equipment, management, training, information, talent, and luck. Indicators based on funding levels represent only some of these elements, such as salaries and equipment. In the case of output indicators, the problems are similar. While input indicators fail to measure all of the input elements, output indicators are distorted because they are influenced by other factors in addition to R&D inputs.

This chapter is complemented by treatments of related topics in the other chapters of this report. The chapter on scientific and engineering personnel deals with the number and characteristics of technically trained employees in industry. The international chapter considers industrial R&D in other countries. The chapter on resources for R&D deals with industrial R&D within the context of the Nation's R&D, and in particular shows how trends in Federal support for industrial R&D are balanced by trends in Federal support for R&D in other sectors. Finally, the chapter on resources for basic research places industrial basic research in the context of the Nation's overall basic research effort.

LEVEL OF R&D EFFORT IN INDUSTRY

Levels of R&D effort are measured in terms of the funds devoted to R&D and in terms of the number of scientific and engineering personnel working in R&D. Some of the pertinent issues have been stated by Shapley and Phillips: "Questions of the allocation of a company's resources to R&D — whether, how much, and for what purposes — are major issues of corporate policy and management. The Federal Government is involved in several different ways. Almost half of its R&D is performed in industry. Federal R&D decisions must take account of the contribution industry-funded R&D programs to national needs, on its own or in cooperative arrangements with the Government. Federal policies and regulations affect almost every aspect of industry R&D, with impacts ranging from encouragement and direct assistance to disincentives and stultification. Universities are interested in industry support for academic research and in industry R&D job opportunities for graduates and tenure-blocked junior faculty members."[2]

In using such measures, questions of quality are not considered. The effectiveness of various expenditures is not discussed, and no effort is made to decide whether funds or persons are used more effectively in one situation than in another.

Total Expenditures for R&D

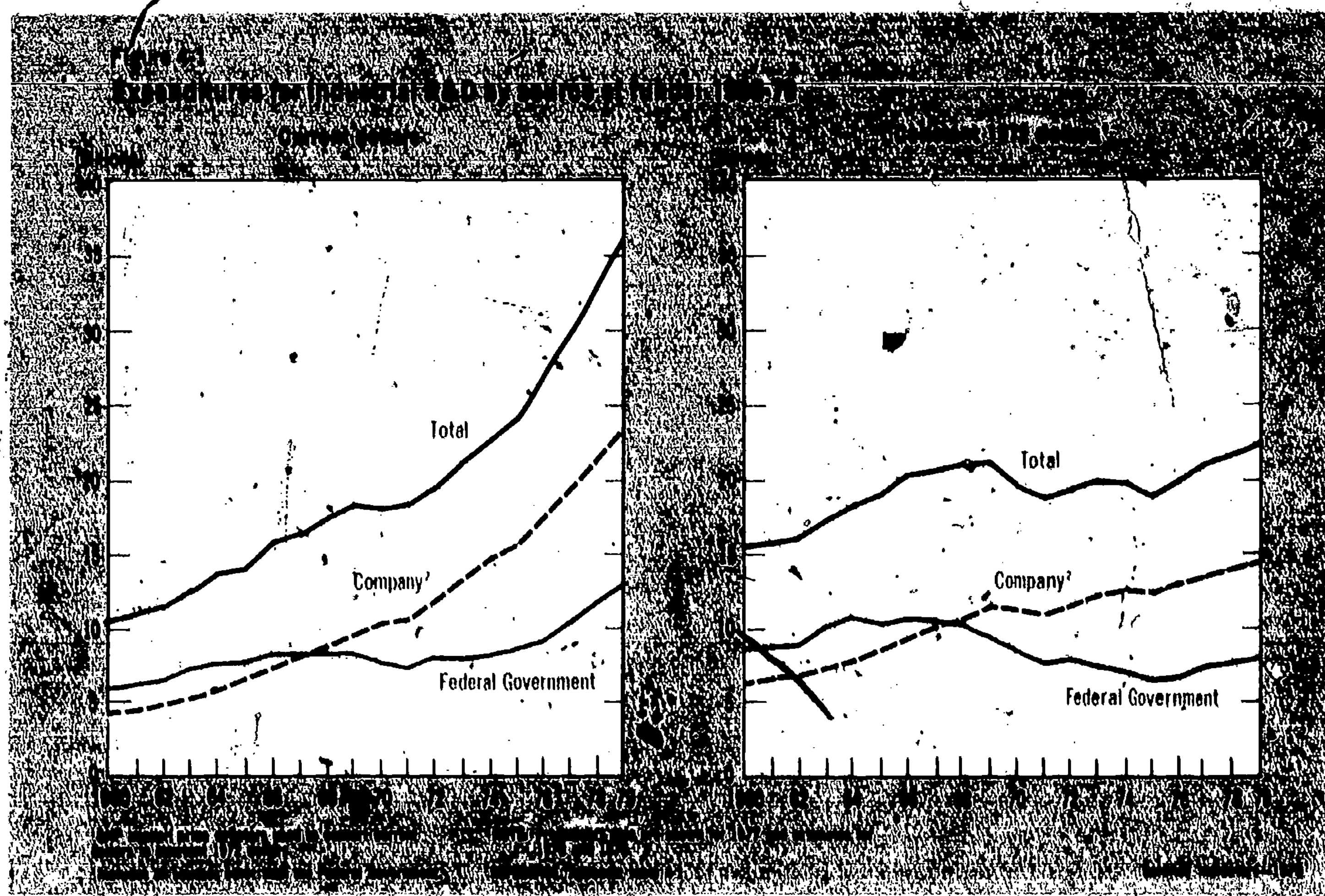
As figure 4-1 shows, total expenditures for industrial R&D were $29.8 billion in 1977, an 11-percent increase from 1976. R&D expenditures in all sectors of the U.S. economy were $42.9 billion in 1977[3]; industry performed 69 percent of all U.S. R&D by this measure. By comparison, an estimated $33.5 billion was spent on advertising in 1976, although at least half of that was probably spent in wholesale and retail trade and in other industries that perform little R&D.[4] Similarly, manufacturing industries spent $40.7 billion for new plant and equipment in 1976.[5] These comparisons suggest that R&D represents a considerable investment in industry, comparable to other major industrial expenditures. Figure 4-1 also shows that considerable increases in industrial R&D spending are estimated for 1978 and 1979. (These estimates will be discussed in detail later in this chapter.)

[2] W.H. Shapley and D.I. Phillips, *Research and Development: AAAS Report III, R&D in the Federal Budget: FY 1979, R&D, Industry, and the Economy* (Washington: American Association for the Advancement of Science, 1978), p. 51.

[3] See Appendix table 2-1 and the chapter on Resources for Research and Development.

[4] *Statistical Abstract of the United States, 1977*, U.S. Department of Commerce, Bureau of the Census, pp. 844, 847.

[5] *General Statistics on Industrial Groups and Industries*, U.S. Department of Commerce, Bureau of the Census, Document M76(AS)-1, 1976, p. 4.



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The R&D picture is different if the effects of inflation are allowed for, as shown in figure 4-1.[6] In these terms, industrial R&D expenditures rose from 1960 to 1969, after which they dropped 10 percent to their 1975 value. An 11-percent increase occurred from 1975 to 1977, and further increases are anticipated, to new highs in 1978 and 1979. If this occurs, some worries that have been expressed about the weakening of industrial R&D[7] should be assuaged, at least to the extent that they are based on levels of expenditure.

Sources of Funding for Industrial R&D

R&D performed in industry is supported primarily by two sources: industry itself and the Federal Government. Federally funded R&D is performed for purposes different from industry-funded R&D, and thus different economic effects may result. Industry's objectives are basically commercial. The Government has three objectives in funding R&D. First, it supports R&D in the private sector to develop products for its own use in public-sector functions, such as defense and space exploration. Because of the special characteristics of the products required for these functions, many program results have no commercial application, although efforts are being made to increase such transfers. Second, the Federal Government supports R&D to develop products for use in the private sector that will help fulfill national goals for which the Federal Government has explicit responsibility: health, energy supply, environmental protection, transportation, agriculture, and education.[8] For these kinds of R&D projects, commercial and other economic considerations are important, but they are not a primary concern. Third, the Federal Government funds R&D for the general advancement of science and technology; private incentives for this kind of investment may be insufficient.[9]

In 1977, Federal support for industrial R&D was 35 percent of the total (figure 4-1). However, before 1968 the Government paid for more than half of all R&D performed in industry. Since 1968, Federal support has diminished, particularly in military and aerospace areas. In 1975, funding reached its lowest constant dollar level since 1964; gradual increases have occurred since 1975.

In contrast, company funds for R&D have increased almost every year in this 1960 to 1977 period, even in constant dollars. Company funding seems to vary in close relation to the manufacturing industry component of the Gross Domestic Product (MGDP). Company funds in constant dollars increased 113 percent from 1960 to 1977, and the deflated MGDP also rose, by 87 percent.[10] Moreover, constant-dollar company funds for R&D dipped below the previous year's value in 1970, 1971, and 1975; the deflated MGDP dipped below its previous year's value in 1970, 1974, and 1975. Hence, the commitment of company money to R&D seems to depend on the state of the economy, as expressed by the MGDP.[11]

R&D Expenditures in Individual Industries

Industrial expenditures for R&D from all sources for the industry in which they occur are reported in a survey conducted by the Bureau of the Census.[12] Industries are classified in terms of

[6] In the absence of a completely adequate deflator for industrial R&D expenditures, this report uses the GNP implicit price deflator. For one effort to develop an industry-specific deflator, see *Probable Levels of R&D Expenditures in 1979: Forecast and Analysis*, (Columbus, Ohio: Battelle Memorial Institute, 1978), pp. 13-16. OECD has also studied this problem. See, for example, Organisation for Economic Co-operation and Development, Committee for Scientific and Technological Policy, *Trends in Industrial R&D in Selected OECD Member Countries 1967-1975*, SPT(78)20 Annex II, September 1978, pp. 3-12. Also see the discussion of deflators for R&D expenditures in the Resources for Research and Development chapter of this volume.

[7] One statement of the problem from an industry perspective is "IEEE Speaks Out on R&D," *IEEE Spectrum*, vol. 12 (September 1975), pp. 76-79.

[8] One aspect of this activity is discussed in W.S. Baer, L.L. Johnson, and E.W. Merrow, "Government-Sponsored Demonstrations of New Technologies," *Science*, vol. 196 (May 27, 1977), pp. 950-957.

[9] On the subject of Federal support for R&D, see also the President's Science and Technology Message to the Congress, March 26, 1979, pp. 2-3, and *The Role of Demonstrations in Federal R&D Policy*, Office of Technology Assessment, 1978. See also the papers in a colloquium on "Relationships between R&D and Economic Growth/Productivity," held November 9, 1977, and forthcoming as an NSF publication.

[10] *The National Income and Product Accounts of the United States, 1929-74: Statistical Tables*, U.S. Department of Commerce, Bureau of Economic Analysis, pp. 18-19; *Survey of Current Business*, U.S. Department of Commerce, Bureau of Economic Analysis (July 1978).

[11] The coefficient of determination (r^2) for the linear correlation between MGDP and company R&D expenditures in constant dollars is .94 for the period 1960-76.

[12] Reported in *Research and Development in Industry, 1976*, National Science Foundation (NSF 78-314). Another source of data on R&D spending by individual industry is the response to the Securities and Exchange Commission's Form 10-K statements that corporations are required to file. The most recent results are shown, by individual company, in *Business Week* (July 3, 1978), pp. 58ff. Unfortunately, the data are aggregated into industry groups different from the SIC groups used in the Census Bureau survey so that no direct comparison is possible. An analysis of these data is given in "A Comparison of National Industrial R&D Estimates with Actual NSF/Census Data," *Reviews of Data on Science Resources*, National Science Foundation (NSF 78-303).

the Standard Industrial Classification (SIC) for industrial establishments.

Figure 4-2 shows expenditures from 1960 to 1977 for the eight industries with the greatest R&D expenditures.[13] These data show the concentration of industrial R&D performance in a few industries. The first two, aircraft and missiles and electrical equipment and communications, together accounted for 44 percent of all industrial R&D in 1977. The first five industries accounted for 79 percent.

In current dollars, all industries have experienced a fairly steady rise in R&D expenditures, with the exception of the aircraft and missiles industry. In constant dollars, this industry has shown a sharp decline in funding from the mid-1960's, due to a drop in Federal support. From 1966 to 1977, for example, this industry experienced a decline of $2.2 billion in 1972 dollars. Declining Federal support also accounts for the similar but less dramatic decline in electrical equipment and communication (particularly in its largest component, communication equipment and communication).

Concentration of Industrial R&D

The preceding discussion mentioned the concentration of R&D expenditures in a few industries. Industrial R&D is also highly concentrated in certain companies, as figure 4-3 indicates. Although the estimated number of R&D-performing companies in the United States ranges from 10,400 to 15,700,[14] the bulk of the work is done by a much smaller number of large corporations. These large corporations are the organizations that report most of the R&D effort discussed in this chapter. Small companies, though not significant in this sense, may be essential contributors to the success of industrial R&D as a whole.[15] Large and small firms seem to play different but complementary roles in the process of technological innovation.[16]

Figure 4-3 also shows that just four companies spend 20 percent of all industrial R&D funds in the United States. As Appendix table 4-3 shows, 20 companies together account for over half of all funding. Some individual industries are, of course, much more concentrated than others. In most industries (at the highest level of aggregation, which the figure shows), at least half of all R&D expenditure is in four companies.

R&D Expenditures in Relation to Net Sales

The fact that one industry conducts more R&D than another, as measured by R&D expenditures, may be largely the result of differences in their total resources or volume of business. For some purposes,[17] one would prefer to have an intensity measure for an industry's R&D. Such a measure would put industries of different capacities on the same footing by showing the share of its volume of business that each industry chooses to put into R&D.

One measure available for this purpose is the ratio of an industry's R&D expenditures to its net sales, for the same year, as shown on table 4-1. For manufacturing industries taken together, there was a drop from 1967 to 1977 in the overall ratio of R&D funding to net sales. The 82-percent increase in industrial R&D expenditures from 1967 to 1977[18] was less than the 152-percent increase in manufacturing industry net sales.[19] The reason for the decline in their ratio seems to be a decline in Federal support for R&D in military and aerospace technology. Thus, company support for industrial R&D increased 142 percent over this period, while Federal support increased only 25 percent.[20] As a result of the large increase in company support, the ratio of company-funded R&D to net sales for all manufacturing industry remained virtually unchanged from

[13] Other industries and disaggregations of these industries are shown in the corresponding Appendix table 4-2.

[14] National Science Foundation, preliminary data.

[15] On the importance of small high-technology companies and their current problems, see: *Report of the SBA Task Force on Venture and Equity Capital for Small Business*, Small Business Administration, 1977; *Innovators and Entrepreneurs—An Endangered Species?*, presentations at the Technical Session, Thirteenth Annual Meeting, November 10, 1977 (Washington: National Academy of Engineering, 1978); and *Capital Formation*, hearings before the Select Committee on Small Business, United States Senate, February 8 and 10, 1978.

[16] J. Jewkes, D. Sawers, and R. Stillerman, *The Sources of Invention*, 2nd ed., (New York: Norton, 1969); M. I. Kamien and N. L. Schwartz, *Market Structure and Innovation: A Survey Summary* (Evanston, Ill.: Northwestern University, 1974).

[17] For example, see the use of R&D intensity as a variable in *Science Indicators—1976*, National Science Board (NSB 77-1), pp. 119-125.

[18] See Appendix table 4-1.

[19] For net sales, see *Research and Development in Industry, 1967*, National Science Foundation (NSF 69-28), p. 60; and National Science Foundation, preliminary data.

[20] See Appendix table 4-1. This table includes R&D in nonmanufacturing industries as well, but the effect of this inclusion is negligible.

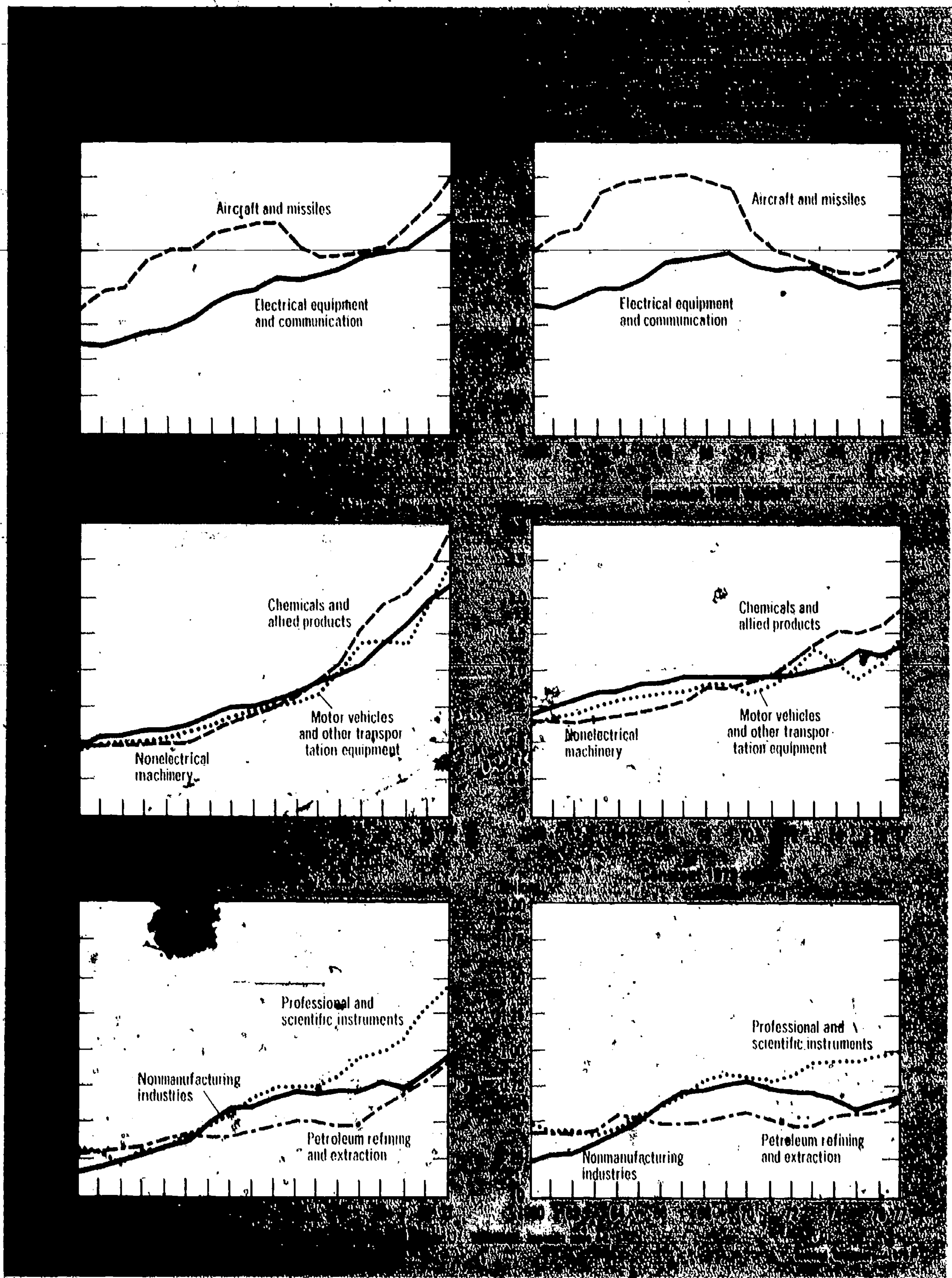
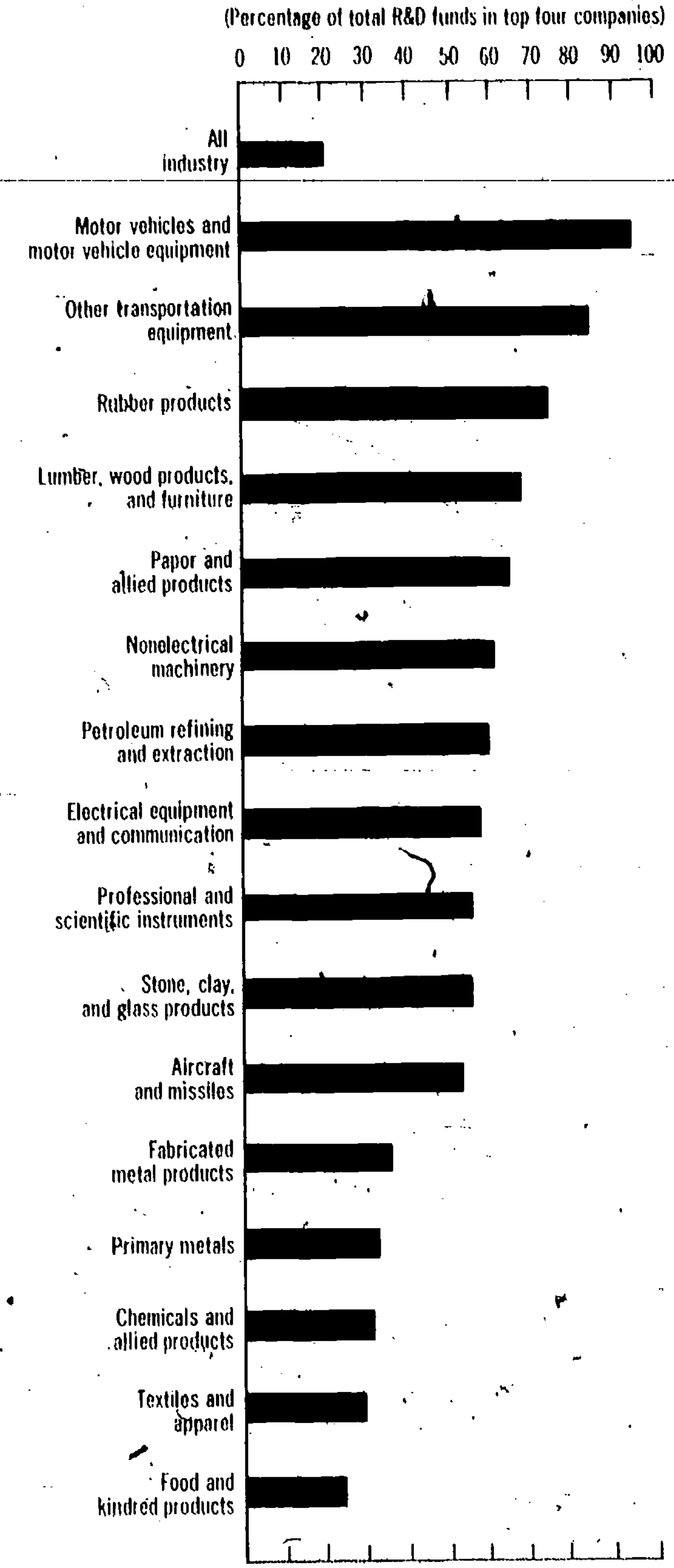

Aircraft and missiles
Electrical equipment and communication
Aircraft and missiles
Electrical equipment and communication
Chemicals and allied products
Motor vehicles and other transportation equipment
Nonelectrical machinery
Chemicals and allied products
Nonelectrical machinery
Motor vehicles and other transportation equipment
Professional and scientific instruments
Nonmanufacturing industries
Petroleum refining and extraction
Professional and scientific instruments
Petroleum refining and extraction
Nonmanufacturing industries

Figure 4-3
Concentration of R&D expenditures in selected industries: 1977



NOTE: Based on preliminary data.
REFERENCE: Appendix table 4-3.

Science Indicators - 1978

1967 to 1977 at 2 percent.[21] Table 4-1 also provides a way of arranging industries on a spectrum from high R&D-intensiveness to low R&D-intensiveness.

Sources of Funding for R&D in Individual Industries.

Trends in R&D funding in individual industries can be better understood if funding by the Government is distinguished from funding furnished by industry itself. Table 4-2 shows the changes in company and Federal funding in constant dollars over a 10-year period. In these terms, Federal funding dropped at an average rate of 3.5 percent per year, while industry's own funds increased by an average of 3.0 percent per year.

More than half of all Federal R&D funding went to one industry—aircraft and missiles—in 1967 and 1977. This industry also has the largest share of all its R&D supplied by the Government, mainly by the National Aeronautics and Space

[21] *Research and Development in Industry, 1976*, National Science Foundation (NSF 78-314), p. 41, and preliminary data.

[illegible]

Table 4-2. Company[1] and Federal funding of industrial R&D in constant dollars[2], for selected industries: 1967 and 1977

[Dollars in millions]

Industry	1967 Company[1] funding	1967 Federal funding	1967 Percent Federal of total	1977 Company[1] funding	1977 Federal funding	1977 Percent Federal of total
Total	$10,149	$10,586	51	$13,073	$7,447	35
Chemicals and allied products	1,641	266	14	2,099	208	0
Industrial chemicals	993	229	19	835	196	19
Drugs, medicines, and other chemicals	648	37	5	1,245	11	1
Petroleum refining and extraction	449	20	4	592	52	8
Primary metals	296	10	3	354	18	5
Ferrous metals and products	170	1	1	179	4	2
Nonferrous metals and products	127	8	6	174	14	7
Fabricated metal products	191	16	8	243	32	12
Nonelectrical machinery	1,271	407	24	2,396	407	15
Electrical equipment and communication	1,988	2,906	59	2,299	1,904	45
Aircraft and missiles	1,440	5,734	80	1,117	5,881	84
Professional and scientific instruments	447	239	35	882	110	11
Scientific and mechanical measuring instruments	85	47	36	216	7	3
Optical, surgical, photographic, and other instruments	362	192	35	624	103	14
Nonmanufacturing industries	218	490	69	363	309	46

[1] Includes all sources other than the Federal Government.
[2] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

REFERENCE: Appendix table 4-4

Administration (NASA) and the Department of Defense (DOD).[22] The second-ranking industry, both in Federal R&D dollars and in Federal share of all R&D dollars, is electrical equipment and communication, which also is largely funded by DOD. These two industries together account for almost all of the drop in constant dollar Federal R&D funds to industry. NASA and DOD both decreased their support, in constant dollars, to these industries.

Nonmanufacturing industries was the other group showing an overall constant dollar drop because of decreasing Federal contributions. This drop may be due to a decreasing amount of contracting with commercial R&D laboratories. In most industries where Federal support dropped, company funding increased by at least the same amount, in constant dollars. The one exception was industrial chemicals, in which there was a decrease in R&D funding from both sources. This industry and aircraft and missiles were the only industries to show a decrease in company funding from 1967 to 1977.

In a few industries, large increases in company R&D funding occurred from 1967 to 1977. Nonelectrical machinery companies, for example, have recently expanded their R&D efforts in important new technologies such as microminiaturization of electronic components. Increases in company funding were also notable in the drug industry.[23]

Estimates of R&D Expenditures

Several sources publish estimates for years subsequent to those for which data have been collected (in this chapter, for years after 1977). This discussion will consider the estimates of

[22] *Ibid.*, p. 17, and National Science Foundation, preliminary data.

[23] Further information on these and other industries may be obtained from the Industry Studies Group, Division of Science Resources Studies, National Science Foundation.

industrial R&D funding published by the National Science Foundation.[24]

NSF publishes estimates of total R&D funding in industry, subdivided according to source. Figure 4-1 contains such estimates for 1978 and 1979.[25] Preliminary data for 1977 show $19.5 billion for company funding and $29.9 billion for total funding—11 percent above 1976 expenditures.[26] Increases are expected in 1978 and 1979, both in current and in constant dollars.

NSF has published projections for 1 and 2 years beyond actual data since 1968 in its *National Patterns of R&D Resources* series. The mean absolute errors of these projections (see Appendix table 4-5) are considerably smaller than the changes projected from 1977 to 1978 and from 1977 to 1979.[27]

NSF also projects a 3-percent increase in overall industrial R&D from 1978 to 1979, to $22.6 billion, in constant dollars. NSF has also projected that $27.3 billion in constant 1972 dollars will be spent on industrial R&D in 1985, with $9.7 billion of this coming from the Government and $17.6 billion from private industry.[28]

Overview

Industry's 1977 expenditures for R&D accounted for 69 percent of all R&D performed in the United States. These expenditures are comparable to the amount spent by industry for advertising or for new plant and equipment; thus it seems that industry considers R&D a major investment. In constant dollar terms, 1969 was the year in which the most support was available for industrial R&D from all sources. There was a low point in funding in 1975, but steadily increasing levels of support are expected to continue to new highs in 1978 and 1979. Federal support was more than half the total from the early 1960's to 1967. This support began to slacken in the mid-1960's, mainly because of decreases in the DOD and NASA budgets for extramural R&D; these figures are still lower in constant dollars, than their 1967 values. By contrast, company funds for R&D have increased almost every year since 1960, in constant dollars. This investment seems to parallel fluctuations in the manufacturing industry component of GDP, which may mean that a generally healthy and expanding economy is necessary for increases in industrial R&D from company funds to occur. NSF projections for total industrial R&D funding, and for industry and Federal support, indicate steady increases in 1978 and 1979.

Industrial R&D expenditures are heavily concentrated in a small number of companies. Of the estimated 10,400 to 15,700 companies that perform R&D, 20 together do more than half. Industries differ greatly in their degree of R&D concentration. For all manufacturing industries, the ratio of R&D to net sales dropped from 4.2 percent to 3.1 percent between 1967 to 1977 because of the drop in Federal funding. The aircraft and missiles industry still spends four times the average, in relation to net sales, while some others spend much less than the average. Company funds as a percentage of net sales for all manufacturing industries remained level at 2 percent from 1967 to 1977.

DISTRIBUTION OF INDUSTRIAL R&D AMONG BASIC RESEARCH, APPLIED RESEARCH, AND DEVELOPMENT

Industrial R&D comprises a wide variety of activities, ranging from research that contributes to the advancement of science and is published in academic journals, to the development of new products and processes, to the testing of new industrial processes in pilot plants. Trends in R&D, therefore, cannot be understood unless the R&D effort is separated into its components. The distribution scheme should be applicable throughout industry as well as in the other R&D-performing sectors. The categories of basic research, applied research, and development[29]

[24] The estimates of industrial R&D expenditures made by the National Science Foundation, by McGraw-Hill Publications Company, and by Battelle Memorial Institute have been checked against subsequent actual NSF data for the years for which the predictions were made. The results are shown in Appendix table 4-5. Mean absolute errors are shown, i.e., the average of the yearly percentage errors, with each treated as a positive number. Comparison is being made with the NSF data shown in Appendix table 4-2. It should be noted that these data have been adjusted from their originally reported values for the years 1968-75, as discussed in "Industrial Spending Reached $26.6 Billion in 1976," *Science Resources Studies Highlights*, National Science Foundation (NSF 78-306). With the older numbers, the errors are slightly lower. An earlier comparative analysis of various industrial R&D estimates is found in "A Comparison of National Industrial R&D Estimates with Actual NSF/Census Data," *Reviews of Data on Science Resources*, National Science Foundation (NSF 78-303).

[25] On the constant dollar chart, the GNP implicit price deflator has also been projected for 1978 and 1979.

[26] See Appendix table 4-1.

[27] On the other hand, they are a considerable fraction of the average year-to-year change in funding, which was 6 percent for total funds, 9 percent for company funds, and 4 percent for Federal funds during this period.

[28] *1985 R&D Funding Projections*, National Science Foundation (NSF 76-314), p. 20.

[29] For definitions of basic research, applied research, and development, see *Research and Development in Industry, 1976*, National Science Foundation (NSF 78-314), p. 1.

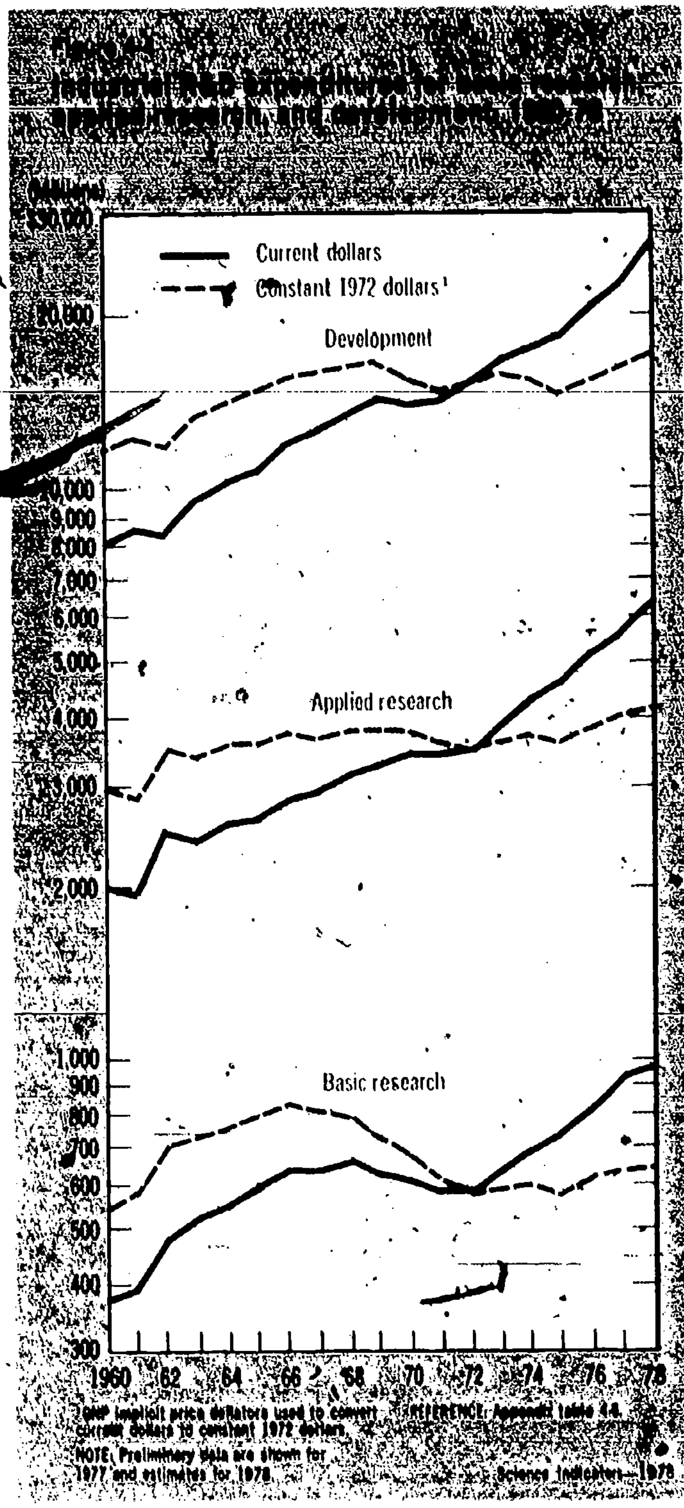
are the most widely accepted for this purpose and are generally used in national data gathering.

Basic research is the component of industrial R&D that gives the performing firm the greatest difficulty in capturing the returns. It also requires the greatest length of time to pay off. It is particularly difficult to demonstrate a payoff from basic research because it typically is either long-range work leading to improved knowledge of an unpredictable nature or medium- or short-range work contributing in some unquantifiable way to a product or process development. Thus, industry will not support basic research extensively unless it is willing to make a long-range speculative investment. However, it has long been accepted that modern technology is heavily dependent on basic research and, indeed, that a high-technology industry cannot continue to grow and remain competitive without constant infusions of knowledge generated by basic research. The role of basic research in technological innovation has been the subject of renewed interest. The discussion is made more intense by the fact that the proportion of industrial R&D expenditures going to basic research has been declining, as the following discussion shows. This decline has caused concern about the future ability of U.S. industry to compete with foreign high-technology imports.[30] On the other hand, U.S. industry may benefit from basic research performed in other sectors of the economy.

Total Expenditures for Basic Research, Applied Research, and Development

The trends in total industrial expenditures in these three areas since 1960 are shown on figure 4-4. In 1977, development received 78 percent of the total, applied research received 19 percent, and basic research, 3 percent. In terms of dollars expended, the industrial R&D system is mainly a development system.

In current dollars, industrial basic research expenditures increased each year from 1960 to 1968, declined from 1968 to 1972, and have increased steadily since 1972. The constant dollar picture is slightly different. In those terms, industrial basic research expenditures began to decline as early as 1967. There was a 27-percent decline from 1966 to 1972, with an apparent small recovery beginning in 1975. The turnaround in the mid-1960's evidently cannot be related to any changes in the national economy. One explanation comes from a recent study sponsored by NSF.[31] Based on extensive interviews with industrial R&D managers, it came to the following conclusions. Top industrial management in the 1950's had placed a great amount of faith in research for its own sake, an attitude which can be



[30] See the chapter of this report on International Science and Technology.

[31] G.E. Manners, Jr., J.A. Steger, and H.K. Nason, *Support of Basic Research by Industry*, (St. Louis, Mo.: Industrial Research Institute Research Corporation, 1978), pp. 18-19.

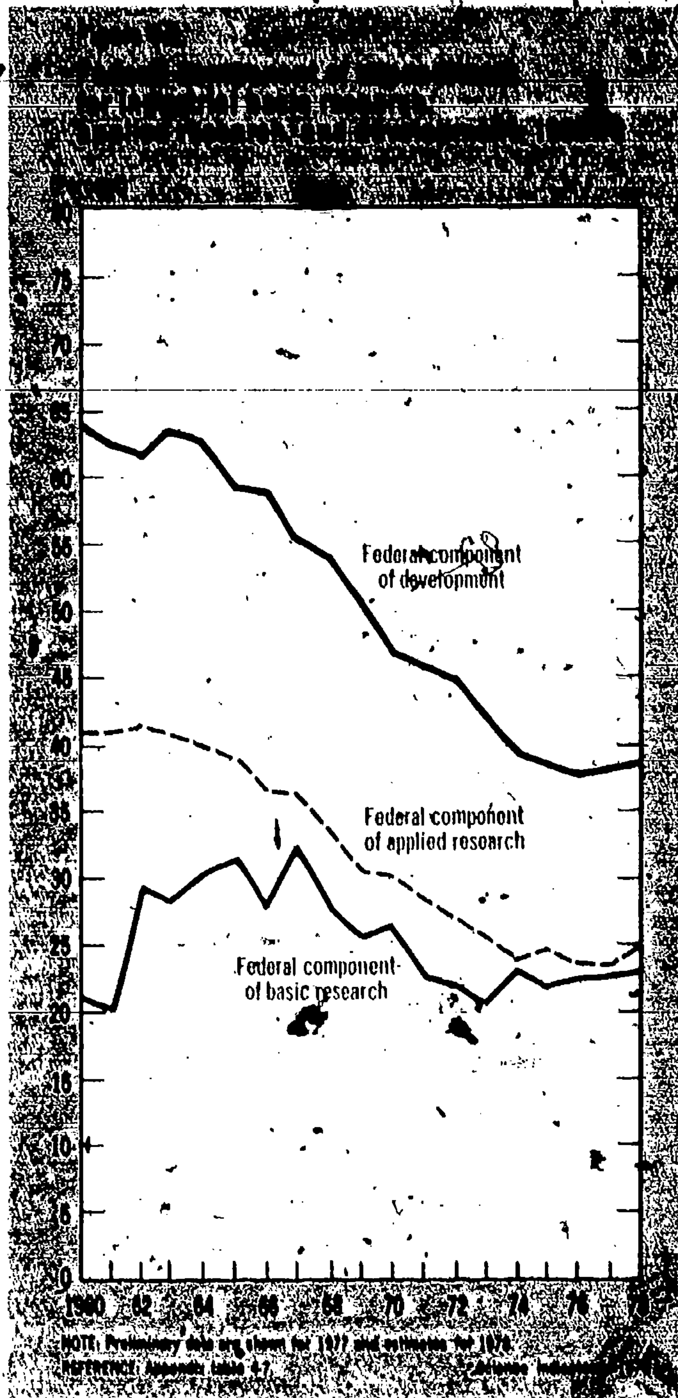
traced to the prestige that science acquired in World War II. In the mid-1960's, however, industry began to manage R&D as a corporate function with a goal-directed emphasis. Thus, a new breed of managers entered the picture, and structures were established in industry that made the R&D efforts more cost-accountable. In this environment, the high basic research expenditures of the past did not seem justified to managers. Other possible reasons are discussed below in connection with the more detailed treatment of basic research in industry.

Applied research expenditures also showed an increase in the 1960's (a 28-percent rise from 1960 to 1968, in constant dollars). Since 1968, however, fluctuations have been relatively small. Development funds seem to be highly dependent on the state of the general economy, with decreases in constant dollars in 1962, 1970, 1974, and 1975. Most of these were years of business slowdown,[32] and hence, years in which industry would have been pessimistic about its prospects for sales and profits and inclined to cut costs. Since 1975, both applied research and development have shown signs of constant dollar recoveries, reaching new highs in 1977 or 1978.

Federal and Company Support for Basic Research, Applied Research, and Development

These three types of activity can be analyzed according to their sources of funding to show the different Federal and company objectives in their support of industrial R&D. Thus, figure 4-5 shows that the Government provides a greater share of development costs than applied research costs, and a greater share of applied research than basic research. However, sharp declines in the Federal share of support in both applied research and development began about 1963 and continued to 1976. This reflects a decline in the Federal contribution to industrial applied research and development while company-originated funding increased. Thus, the levels of applied research and development effort seen in figure 4-4 have been sustained in the 1970's much more by industry than by the Government.

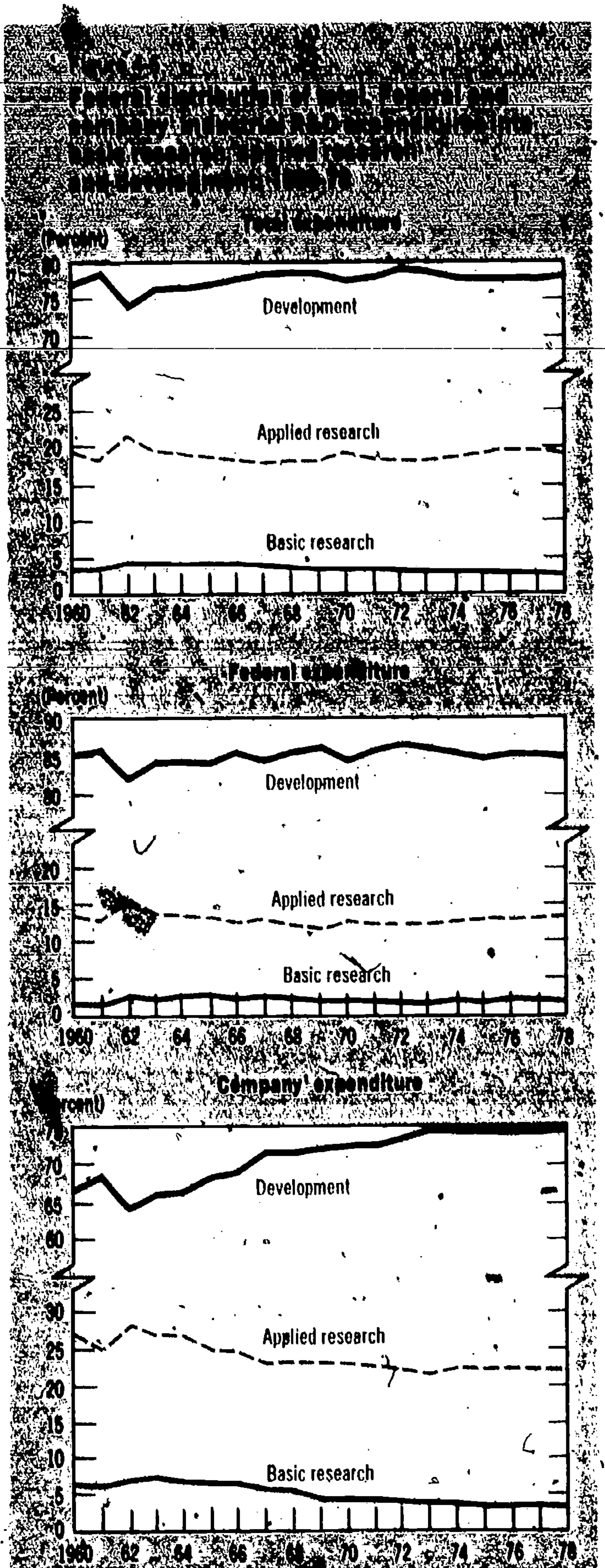
In basic research, the Federal share of support has dropped from the 30-percent levels of the mid-1960's to approximately 20 percent. Increased Federal interest in energy and space has led to small increases in the Federal share since



1973, and these increases are expected to continue. In current dollar terms, Federal funding has returned to the level of the mid-60's, after reaching a low point in 1972. Company funding has increased steadily since the early 1960's. However, in constant dollars, funding from both sources has dropped since the mid-1960's. There was no such drop in company funding in the case of applied research and development.

The different objectives held by the sources of industrial R&D funding are evident from figure 4-6. The Federal Government places exceptional emphasis on industrial development as opposed

[32] As measured by the MGDP; see *The National Income and Product Accounts of the United States, 1929-74: Statistical Tables*, U.S. Department of Commerce, Bureau of Economic Analysis, pp. 18-19, and *Survey of Current Business*, U.S. Department of Commerce, Bureau of Economic Analysis (July 1977), p. 20.



¹Includes all sources other than the Federal Government.
NOTE: Preliminary data are shown for 1977 and estimates for 1978.
REFERENCE: Appendix tables 4-7 and 4-8.
Science Indicators—1978

to applied research and basic research. Although there have been small fluctuations, the distribution of Federal funds to the three types of work has not changed greatly over time.

In the case of company expenditures, the emphasis on development is less, but it has increased from 66 to 74 percent of the total since 1964. Both applied and basic research have declined, in percentage terms, in favor of development. Both, of course, have increased in current dollar funding (Appendix table 4-7). In constant dollars, company support for basic research rose 1 percent from 1962 to 1977 but increased 50 percent for applied research. For development, the increase was 122 percent.

Several reasons have been given for this trend away from basic research, which has been discussed extensively. One study[33] suggests the following reasons, based on extensive interviews conducted in 1977 and 1978 with company officials:

1. Inventions made in the late 1960's have led to current needs for development with an emphasis on exploiting possibilities that have already opened up.
2. The relative profitability of private enterprise has decreased since the mid-1960's, making less discretionary money available for investment in basic research.
3. Government regulations have increased, thus diverting research funds to efforts designed to comply with the regulations.
4. More R&D funding is going to applied research and development for energy conservation, which promises a relatively quick and easy return on investment.

Another possible explanation suggests that the trend toward development is due to the expectation that inflation will continue. The increasing business uncertainty resulting from high inflation rates leads to higher return targets for future years and, therefore, to investments in projects that have a higher probability for shorter-term returns.

Federal Funding in Individual Industries

For a few industries, it is possible to show the Federal share of funding for the three types of R&D activity (table 4-3). Such information is helpful in seeing where the leveling-off of current dollar Federal funding and the reallocations of company funds have occurred. In

[33] G.E. Manners, Jr., and H.K. Nason, "Trends in Industrial Research," *Science* (forthcoming).

in nearly every industry shown, the Federal component of support is greater for applied research than for basic research, and greater for development than for applied research. Between 1967 and 1977, the Federal share of funding for each of the three types of R&D decreased in almost every industry for which data are available.

[illegible]	[illegible]	[illegible]
[illegible]		
All industry	[illegible]	[illegible]
Chemicals and allied products	[illegible]	[illegible]
Industrial chemicals	[illegible]	[illegible]
Drugs and medicines and other chemicals	NA	[illegible]
Fabricated metal products	NA	[illegible]
Nonelectrical machinery	[illegible]	[illegible]
Electrical equipment and communication	[illegible]	[illegible]
Communication equipment and communication	[illegible]	[illegible]
All other electrical equipment	[illegible]	[illegible]
Aircraft and missiles	[illegible]	[illegible]
Professional and scientific instruments	NA	[illegible]
Applied research:		
All industry	[illegible]	[illegible]
Chemicals and allied products	[illegible]	[illegible]
Industrial chemicals	NA	[illegible]
Drugs and medicines and other chemicals	NA	[illegible]
Fabricated metal products	[illegible]	[illegible]
Nonelectrical machinery	34	[illegible]
Electrical equipment and communication	[illegible]	[illegible]
Communication equipment and communication	[illegible]	[illegible]
All other electrical equipment	[illegible]	[illegible]
Aircraft and missiles	[illegible]	[illegible]
Professional and scientific instruments	NA	6
Development:		
All industry	[illegible]	[illegible]
Chemicals and allied products	[illegible]	[illegible]
Industrial chemicals	NA	[illegible]
Drugs and medicines and other chemicals	NA	[illegible]
Fabricated metal products	9	[illegible]
Nonelectrical machinery	26	[illegible]
Electrical equipment and communication	62	[illegible]
Communication equipment and communication	[illegible]	[illegible]
All other electrical equipment	[illegible]	[illegible]
Aircraft and missiles	[illegible]	[illegible]
Professional and scientific instruments	NA	[illegible]

NA = Not available.

REFERENCE: Appendix table 4-9.

Basic Research in Industry

The recent shift in company funds from basic research to development has caused concern among those interested in national science policy. Basic research, whether performed in industry or elsewhere, underlies and leads to the applied research and development that is then phased into commercialization by the private sector.[34] However, it is important to know how the knowledge produced by basic research is useful in the creation or improvement of commercially significant processes or products. Some well-known studies have addressed this problem.[35]

According to a simple and commonly used model, basic research, applied research, development, and commercialization are distinct events that follow one another, with each stage causing the next. This model has been highly criticized recently,[36] but it still has validity in certain high-technology industries, such as electronics and chemicals. Such industries look for definite discoveries from basic research, which are pushed through the subsequent stages and are embodied in commercial products. The discovery of the transistor is an example. Industries of this kind are the ones most likely to perform substantial amounts of basic research in-house.[37]

However, not all technological innovations are related to basic research in this way. In fact, much of technology is "self-contained" in the sense that it exploits knowledge that has been produced

[34] Frank Press, "Towards New National Policies to Increase Industrial Innovation," *Research Management* (July 1978), p. 12; and F.H. Healey, "Industry's Needs for Basic Research," *Research Management*, vol. 80 (November 1978), pp. 12-16.

[35] *Technology in Retrospect and Critical Events in Science* (Chicago: IIT Research Institute, 1968); *Interactions of Science and Technology in the Innovative Process: Some Case Studies* (Columbus, Ohio: Battelle Memorial Institute, 1973); *Project Hindsight Final Report*, U.S. Department of Defense, Office of the Director of Defense Research and Engineering, 1969.

[36] See, for example, E. Layton, "Conditions of Technological Development," in Ina Spiegel-Roesing and Derek de Solla Price (eds.), *Science, Technology, and Society: A Cross-Disciplinary Perspective* (Beverly Hills, Calif.: Sage Publications, 1977), pp. 203-207; Derek de Solla Price, "An Intrinsic Value Theory for Basic and 'Applied' Research," in J. Haberer (ed.) *Science and Technology Policy: Perspectives and Developments* (Lexington, Mass.: D.C. Heath & Co., 1977), pp. 25-36.

[37] W.H. Shapley and D.F. Phillips, *Research and Development: AAAS Report III. R&D in the Federal Budget: FY 1979, R&D, Industry, and the Economy* (Washington: American Association for the Advancement of Science, 1978), p. 71.

within technology, not knowledge imported from the scientific world.[38]

Even when basic research does not provide the central idea that comes to be embodied in a technological innovation, it can help the innovation process in many indirect ways.[39] However, since research outside industry can also provide this assistance, many industrial managers in fact feel that basic research should be performed outside industry, preferably at universities.[40]

Thus, the question arises as to how much basic research should be performed in industry. On the assumption that higher levels of basic research performance in industry are desirable, some Government policy options to achieve these levels have been suggested.[41]

Table 4-4 shows that industrial basic research is concentrated in a small number of industries. Of the $869 million spent on industrial basic research in 1977, 39 percent was spent in chemicals and allied products alone. Another 21 percent was spent in electrical equipment and communication. Comparison of this table with figure 4-2 shows that basic research is more concentrated by industry than is total R&D. Table 4-3 shows that in 1977 these two industries had 25 percent or less of their basic research supported by the Government. Hence, their large basic research efforts are mainly due to private industry's own funding. These two industries appear to be the ones that most often turn in-house basic research discoveries into technological innovations.

Table 4-4 also shows that the chemicals industry has a ratio of basic research to net sales nearly twice as great as any other industry. This table can be compared with table 4-1, which shows the ratios of all R&D to net sales for each industry. The aircraft and missiles industry leads in total R&D as a percent of net sales, but not in basic research as a percent of net sales.

[illegible]	[illegible]	[illegible]
Electrical equipment and communication	181	[illegible]
Motor vehicles and motor vehicle equipment	14	[illegible]
Aircraft and missiles	56	10
Professional and scientific instruments	22	[illegible]

REFERENCE: Appendix table 4-10.

In terms of the distribution of basic research expenditures by field of science (figure 4-7), chemistry is the single most important field. In 1977, chemistry received 31 percent of all expenditures for industrial basic research. This is consistent with the heavy expenditure for basic research that occurs in the chemicals industry (table 4-4). In terms of constant dollars, almost all fields of science have seen a drop in funding since the late 1960's, although there seems to be a new upward trend since 1975.[42] For example, funds for basic research in engineering dropped 35 percent from 1967 to 1975, with a 16 percent recovery from 1975 to 1977. Funding for physics and astronomy first dropped 61 percent and then rose 18 percent. In contrast, funds for basic research in the life sciences remained relatively steady up to 1975, after which they also increased.

[38] See N. Rosenberg, "Thinking about Technology Policy for the Coming Decade," in *U.S. Economic Growth from 1976 to 1986: Prospects, Problems, and Patterns: Volume 9 - Technological Change*, studies prepared for the use of the Joint Economic Committee, Congress of the United States, January 3, 1977. Also see E.T. Layton, Jr., "Technology as Knowledge," *Technology and Culture*, vol. 15 (January 1974), pp. 31-41.

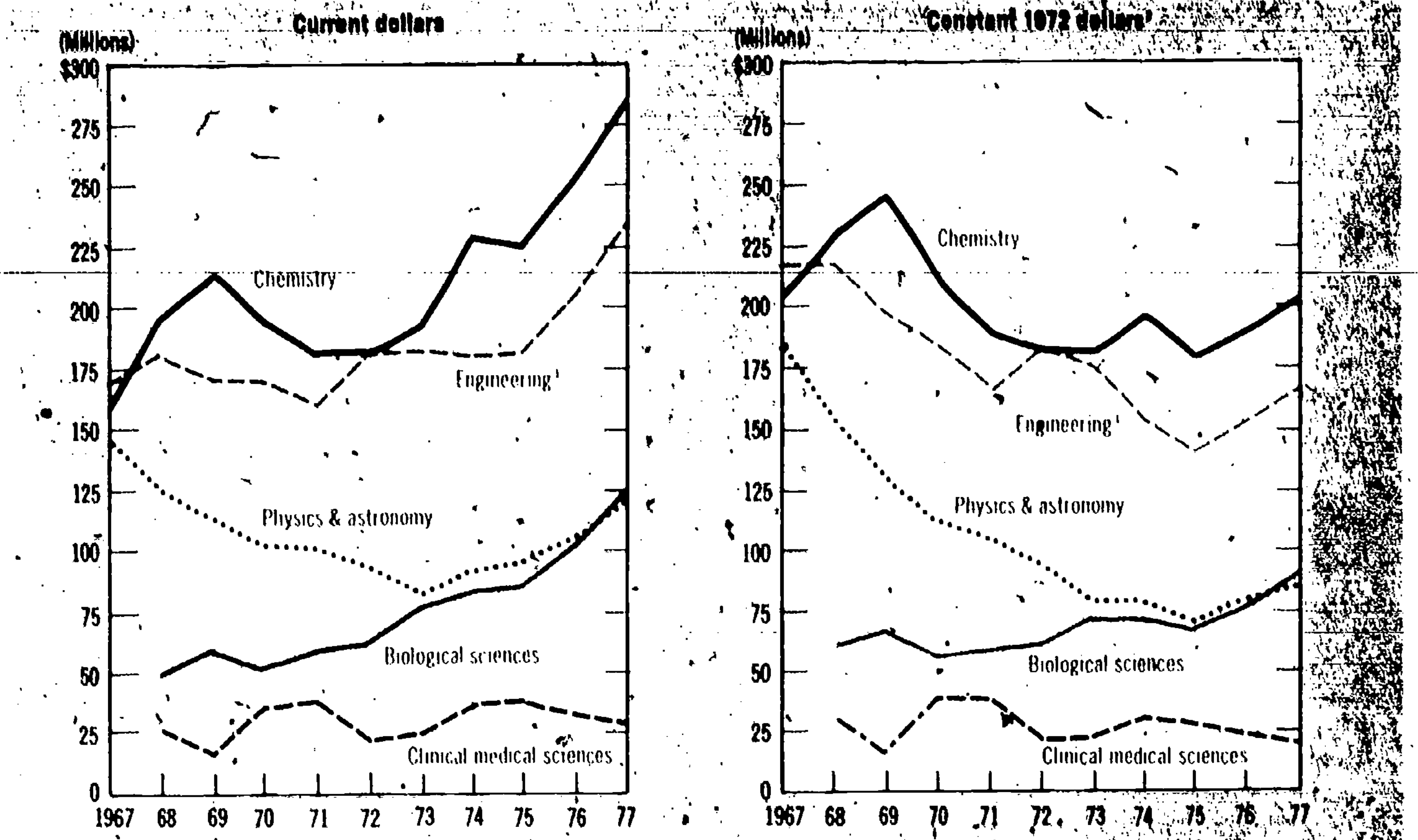
[39] M. Gibbons and R. Johnston, "The Roles of Science in Technological Innovations" *Research Policy*, vol. 3 (1974), pp. 220-242.

[40] G.E. Manners, Jr., J.A. Steger, and H.K. Nason, *Support of Basic Research by Industry*, (St. Louis, Mo.: Industrial Research Institute Research Corporation, 1978), pp. 18-19; W.H. Shapley and D.I. Phillips, *Research and Development: AAAS Report III, R&D in the Federal Budget: FY 1979, R&D, Industry, and the Economy* (Washington: American Association for the Advancement of Science, 1978), p. 35.

[41] *Government Involvement in the Innovative Process*, Office of Technology Assessment, 1978.

[42] These data series have undergone several revisions since they first began in 1957; small differences should be interpreted with caution.

Figure 4-7
Expenditures for basic research in industry by field of science: 1967-77



¹Includes metallurgy.
²GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NOTE: Preliminary data are shown for 1976 and 1977.
REFERENCE: Appendix table 4-11.

Science Indicators—1978

One reason industry has cut back on its own constant-dollar funding of basic research may be a conviction that basic research should be done in outside laboratories instead. Thus, it is useful to know whether industry has at the same time increased its support for basic research in other sectors, and to what extent.

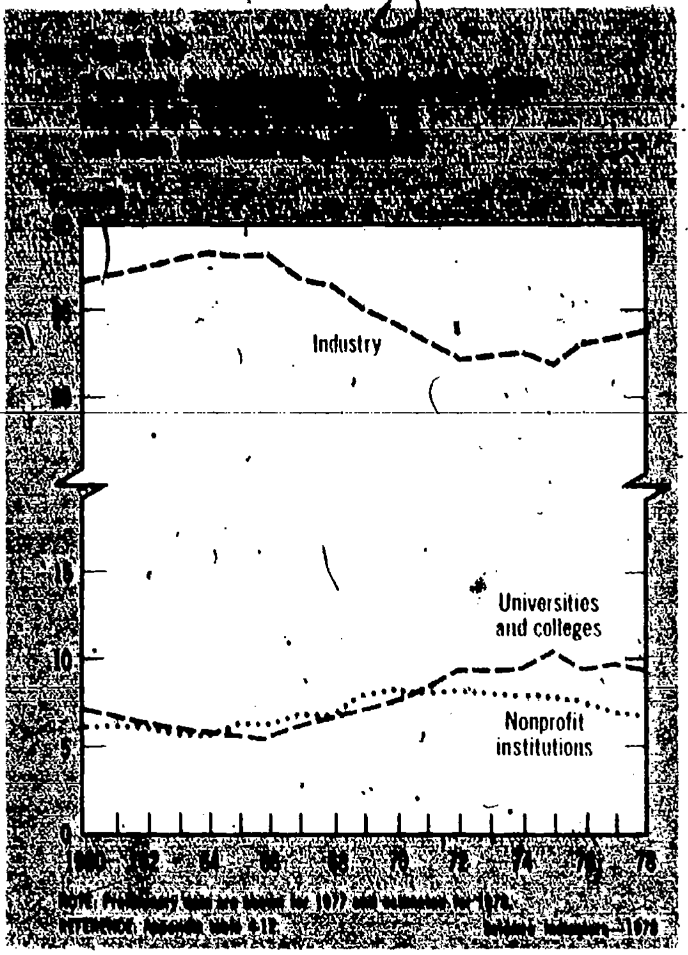
From 1960 to 1966, industry performed about 87 percent of its own basic research[13] (figure 4-8). This share then dropped to 82 percent in 1972, and has remained fairly stable since. In terms of constant dollars, industry's support for basic research in all sectors dropped from $665 million in 1966 to $593 million in 1977, or 11 percent.[14] This decrease occurred despite a 29-percent constant dollar increase in support to the other sectors, universities and colleges in particular. Thus, when allowance is made for inflation, the increase in industry's basic research support to other sectors is not enough to compensate for the decrease in its within-industry funding. While industry funding for R&D performed in industry has increased from its 1975 low, there has been no significant change, in constant dollars, in funding to other sectors. No significant change in industry's funding to any sector is expected from 1977 to 1978.

Overview

Industrial R&D funds have traditionally been allocated so that development received by far the greatest share, and basic research the smallest share. Basic research expenditures, in constant dollars, have declined from their peak value in

[13] This includes the basic research that one industrial concern performs under contract with another.

[14] Some of the numbers in figure 4-8 and Appendix table 4-12 are estimates. Caution is needed in interpreting detailed trends.



1966, but have remained stable since 1972, with an apparent upward trend since 1975. This decline may be due to an increasingly critical attitude toward basic research within industry, which demands more evidence of tangible payoff in the shorter term in a period of high inflation. Applied research and development had peak funding values, in constant dollars, in 1969. Applied research funding exceeded its 1969 value in 1977, and development is estimated to have done so in 1978. Continuing increases are expected. Levels of development expenditure seem to depend on the state of the general economy.

Federal support of R&D in industry is heavily skewed toward development, even more so than is industry's support. The Federal component of applied research and development expenditures dropped considerably between 1963 and 1977 because Federal support remained fairly level, in current dollars, while industry funding increased. The Federal component of the support of industrial basic research rose from 20 percent in the early 1960's to 30 percent in the mid-1960's, and returned to 20 percent in the early 1970's. Again, Federal current dollar expenditures for basic research have returned to the level of the mid-1960's, after reaching a low point in 1972. Company R&D funding has increased steadily since the early 1960's. Increasing Federal interest in energy and space has produced a slight increase in the Federal share of basic research, applied research, and development in the last few years. The Government supported 23 percent of industrial basic research in 1977, 24 percent of applied research, and 38 percent of development.

Company funding has gradually been shifting in the direction of development. Both applied and basic research have received declining percentage shares. Besides the increasing demand for visible payout, this trend is attributable to (1) the need to develop inventions made in the late 1960's, (2) lower profits and hence less discretionary money for basic research, (3) the need for more applied research to comply with increasing Government regulation, (4) easy and attractive payouts from applied research and development for energy conservation, and (5) industry demand for shorter term and more certain payoff from investments because of worries about future inflation.

This trend has caused concern because basic research is considered the foundation for much of the Nation's technological innovation. Innovation in turn influences the level of industrial productivity, the balance of payments, and other aspects of the economy. However, basic research is not always necessary for technical innovation; when it does help the process, it can do so in various ways. Since 1966, industry has decreased its own funding for basic research, in constant dollars, and has increased its support for basic research in universities and colleges and in nonprofit institutions. However, the net effect, in constant dollars, is an overall decrease in industry's support of basic research. Again, there are signs of an increase since 1975.

APPLICATION AREAS FOR R&D

The indicators in this section show the specific technological areas to which industrial R&D efforts are directed. These data are of interest because they show the product fields in the private economy where corporate management has felt that investment was desirable. These indicators may help in forecasting the areas in which future technological innovations will occur. The data show the effect of Government decisions, e.g., in the balance between the military/space and the civilian components of Government R&D expenditures in industry. They also show the effect on R&D of events such as the 1973 oil embargo and the environmental movement; which have led to special R&D efforts related to energy and pollution abatement. Finally, they can help to show the areas of technology in which more (or less) R&D may be needed. Government policy can affect these levels of effort through direct funding or through indirect incentives and disincentives.

Applied Research and Development by Product Field

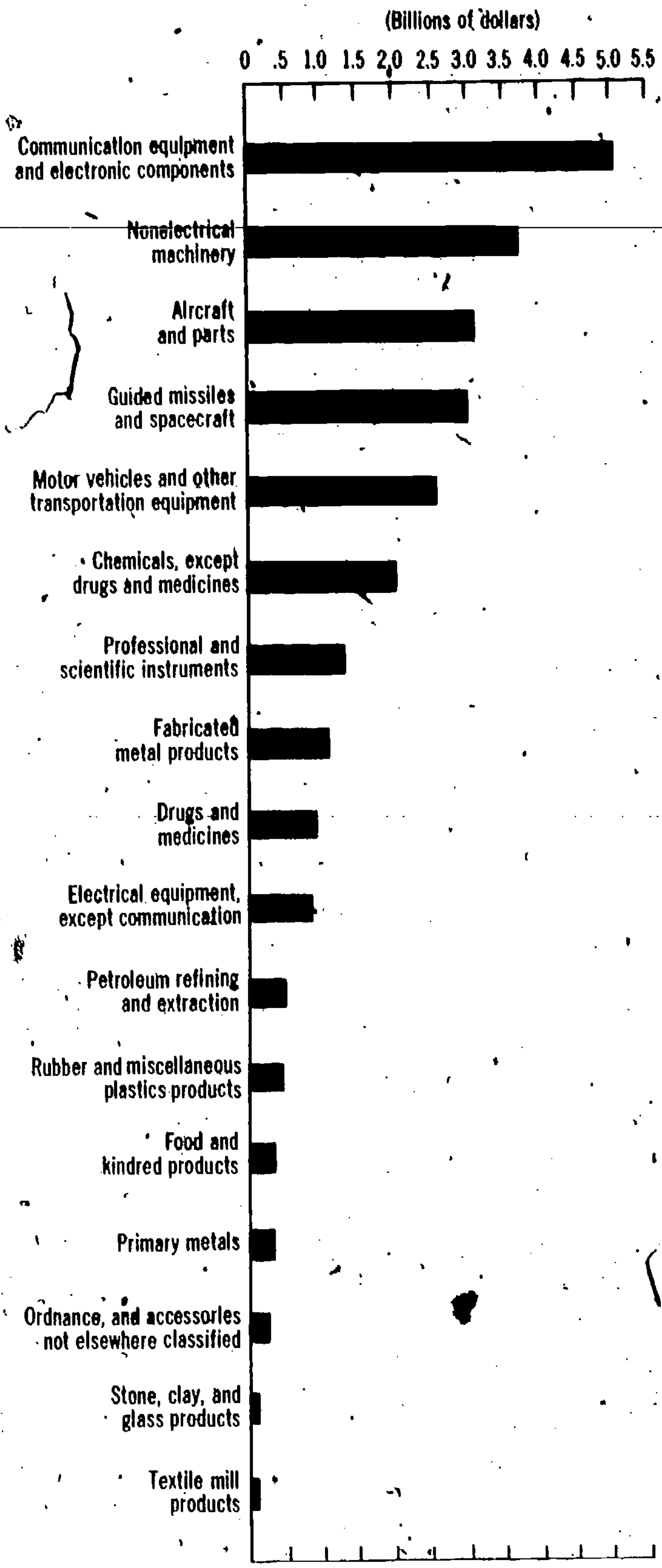
The distribution of R&D expenditures according to individual industries was discussed earlier in this chapter. When R&D expenditures are classified by industry only, all of the R&D of a large, diversified company is assigned to the same industry. This method does not show the actual areas of technology that the company is working on. Another mode of analyzing industrial R&D expenditures is also available, i.e., according to product field.[45] R&D expenditures by product field represent a finer breakdown than those according to performing industry. However, data are harder to obtain by product field, and many of the data presentations possible by performing industry cannot be made by product field. Hence, the two kinds of data complement one another.

Figure 4-9 shows the distribution of applied research and development (AR&D) expenditures in U.S. industry according to product field.[46] The first four product fields shown together accounted for about half of all industrial AR&D. To the extent that technological innovation depends on levels of R&D expenditures,[47] these are the areas of technology in which future technological developments in the United States can be expected to be concentrated.

Information is also available on Federal support for most of the major product fields (figure 4-10). The Government's product field interests can be compared with those of private industry. Clearly,

Figure 4-9

Applied research and development expenditures by major product field: 1977



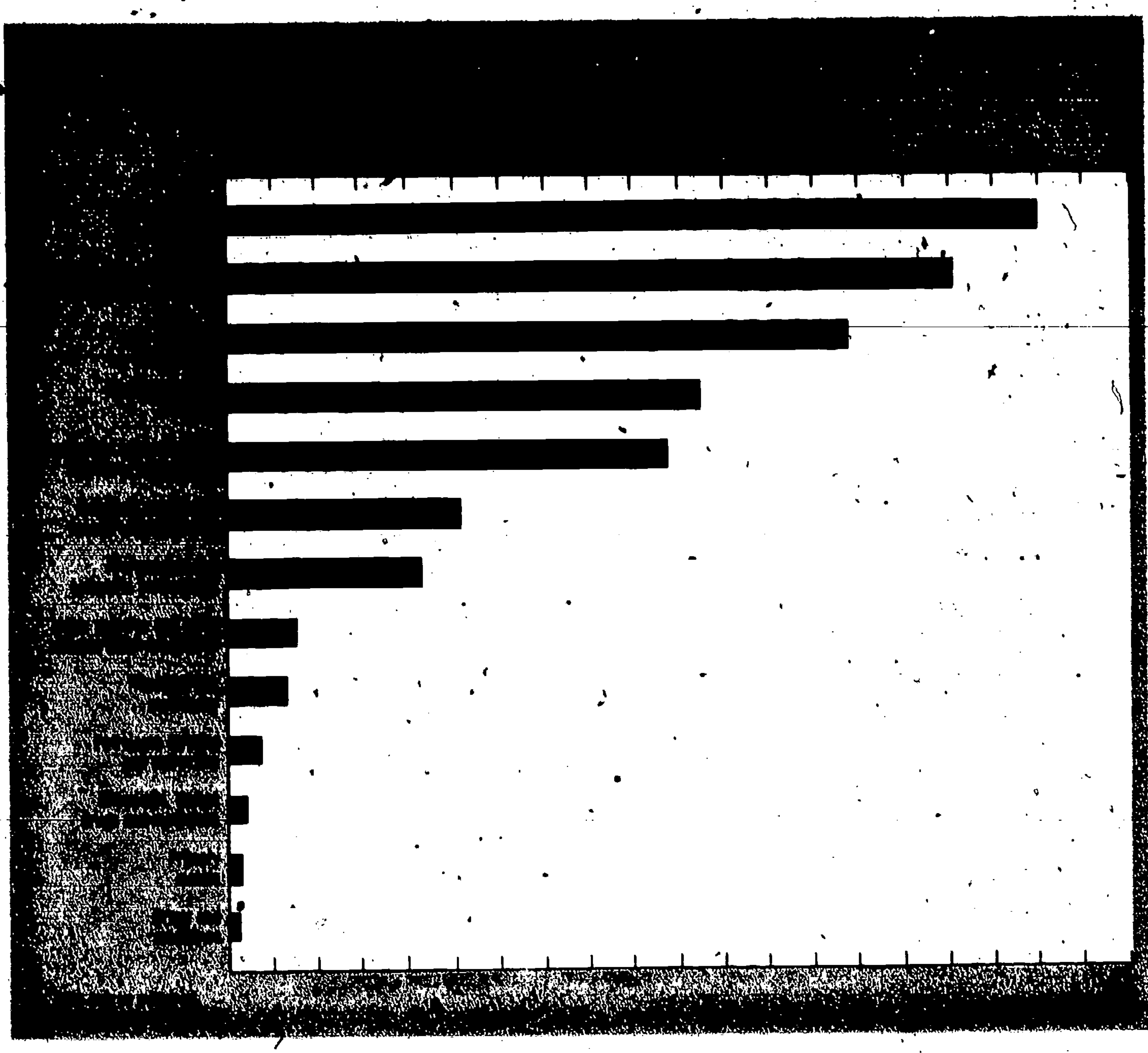
NOTE: Data are preliminary.
REFERENCE: Appendix table 4-13

Science Indicators—1978

[45] The taxonomy of product fields corresponds approximately, but not exactly, with the manufacturing industry taxonomy used earlier in this chapter. Both consumer products and intermediate products sold to other organizations are included.

[46] Basic research expenditures are not included because, by definition, they are not directed to specific product lines. Figure 4-9 shows only major product fields, i.e., those at the highest level of aggregation. Data on the more disaggregated product fields can be found in Appendix table 4-13.

[47] A summary of the extensive literature on this relationship can be found in C. Freeman, "Economics of Research and Development," in Ina Spiegel-Roesing and Derek J. de Solla Price (eds.) *Science, Technology, and Society: A Cross-Disciplinary Perspective* (Beverly Hills, Calif.: Sage Publications, Ltd., 1977), pp. 223-275.



the Government is mainly interested in space- and defense-related products. Industry is virtually self-sufficient in its support of AR&D in the last four fields shown, which are directed primarily to the civilian economy. In terms of total dollars, most Federal money went into guided missiles and spacecraft, communication equipment and electronic components, and aircraft and parts. Most company money went to the nonelectrical machinery, communication equipment and electronic components, motor vehicles, and chemicals product fields (see Appendix table 4-13). Thus, only the communication equipment and electronic components field, which has both civilian and military aspects, receives heavy support from both sectors.

It is also important to look at changes in R&D expenditures by product field over time, in order to observe any shifts of emphasis that may have occurred in industrial AR&D. Table 4-5 shows the broad product fields with the greatest changes from 1971 to 1977.[48] Definite decreases from 1971 to 1977 took place in product fields related to aerospace, where the Government's share of overall support was the highest.[49] The

[48] Appendix table 4-14 shows the percentage changes for all product fields. Funding levels by product field for 1977 are shown in Appendix table 4-13.

[49] Recent shifts in the Government's support for R&D in these fields are discussed in the chapter on Resources for Research and Development.

[illegible]

REFERENCE: Appendix table 4-14.

rapid decreases in these product fields do not imply, however, that Federal support for all industrial R&D has dropped at a comparable rate. As figure 4-1 shows, Federal funding for industrial R&D increased from 1971 to 1977, even in constant dollars.

The product fields showing the greatest increases from 1971 to 1977 are, almost without exception, the ones that depend least on Federal support. There is not enough information available to explain all these changes. However, sales in the instrument field, where AR&D is mainly company-supported, seem to go up and down with the economy as a whole. Instruments are usually sold to other industries, and their purchase can be postponed when times are bad. According to discussions with industry officials, an increased commitment of company money to this product field, which has occurred in recent years, may reflect optimism about the economy. There has been an increased R&D effort in drugs, in part because of increasingly stringent regulations put forth by the Food and Drug Administration that have required increasingly high company expenditures for the safety and efficacy testing of products. The increased AR&D in petroleum is closely related to the increased interest in energy technologies and recent increased sales in the petroleum industry.

Increases in the nonelectrical machinery field can be traced to some of its subfields (see Appendix table 4-14). Outstanding among these are farm machinery and equipment and engines and turbines, which had a greater AR&D increase than any other subfield in the 1971-77 period. The increase in engines and turbines was due largely to efforts within the motor vehicles industry to develop improved diesel engines.[50]

Energy-Related R&D

Interest in energy as a separate area of technology has been intensified by several recent well-known events, in particular the 1973 Arab oil embargo. Since that time, both private industry and the Federal Government have sought to diminish U.S. imports of petroleum by developing domestic supplies, developing and adapting to alternative energy sources, and practicing conservation. R&D has been an important part of this effort.[51] In 1977, $1.9 billion were spent on energy-related R&D in industry (table 4-6 and Appendix table 4-15). This expenditure was 6 percent of all industrial R&D. It was also 44 percent more, in constant dollars, than the energy R&D expenditure in 1973, the first year in which such data were collected. Almost half of this amount was provided by the Government. However, the following discussion shows that emphases and trends have been different for public and for private funding.

Much of the increase in energy R&D funding since 1973 has been in the nuclear technologies, which have consistently taken up about half of the total funding and an even larger portion of the Federal share. In 1973, 95 percent of Federal moneys for energy-related industrial R&D went into nuclear technologies; even with increased Federal interest in other technologies, the share was 73 percent in 1977. The Government has traditionally taken the major responsibility for nuclear energy R&D largely because of its military connections, but also because the large

[50] Further information on individual product fields can be obtained from the Industry Studies Group, Division of Science Resources Studies, National Science Foundation.

[51] A general discussion of energy-related R&D and innovation can be found in "Innovation in Energy Systems," in K.F. Gordon (ed.), *Technological Innovation and Economic Development: Has the U.S. Lost the Initiative?*, Energy Research and Development Administration, 1976. For the Federal Government's current interests in basic research in this area, see *Special Analyses: Budget of the United States Government, Fiscal Year 1979*, Office of Management and Budget, p. 317. For the definition of energy-related R&D used in this chapter, see *Research and Development in Industry, 1976*, National Science Foundation (NSF 78-314), p. 70

ERIC

Table 4-6. Total industrial expenditures for energy R&D and Federal component by primary energy technology: 1973-78

[Dollars in millions]

Primary energy technology	1973	1974	1975	1976	1977	1978 (est)
	Total expenditure					
All technologies	$1,004	$1,213	$1,374	$1,606	$1,930	$2,146
Fossil fuel	433	507	532	583	695	803
Oil	297	325	321	368	420	443
Coal	49	65	109	127	177	246
Gas	51	74	66	68	78	84
Shale	7	13	14	15	15	23
Other fossil fuels	29	30	23	5	5	7
Nuclear	501	601	700	799	906	943
Fission	476	568	659	741	823	867
Fusion	25	34	41	58	83	76
Geothermal	1	2	6	13	24	26
Solar	2	7	19	43	65	90
Conservation and utilization	67	20	52	83	124	170
All other energy technologies		76	64	85	116	134
	Federal expenditure as a percent of total					
All technologies	38	40	45	47	47	NA
Fossil fuel	2	3	8	14	19	NA
Oil	1	1	2	8	4	NA
Coal	14	14	29	37	49	NA
Gas	1	1	4	24	26	NA
Shale				27	33	NA
Other fossil fuels						NA
Nuclear	73	74	77	75	74	NA
Fission	73	74	76	74	72	NA
Fusion	72	68	90	93	93	NA
Geothermal	33	33	48	62	38	NA
Solar				60	66	NA
Conservation and utilization	12	40	19	20	26	NA
All other energy technologies		18	28	27	28	NA

NA = Not available.

REFERENCE: Appendix table 4-15.

amounts of capital required and the long time before payoff made various technologies unattractive to private industry at various times. However, private industry funding in this area has also increased in recent years, so that the Federal share has been approximately constant. The industry that performs the most energy-related R&D and receives the most Federal support is electrical equipment and communication.[52] Much of this expenditure is for the development of large nuclear facilities to produce electric power. Energy R&D in this industry increased by 26 percent from 1975 to 1976 alone. Electrical industry spokesmen attributed this rise to projects evolving from research into the more costly development stage.[53] An additional increase of 20 percent occurred from 1976 to 1977.

Most support for nuclear R&D has traditionally gone into fission technologies, which are the only nuclear technologies in operation. Nuclear fusion has seemed a relatively long-range possibility, but recent public and governmental concern with fission technology has caused increased interest in the slowly developing fusion

[52] *Research and Development in Industry, 1976*, National Science Foundation (NSF 78-314), p. 44, and preliminary data.

[53] "Industrial R&D Spending Reached $26.6 Billion in 1976," *Science Resources Studies Highlights*, National Science Foundation (NSF 78-306), p. 1.

technologies and greatly increased Federal support.

Fossil fuel technology receives the next largest amount of R&D funding, which also increased considerably from 1973 to 1977. The petroleum industry performs the second largest amount of energy-related R&D, mostly in connection with oil and gas, although some companies have moved into less traditional areas. Energy-related R&D in this industry amounted to $531 million in 1977, 58 percent of its total R&D expenditures.[54] Unlike the nuclear technologies, oil receives very little R&D support from the Federal Government, and the same is apparently true for gas and shale. The petroleum industry built up a strong R&D effort early in its history, and has maintained it largely without Government involvement.

New technologies are being developed in coal so that domestic coal reserves can begin to be substituted for oil and gas. Thus, some Federal R&D funding has begun to go to this traditional field, with an especially large increment occurring from 1976 to 1977.

Other alternative technologies are geothermal and solar energy. These are long-term approaches to the energy problem that probably will not soon make a large dent in oil imports. Thus, the share of Federal support is fairly high. Solar energy is particularly attractive as a nonpolluting, renewable, and widely distributed energy source; as a result, solar technology is attracting increased Federal and private funding. Industry officials indicate that expenditures for these energy sources will remain small in the next 5-year period, in comparison with fossil fuel and nuclear energy, but that the sharp year-to-year increases will undoubtedly continue.[55] This expectation applies also to conservation and utilization, much of which has to do with the energy efficiency of industrial processes and is a matter of considerable interest to private industry. This interest may help to account for the almost eightfold increase in company funds for this area of R&D from 1974 to 1977.

R&D for Pollution Abatement

Pollution abatement is a task that industry has been required to assume primarily for the sake of public health and safety, though this effort sometimes leads to new technologies that provide business for private industry and add to the GNP.[56] The amounts spent for pollution abatement R&D are less than those spent for energy-related R&D (tables 4-6 and 4-7), although the amount spent in 1977 is still greater than the AR&D expenditures for many product fields (Appendix table 4-13). The increase in R&D expenditures for pollution abatement from 1973 to 1977 was not quite enough to keep up with inflation. However, there were substantial increases from 1975 to 1976 and from 1976 to 1977. Most of these increases can be attributed to R&D on automobile emissions.

Another conclusion to be drawn from table 4-7 is that, the Government bears a much smaller share of the R&D costs in this area than in energy. The area called "All other types" of pollution, which receives the largest percentage share of Federal support, includes such areas as radiation and noise pollution. With regard to radiation, the Government is especially involved in the problem of disposing of radioactive waste. Noise abatement is a problem for the aircraft industry because of public concern over noise in the vicinity of airports, and the Government shares in the costs. In 1977, the Government spent $8 million on all pollution-abatement R&D in the aircraft industry, 14 percent of its expenditures for pollution R&D.[57]

By far the greatest share of pollution abatement R&D is directed to the problem of air pollution (table 4-7). The great bulk of these funds is directed to motor vehicle emissions (Appendix table 4-16); 53 percent of all pollution-related R&D performed in industry in 1977 was in the motor vehicles industry. The next most impacted industry is chemicals and allied products, which spent $84 million in 1977 on R&D to control its wide variety of effluents.

PATENTED INVENTIONS

R&D activities have many results or products which, if they could be measured, would gauge the aggregate success of these activities. Ideally,

[54] National Science Foundation, preliminary data.

[55] "Industrial R&D Spending Reached $26.6 Billion in 1976," *Science Resources Studies Highlights*, National Science Foundation (NSF 78-306), p. 4.

[56] For a definition of pollution abatement R&D, see *Research and Development in Industry, 1976*, National Science Foundation (NSF 78-314), p. 70. A broad discussion of industry's response to the environmental problem, as seen from an industrial viewpoint, can be found in J.T. Long, "Long and Short Term Impacts of Environmental Regulations on Industrial Research and Development," paper presented to the annual meeting of AAAS, February 15, 1978. An academic study of the effects of environmental regulations on one industry is G.E. Schweitzer, *Regulations and Innovation: The Case of Environmental Chemicals* (Ithaca, N.Y.: Cornell University Program on Science, Technology, and Society, 1978).

[57] National Science Foundation, preliminary data.

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Table 4-7. Total industrial R&D expenditure for pollution abatement and Federal share of expenditure, by type of pollution: 1973-78

[Dollars in millions]

Year		Type of pollution: All types	Air	Water or solid waste	All other types
1973	Expenditure	$603	$461	$86	$56
	Federal share	6%	2%	5%	38%
1974	Expenditure	657	508	74	75
	Federal share	8	3	7	39
1975	Expenditure	647	478	94	75
	Federal share	6	3	4	31
1976	Expenditure	759	571	108	80
	Federal share	7	5	7	21
1977	Expenditure	918	685	133	100
	Federal share	6	3	11	20
1978 (est)	Expenditure	1,050	787	144	119

REFERENCE: Appendix table 4-16.

such measures, or "output indicators," would provide enough information to enable policymakers to decide whether the level of R&D effort is adequate and is producing what is expected, in view of the inputs it receives. Actually, the output indicators that can be offered are few and imperfect. They are selected primarily because they are measurable, are products of R&D activity (though also affected by other influences), and are believed to provide partial information about the varying amount and success of that activity.

Counts of patents granted by the U.S. Patent and Trademark Office fall into this category. They serve as an indicator of the rate of production of inventions, which are largely an output of R&D efforts.[58] These patents are based on work done in all sectors of the economy, not only in industry. Nevertheless, industry is responsible for most of them, and most patents that are used are ultimately used in industry.

[58] The Patent Office grants patents for inventions, in addition to a smaller number for designs and for botanical plants. This chapter will consider patents for inventions only.

Relation of Patents to Applied Research and Development

Compared with other output indicators, patent counts present relatively few problems of data collection or of sample and population definition. Indeed, national patent offices contain what is probably the most complete, the most detailed, and the longest running record of information on technical activity in industry. In the conventional scheme whereby R&D is divided into basic research, applied research, and development, patents arise mainly from applied research work and from development.[59] Thus, the "input" categories to be related to patent "output" are the combined inputs into applied research and development. In some industries Mueller found strong correlations between input data for development work by individual industries and lagged patent data; in others, he found a stronger

[59] C. Freeman, *Measurement of Output of Research and Experimental Development*, A Review Paper, UNESCO, 1969, p. 20. Other interpretations in this chapter related to patents were provided by James Harris, Mary Holman, Edmund Kitch and Keith Pavitt.

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correlation for applied research and lagged patents.[60] Some "inventive work" is done outside the organized R&D system altogether.

The patent system leaves the inventor (or his employing firm) free to determine when in the process he wishes to apply for a patent. The patent system does, however, place strong incentives on an inventor to apply as soon as he believes he has a patentable result, for two reasons. First, the inventor's rights can be cut off by the activities of others in ways that he cannot foresee or control. Their publication or use in the public domain will activate the time limitations of the patent statute. A patent cannot be filed for an invention more than one year after its first publication or public use. Second, the patent application date is important in any subsequent contest over priority, with a strong *prima facie* advantage going to the first applicant. Thus, although a patent may reflect an "invention" that ranges anywhere from a preliminary laboratory result to a fully commercialized product, these incentives insure that most patents will come early in the process. A commercialized invention will usually incorporate not just one patent, but a whole string of patents emanating from each stage of the innovation process.

Past Use of Patents as Output Indicators

There have been a number of detailed economic studies using patent counts, which underscore their potential value as output indicators. For example:

1. Economists have found a high correlation between value added in an industry (i.e., the dollar value of sales minus the dollar value of intermediate goods and services) and the number of patents for inventions on capital goods products.[61] Similarly, several researchers have shown that a rather strong statistical correlation exists between such inputs as R&D activities by a firm and the numbers of patents acquired.[62]
2. Economists have also found interindustry differences that support the notion that patents can be an index of technological change. Annual patenting and net sales were found to be strongly correlated for high-technology industries and weakly correlated for low-technology industries.[63]
3. Economic research has found that the production of patents reflects the typical production phenomenon of increasing and then decreasing returns (or decreasing and then increasing costs). As an industry matures, the rate of patent activity first rises at an increasing rate, then at a decreasing rate, and finally patent activity declines.[64] Research has also indicated that the numbers of new patents in relation to the numbers of expired patents, coupled with the ages of patents cited by a given patent, reflect the life cycle and the rate of progress of a technology.[65] Thus, patent counts can be used to aid in analyzing the life cycle of an industry or a single technology.
4. Another analysis has used patenting by foreign countries in the United States as a means for comparing their national technical efforts. Patent counts are said to show the technical strengths and weaknesses of various countries in various industries, and they can be used in conjunction with statistics showing the international trade patterns of those countries.[66]
5. An important application of patent statistics has been Schmookler's argument that inventive activity in several major capital goods industries was demand-induced. He compared the long-run waves in successful patent applications with indicators of output in the same industries and found a high degree of correlation. He also found that trends for the 900 "important inventions" that he analyzed exhibited these same features. His findings, according to Freeman,

[60] D.C. Mueller, "Patents, Research and Development, and the Measurement of Inventive Activity," *Journal of Industrial Economics*, vol. 15 (November 1966), Part L, pp. 26-37.

[61] Jacob Schmookler and Zvi Griliches, "Inventing and Maximizing," *American Economic Review*, vol. 53 (September 1963), pp. 725-729. Also see Jacob Schmookler, *Invention and Economic Growth* (Cambridge, Mass.: Harvard University Press, 1966), p. 184.

[62] Frederic M. Scherer, "Corporate Inventive Output: Profits and Growth," *Journal of Political Economy*, vol. 73 (June 1975), pp. 290-297. Also see William S. Comanor and Frederic M. Scherer, "Patent Statistics as a Measure of Technological Change," *Journal of Political Economy*, vol. 77, (May/June 1969), pp. 392-398.

[63] Frederic M. Scherer, "Firm Size, Market Structure, Opportunity, and the Output of Patented Inventions," *American Economic Review*, vol. 55 (December 1965), pp. 1097-1125.

[64] Edwin Mansfield, *The Economics of Technological Change* (New York: Norton, 1968), p. 36.

[65] Richard S. Campbell and Robert McGinnis, *Patents and Other Indicators of Applied Scientific Productivity*. Unpublished paper; D.J. de Solla Price, "Citation Measures of Hard Science, Soft Science, Technology and Nonscience," in *Communications Among Scientists and Engineers*, C.E. Nelson and D. Pollack (eds.) (Lexington, Mass.: D.C. Heath and Co.), pp. 3-22.

[66] Keith Pavitt, "Technical Effort and Economic Performance: Some International Comparisons" (in preparation).

provide ample justification for the careful use of patent statistics in economic analysis.[67]

Weaknesses of Patent Counts as Output Indicators

The tendency of a company or an industry to refrain from patenting its inventions may affect the validity of patent counts as a measure of the inventions produced in industry. Generally, company policy with respect to inventions is reflected in the balance between reliance by the company on trade secrets and its dependence on patents. A number of factors may favor reliance on trade secrets. A company has to decide whether the use of the matter disclosed by a patent can be policed, whether adequate claims can be obtained, and whether the litigation costs are worth the gain. Another pertinent consideration is that trade secrets, if they can be guarded, are a means of gaining exclusivity quickly, especially in fields of rapid technical change, without disclosing the new technology. In such cases, the technology may be obsolete before a patent can be obtained. Some research findings suggest that trade secrets are especially important for process patents because it is difficult to protect processes from imitation even with patent protection.[68]

There are also some differences in the "propensity to patent" between different industries. This propensity is highest in industries in which a technical advance can very easily be copied by competitors without much independent development work; an example is the drug industry. The propensity to patent is lowest in industries in which technical advances can be copied only with great difficulty and with much independent design and development lasting many years, or in which Government contracts play a large role. In such cases, technical leadership may often be maintained without strong patent protection. In other cases, differences in the patentability of technical developments may seriously affect comparisons between industries. For example, in the computer industry advances in hardware are usually patentable, but those in software are not.[69]

Other factors may favor patenting, however. Once a trade secret is made public, it is generally no longer protectable. A confidential disclosure of a trade secret is more difficult to protect legally than a patent. If a firm does not control the complementary resources necessary to carry the invention forward to commercialization, the propensity to patent will also be increased. A company cannot negotiate with another organization for venture capital without disclosing what technology it plans to exploit, and it cannot do this without applying for patent protection. Thus, small firms and individual inventors have a higher propensity to patent than do large firms or firms that dominate a particular area of technology.

A number of additional points can be made about the limitations of patent counts when used as output indicators:

1. Patent statistics do not separate origination from development. A brilliant idea or concept contained in a single patent may be a more significant inventive output than are subsequent patents that develop the initial idea. The latter inventions may simply modify or slightly improve the original concept.[70] Since patents differ in their technical significance, the use of patent statistics embodies the assumption that more significant and less significant patents are evenly distributed.
2. Competition can induce firms to acquire patents on inventions that the owner has no intention of using. Of course, it is impossible to know from the patent document whether it was obtained for protection in commercial use or whether it was obtained to establish or to protect a patent position, for reasons of prestige, to reward an employee, or for some other noncommercial motive. However, some patents that are not used commercially serve to defend patents that are used, or are used by the owners in bargaining with competitors, and therefore are still valuable to their owners.
3. Patents owned by the Government and patents resulting from Government-financed R&D, whether owned by Government employee inventors or by private contractors, have a much lower incidence of commercial use than patents arising from private R&D. For patents arising from Government-financed R&D, the rate of commercial use appears to be between 7 and

[67] C. Freeman, *Measurement of Output of Research and Experimental Development: A Review Paper*, UNESCO, 1969, p. 23. The report *Utilization of Scientific Literature by U.S. Patents* (Cherry Hill, N.J.: Computer Horizons, Inc., November 30, 1978), discusses a different way of using patent information. The citations from recent patents to the scientific journal literature are analyzed to determine citation patterns.

[68] T.H. Noone, "Trade Secret vs. Patent Protections," *Research Management*, vol. 21 (May 1978), pp. 21-24.

[69] C. Freeman, *Measurement of Output of Research and Experimental Development: A Review Paper*, UNESCO, 1969, p. 22.

[70] J.E.S. Parker, *The Economics of Innovation: The National and Multinational Enterprise in Technological Change* (London: Longman Group, Ltd., 1974), pp. 33-34.

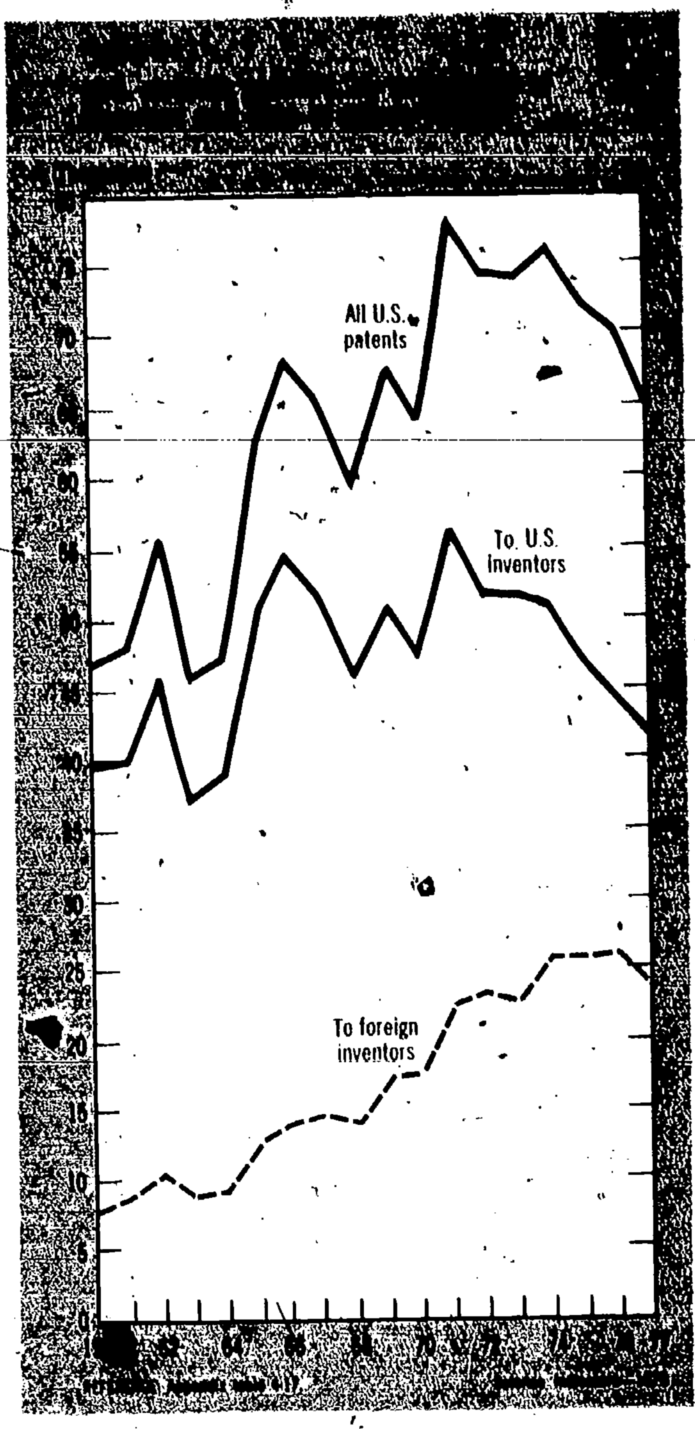
13 percent. This percentage compares with a rate of commercial utilization for patents arising from private R&D money of about 50 percent.[71]

4. In addition to the fact that patent statistics do not distinguish major from trivial technological advances, patent statistics do not take note of the varying economic quality of inventions. The economic value of a patented invention only materializes after innovation takes place, and innovation is inextricably linked with market forces. Some argue that the economic potential of many, if not most, patented inventions is conjectural.[72]

The various successful uses of patent statistics show that their limitations and drawbacks do not prevent their being used effectively. Still, these limitations must be taken seriously. Because of them, each specific use of patent statistics must be examined to see that the limitations do not compromise the validity of the conclusions being drawn. This situation commonly arises in using output indicators.

Inventors and Owners of Inventions Patented in the United States

The rate of domestic patenting by American inventors generally increased from 1960 to the early 1970's (figure 4-11) but it has shown a steady decline from 1971 to 1977.[73] Foreign patenting in the United States increased more steadily, and at the same time increased its share of total U.S. patenting from 16 percent in 1960 to 36 percent in 1977. A more extensive discussion of foreign patenting in the United States can be found in the international chapter.



The decline in patenting by U.S. inventors since 1971 has several possible causes. From figure 4-12 it is evident that this drop is mainly related to patenting by persons employed in U.S. corporations. A possible reason is that inventions are not needed as much as they once were because many inventions made in the 1960's remain to be exploited commercially before any new ones are

[71] Donald S. Watson, Harold F. Bright, and Arthur E. Burns, "Federal Patent Policies in Contracts for Research and Development," *Patent, Trademark, and Copyright Journal*, vol. 4 (Winter 1960), p. 342; Richard L. Sandor, "The Commercial Value of Patented Inventions," *Idea*, vol. 15 (Winter 1971-72), pp. 557-563; Mary A. Holman, "Concentration, Monopoly, and Economic Control," *The Political Economy of the Space Program* (Palo Alto, Calif: Pacific Books, 1974), p. 299; and R. Solo, "Patent Policy for Government-Sponsored R&D", *Idea*, vol. 10 (Summer 1966), pp. 143-206.

[72] Simon Kuznets, "Inventive Activity: Problems of Definition and Measurement," in *The Rate and Direction of Inventive Activity: Economic and Social Factors*. (Princeton: Princeton University Press, 1962), pp. 19-43.

[73] When a patent is granted, a certain individual or group of individuals is designated as the inventor. Ordinarily, an owner (or "assignee") is also designated. This can be the inventor, especially if he or she is self-employed. Otherwise, it may be the employee's corporation that has the contractual right to the invention or the Government agency that supported the research at a university or in industry, or perhaps a financial backer to whom the inventor assigns the rights. The addresses of the inventor and the owner are both filed with the patent. The patenting by various foreign countries in various product fields is discussed in the chapter on International Science and Technology.

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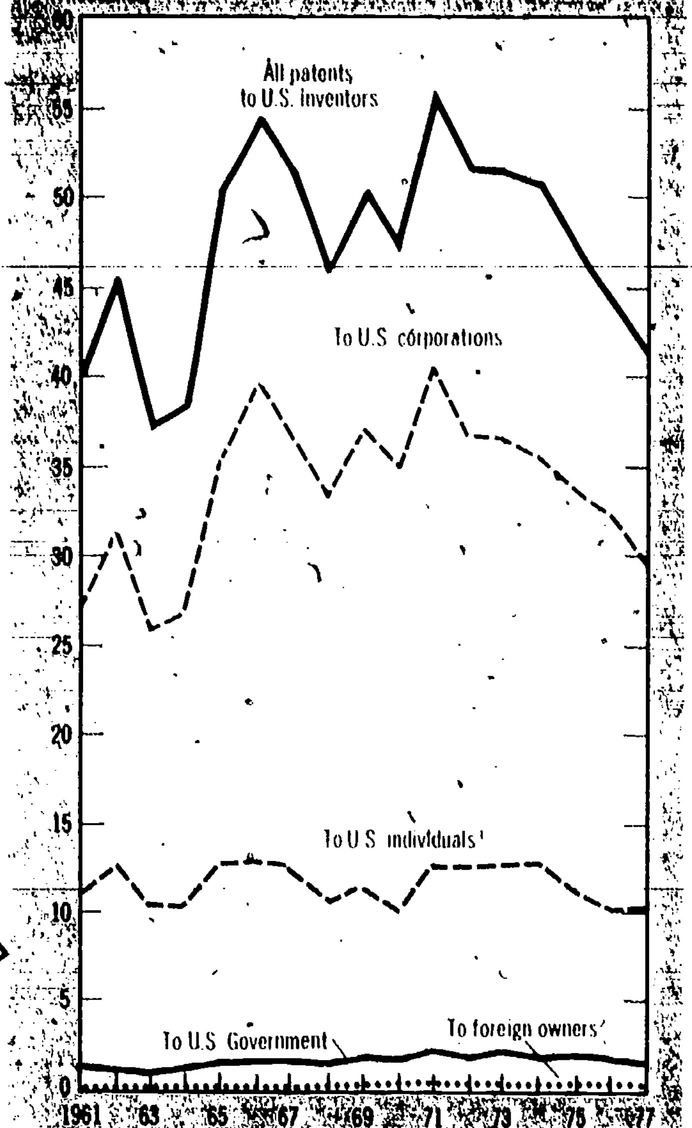
needed, or because lower profit margins have made it unattractive to expand product lines through new inventions. Another possible explanation is that industry has a large commitment in capital to existing products and processes and is not looking for ways to change them. Or, U.S. corporations may be less inclined to patent their inventions and may be depending more on trade secrets. Some industries may be controlling the costs of obtaining patents by screening patentable ideas more severely. If true, this would imply that the quality and economic promise of the inventions they do patent is increasing. However, these factors operate to different extents in the various product fields. Since the drop in patenting after 1971 is seen in almost all product fields,[74] it does not seem to be primarily attributable to any of these factors but may well indicate a decrease in the rate of production of inventions in U.S. industry.

Figure 4-12 shows the patents due to U.S. inventors, divided according to their owners or assignees.[75] In 1977, 71 percent of all patents were assigned to U.S. corporations.[76] The annual number of granted patents owned by corporations has been decreasing in recent years; it declined 27 percent from 1971 to 1977. Individual owners and the Government have not experienced the decline of patenting that occurred in corporate industry.

Figure 4-12
U.S. patents granted to U.S. inventors by type of owner and date of grant: 1961-77



¹Includes unassigned patents.
²Comprises patents assigned to foreign corporations, governments, and individuals.
REFERENCE: Appendix table 4-18.
Science Indicators—1978

Patent Grants by Field of Invention

The Patent Office has a classification system whereby any patent issued in the United States is placed within one of 95,000 possible classes on the basis of the type of device, material, or process that is being patented. In addition, each patent is cross-referenced to as many other Patent Office classes as are judged to be pertinent to the subject matter of the patent. The Patent Office classes correspond to structural elements of the devices and materials invented and to their process of preparation, regardless of the field of technology to which they apply. Hence, patent counts distributed according to this system are not suitable for the study of patenting activity in various areas of technology.

For this reason, the Patent Office, with NSF sponsorship, has developed a concordance that relates the Patent Office Classification (POC) system to the Standard Industrial Classification (SIC). The SIC is divided for this purpose into 55 technology groups, and each Patent Office class is

[74] U.S. Patent and Trademark Office, Office of Technology Assessment and Forecast, *Indicators of the Patent Output of U.S. Industry, III (1963-77)*, June 1978. There are some important exceptions, e.g., in the product fields related to chemicals, drugs, and aircraft.

[75] Some patents are assigned to owners after the grant date or are transferred from one owner to another. Such transactions are not captured in the present data. However, recent studies have shown that fewer than 1 percent of all patents change owners, and fewer than 3 percent of unassigned patents are later assigned. See J.F. O'Bryon, "A Profile of Users of the U.S. Patent System: 1968 and 1973," M.S. Dissertation, Massachusetts Institute of Technology, (unpublished), August 1975.

[76] This share was mainly composed of patents taken out by employees of those companies, but it also included some inventions created by private individuals and sold to corporations before the patents issued.

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correlated with one or more of these groups. An SIC group is assigned to a Patent Office class according to the judgment of Patent Office personnel as to the type of establishment that would be engaged in producing the product or apparatus encompassing the structural features represented by that patent classification or in carrying out the process steps included in the patent classification.[77] The classes of patents produced by this concordance correspond approximately to the product fields treated earlier in this chapter.[78]

The patenting in the various product fields can be studied in terms of the distribution of patent ownership. Corporations, private individuals, and the Government own different shares of the patents in the various fields because of important differences between the technologies themselves and between the objectives and capabilities of these three classes of owners. Patent counts by individual product field are described in table 4-8.[79] In the areas of highest corporate ownership, corporations hold nearly all the patents—over 90 percent. All five of the highest areas in 1977 are related to chemicals. Earlier in this chapter, it was noted that the chemical industry is particularly R&D-intensive, that it supports an exceptionally high level of basic research, and that applied

[77] *Technology Assessment and Forecast: 6th Report*, U.S. Patent and Trademark Office, Office of Technology Assessment and Forecast, 1976, p. 158.

[78] The concordance allots more than one SIC group to some Patent Office classes. The result is that when the concordance is applied to the patents granted in a certain year, some patents will fall into more than one SIC group, and thereby will be counted more than once. This multiple counting leads to difficulties when patent counts in SIC groups at lower levels of aggregation are added to make up a higher-level SIC group, or when the highest level SIC groups are combined to show the total patenting for some year. A patent can be counted more than once in the various subgroups, but in the higher level group it will be counted only once. Hence, such additions will not work in general.

[79] These data are obtained by applying the concordance to patent counts, distributed according to the Patent Office classification, in such a way that each patent is identified by its one principal POC class (its "original reference") only. It is also possible to count each patent under all of its cross-referenced POC classes. This method would lead to counts and distributions, in terms of the Standard Industrial Classification, slightly different from those in this chapter.

Table 4-8. Ownership of U.S. patents due to U.S. inventors, by product field: 1967 and 1977[1]

1967 Product field	Percent of patents in each product field	1977 Product field	Percent of patents in each product field
Highest share owned by U.S. corporations:		Highest share owned by U.S. corporations:	
Plastics materials and synthetic resins	94	Industrial organic chemicals	94
Industrial organic chemicals	92	Plastics materials and synthetic resins	93
Petroleum and natural gas extraction and petroleum refining	91	Agricultural chemicals	92
Drugs and medicines	90	Drugs and medicines	91
Soaps, detergents, and cleaning preparations, perfumes, cosmetics, and other toilet preparations	89	Soaps, detergents, and cleaning preparations, perfumes, cosmetics, and other toilet preparations	91
Highest share owned by U.S. Government:		Highest share owned by U.S. Government:	
Ordnance, except missiles	29	Ordnance, except missiles	36
Guided missiles and space vehicles and parts	19	Guided missiles and space vehicles and parts	18
Highest share owned by U.S. individuals:[2]		Highest share owned by U.S. individuals:[2]	
Ship and boat building and repairing	44	Ship and boat building and repairing	50
Farm and garden machinery and equipment	43	Aircraft and parts	44
Motor vehicles and motor vehicle equipment	38	Farm and garden machinery and equipment	43
Construction, mining, and material handling machinery and equipment	37	Engines and turbines	43
Aircraft and parts	36	Motor vehicles and motor vehicle equipment	40

[1]Date of patent grant.
[2]Includes unassigned patents.

REFERENCE: Appendix table 4-19.

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research and development in the chemicals product field receive an exceptionally high share of their support from industry rather than from the Government.

From 1967 to 1977, industry's share of patenting in agricultural chemicals increased, accompanying an increase in total patenting in this product field (see Appendix table 4-20). This may be due to the increasing importance of pre-emergence herbicides and growth regulators.

The fields of relatively low corporate ownership still show fairly high percentage levels of such ownership. The percentages dropped from 1967 to 1977, which is consistent with the overall decline in corporate ownership, as compared with the other sectors (table 4-8). These fields are related to machinery or transportation. The interest of the Government and individuals in patenting in these product areas is also shown in table 4-8.

Government ownership of U.S. patents shows an obvious concentration in military and space product fields that is consistent with the concentration of the Government's R&D support in these areas, seen earlier in this chapter (figure 4-10). Federal support for R&D is also high in the aircraft product field, although few of the resulting patents are granted to the Government.

Table 4-9 shows the product fields in which patenting has increased or decreased the most over the period from 1967 to 1977. For all product fields taken together, there was a 19-percent drop in patenting (Appendix table 4-20). However, a few fields showed substantial gains. These were in areas related to chemicals and to aircraft. Most of the large decreases were in areas related to electrical or nonelectrical machinery.

Table 4-9. Percent change in patent grants to U.S. inventors, for product fields with the greatest changes: 1967-77

Decreases of 30 percent or more	Percent
Household appliances	-39
Electrical industrial apparatus	-38
Primary ferrous products	-37
Electrical transmission and distribution equipment	-34
Refrigeration and service industry machinery	-34
Guided missiles and space vehicles and parts	-32
General industrial machinery and equipment	-31
Special industry machinery	-30
Increases of 30 percent or more	**Percent**
Agricultural chemicals	79
Drugs and medicines	64
Paints, varnishes, lacquers, enamels, and allied products	32
Aircraft and parts	36

REFERENCE: Appendix table 4-20.

Overview

A number of investigators have shown that patent counts are useful in the study of individual industries. An especially important study related patented inventions to capital goods output and thereby argued that inventive activity in some industries is demand-induced. Some considerations limit the utility of patent counts as output indicators. Individual patents vary greatly in their technical and economic significance. Much of the R&D supported by the Government does not lead to patents, and many of the patents that do result are never worked commercially.

The number of patents granted annually to American inventors generally increased from 1960 to the early 1970's, but showed a steady decline from 1971 to 1977. This decline was in patents owned by U.S. corporations and seems to indicate an actual decrease in the rate in which these corporations are producing inventions. However, patents owned by the U.S. Government and U.S. individuals did not decrease in number. The drop in U.S. corporate inventions may be due to inventions created in the 1960's that have not yet been exploited commercially and constitute a backlog that makes new inventions less attractive. A large commitment of capital to existing products and processes may also reduce interest in new inventions. Reliance on trade secrets, which the patent data would not show, may be increasing. However, the wholesale decrease in corporate patenting across almost all product fields suggests a genuine decline in industry's production of inventions during the 1970's.

U.S. corporations hold the major share of all U.S. patents and are particularly dominant in the chemical technologies. These technologies require particularly high levels of investment and technical ability in order to produce new inventions. They are also technical areas in which high levels of corporate basic research produce results that are moved along through company-supported applied research and development to commercial application. Government-owned patents are mainly in ordnance and space technology.

ERIC

EFFECTS OF R&D FUNDING

The economic returns from industrial R&D and innovation are important enough to be treated in a chapter on industrial R&D even though, in the present state of knowledge, very few quantitative indicators can be presented. In place of a set of indicators, the results reported in the most recent literature will be summarized. The economic and social results of industrial R&D are important because, in principle, they should provide the ultimate output indicators. The U.S. R&D enterprise benefits the public in part by way of the technological improvements that it promotes in U.S. industry. Output indicators are needed to measure not only these technical improvements but, beyond these, the economic and other benefits they bring to society. Some work has been done on the rate of production of technological innovations in industry as an indicator of the output of industrial R&D.[80] The economic benefits are discussed below. The noneconomic benefits to the public present an especially difficult problem. They have not yet been defined adequately, and no satisfactory method of measurement currently exists.

Recent research has reinforced earlier findings that the contribution of R&D to economic growth and productivity is high. In addition, the research on industrial R&D suggests the contributions differ by industry and by source of funding (e.g., Government versus private). Also, the research shows that the economic benefits to society exceed substantially the returns received by the firms producing the R&D outputs. However, many problems remain in measurement and modeling.[81]

A well-known investigation of long-term U.S. economic performance has indicated that about 34 percent of measurable U.S. economic growth between 1948 and 1969 derived from advances in knowledge.[82] This computation does not take into account improvements not measured by national income accounting techniques. Examples of these exclusions are major qualitative changes in products (e.g., computer performance) or developments of new forms of business organization (e.g., self-service stores and super markets in retail trade).

A recent study of selected U.S. industries shows a strong association between the ratios of their R&D spending to sales and their growth of labor productivity and output. The results of that study (table 4-10) show that industries that have high R&D-to-sales ratios (e.g., chemicals, electrical machinery) experience substantially higher growth of productivity and output than industries that have low ratios (e.g., textiles).[83] In addition, other empirical research studies have demonstrated substantial increases in output associated with expenditures for R&D after allowing for increased inputs of labor and

[80] See *Science Indicators—1976*, National Science Board (NSB 77-1), pp. 115-125.

[81] For a general review of this problem and of attempted solutions, see M.G. Boylan, "The Sources of Technical Innovations," in Bela Gold (ed.), *Research, Technological Change, and Economic Analysis* (Lexington, Mass.: Lexington Books, 1976).

[82] Edward F. Denison, *Accounting for United States Economic Growth, 1929-1969* (Washington, D.C.: The Brookings Institution, 1974), p. 128. Elsewhere it has been estimated that technological innovation was responsible for 45 percent of the Nation's economic growth between 1929 and 1969. See B. Ancker-Johnson and D.B. Chang, *U.S. Technology Policy: A Draft Study*, U.S. Department of Commerce, March 1977.

[83] However, such studies cannot demonstrate that high ratios of R&D expenditures to sales cause these benefits.

[illegible]

capital.[84] These studies show $30 to $50 increases in annual output associated with a $100 investment in R&D. These findings come from studies of chemicals, petroleum refining, and agriculture.

Other studies of individual product and process innovations indicate a high, but highly variable, average return from the development of new or improved technologies by firms. Results from a number of recent attempts to measure the returns to the innovating firms from their expenditures to develop new or improved products or processes show that, on the average, firms earned 25- to 35-percent returns for each sample of such investments studied.[85] These rates of earnings are higher than average rates of returns from other types of investment outlay. However, the results of the available studies also show that in a substantial fraction of the cases studied the firms earned little or no return from their investment in technological innovation. This high variability in returns suggests a large degree of uncertainty in predicting the likely profitability of investment in R&D.

Investments in R&D not only result in greater productivity and output for the firms developing the new or improved technology, but for the buyers as well. This diffusion of benefits has been noted especially for machinery (e.g., computers, electrical generating equipment) and for materials (e.g., plastics) or components (e.g., semiconductors). One recent attempt to quantify these benefits estimated that for manufacturing during the 1960's, the average productivity returns to R&D conducted in an industry amounted to about 30 percent per year; the benefits accruing to firms purchasing from the producers of technological innovations were about 50 percent.[86] Another study of 17 modest technological innovations showed that more than half of the measurable economic returns from these innovations went to the buyers and users.[87]

All of the above findings relate to spending by private firms and do not include Government expenditures for R&D. Estimates of returns from Government-funded R&D are generally unreliable and have not produced acceptable statistically significant results.[88] One major difficulty in attempting to assess such a relationship is that Federal R&D spending is concentrated in industries whose products are subject to a high rate of technological change which is difficult to measure. Another is that there is generally no competitive market price by which to measure the value of the products resulting from Government R&D.

There are a number of difficulties in obtaining a more precise measurement of the contribution of R&D and technological innovation to economic progress. Since it is currently impossible to measure fully changes in the quality of goods and services produced, there is no way to assess properly the influence of new or improved technology on quality. However, there is good reason to believe that if qualitative factors were included, the measured returns would be higher.[89] Second, there is the problem of tracing the technology's contribution to economic progress. Bringing out new or improved products and production processes involves a number of complex, interrelated tasks. Third, there is a lack of information and technique to measure, assess, and properly adjust productivity figures for the change in the level of harmful byproducts of technology that result from R&D activity.

Thus, there is persuasive empirical evidence (although surrounded by significant limitations) that R&D and technological innovation have had a significant positive effect on economic growth and productivity increase in the United States.

[84] For a summary and assessment of these studies, see *Research and Development and Economic Growth/Productivity; Papers and Proceedings of a Colloquium*, National Science Foundation (NSF 72-303).

[85] Edwin Mansfield, *et al.*, "Social and Private Rates of Return from Industrial Innovations," *Quarterly Journal of Economics*, vol. 91 (May 1977), pp. 221-240; Grabowski and Mueller, "Rates of Return on Corporate Investment," 1974 (unpublished manuscript); James Tewskbury, *et al.*, *Net Rates of Return on Innovations* (Washington, D.C.: Foster Associates, Inc., 1978), John Beyer, *et al.*, *Net Rates of Return on Innovations*, (Washington, D.C.: Robert R. Nathan Associates, Inc., 1978).

[86] Nestor E. Terleckyj, "Effects of R&D on the Productivity Growth of Industries: An Exploratory Study," (Washington, D.C.: National Planning Association, 1974).

[87] Edwin Mansfield, *et al.*, "Social and Private Rates of Return from Industrial Innovations," *Quarterly Journal of Economics*, vol. 91 (May 1977), pp. 221-240.

[88] Michael Evans, *The Economic Impact of NASA R&D Spending*, (Bala Cynwyd, Pa.: Chase Econometric Associates, 1976); *NASA Report May Overstate the Economic Benefits of Research and Development Spending*, U.S. General Accounting Office, October 1977; Zvi Griliches, "Returns to Research and Development Expenditures in the Private Sector," paper presented at the Conference on Research in Income and Wealth, National Bureau of Economic Research, Washington, D.C., 1975.

[89] For a summary and assessment of these studies, see *Research and Development and Economic Growth/Productivity, Papers and Proceedings of a Colloquium*, National Science Foundation (NSF 72-303), p. 3.

Chapter 5

Science and Engineering Personnel

ERIC

Scientific and Engineering Personnel

INDICATOR HIGHLIGHTS

- The utilization level of scientists and engineers (S/E's) is improving when compared with the growth of total U.S. employment and the level of economic activity. (See pp. 112-113.)
- As the economy recovered from a recession between 1974 and 1976, employment of S/E's increased at a faster rate than general economic activity or total employment. In contrast, over the 1970-74 period, employment of S/E's grew more slowly than general economic indicators. (See p. 113.)
- About three-fifths of all S/E's were employed in private industry in 1976. However, a declining ratio of S/E's to total support staff in selected industries suggests that the relative need for S/E's in these industries may be declining. (See pp. 113-114.)
- Available labor market indicators suggest that the supply of scientists is more than ample to satisfy the current demand in most occupational fields and that the demand for engineers is in rough balance with the available supply. (See pp. 118-123.)
- Projections developed by the National Science Foundation and others indicate that the supply of S/E's in most fields will be more than adequate to meet anticipated demands through the 1980's. (See pp. 123-125.)
- Questions have recently been raised concerning a decline in the quality of the S/E work force. These questions are difficult to answer, since there are no direct measures of work force quality. However, two related measures suggest that the quality of S/E's has not decreased; experienced S/E's continue an undiminished participation in training programs; and test scores for prospective S/E graduate students on both the verbal and quantitative components of the Graduate Record Examination remain high and unchanged, both absolutely and relative to nonscience fields. (See pp. 125-129.)
- Recent employment of doctoral level S/E's has increased at a faster rate than total S/E employment, and by this measure the quality of the S/E work force is increasing. (See p. 126.)
- In the context of science and engineering markets, equity can be interpreted with respect to employment and salary practices for individuals of comparable skills. Disparities in labor market variables between men and women, and between racial minorities and others, can be indicators of inequity. However, such indicators alone may not be sufficient to warrant the inference of inequity because these disparities may also be due to differences in occupational preferences, age, work experience, and other such factors. (See pp. 129-130.)
- Although the employment of women in science and engineering has been increasing at a fairly rapid rate (12 percent between 1974 and 1976 compared to a 5 percent increase for men), women are still underrepresented in science and engineering. While women constituted about 8 percent of all employed S/E's in 1976 (197,200), about 40 percent of all employed persons were women. (See p. 131.)
- Both the number and proportion of women receiving degrees in science and engineering have increased significantly. At the doctoral level, the number of degrees in science and engineering awarded to women increased by about 90 percent (about 1,500) between 1970 and 1977, and almost 20 percent (about 500) between 1974 and 1977. Among men, the number of degrees awarded declined by 11 percent (about 1,800) over the 1970-77 period, and about 9 percent (almost 1,500) between 1974 and 1977. (See pp. 133-134.)
- The number of employed minority group members in science and engineering (98,200) represented 4.1 percent of the total in 1976. Over 40 percent of the employed S/E minorities were of Asian extraction, with blacks representing an additional 34 percent. Since 1976, however, minorities have continued to be underrepresented in science and engineering; about 11 percent of all employed persons are members of racial minority groups. (See pp. 134-136.)

- Employment of minorities in science and engineering has been increasing at a faster rate than for whites. Among doctoral level S/E's, for example, employment of blacks increased by 35 percent (up 700) between 1973 and 1977, while the increase for those of Asian extraction was about 70 percent, or 6,300. The comparable increase for whites was 26 percent, or 52,600. (See pp. 135-136.)

- Blacks continue to be underrepresented in science and engineering, since in 1976 they represented about 9 percent of all employed persons but only about 1.4 percent (33,000) of the employed doctoral-level scientists and engineers. (See Appendix table 5-32.)

Scientists and engineers carry out many functions vital to the progress of science and technology. They conduct R&D, instruct and train the Nation's future scientists and engineers, contribute to solutions of social problems, and play a significant economic role by contributing to increases in productivity, technological innovation, and the value of goods and services.

This chapter contains three major themes: (1) the current and future supply and utilization of S/E's, (2) the quality of the S/E work force, and (3) the roles accorded women and minorities in the composition of the S/E population.

Exploration of this chapter's first theme requires indicators for assessing the adequacy of the current and projected supply and utilization of S/E's. But adequacy is a difficult concept to determine quantitatively since no single standard defines an adequate level for the utilization of S/E's to meet the needs of science or of society. However, the number, distribution, and employment of S/E's and changes over time in these measures can be compared with selected normative values and used as indicators of the adequacy of the current levels. Unemployment rates, the experience of recent S/E graduates, relative salaries, and other labor market variables can indicate the degree of balance between the current S/E supply and demand for its services. Projections from NSF and others address questions relating to the adequacy of the future supply of S/E's.

Recent questions have arisen about possible declines in the quality of the S/E work force, owing to its rapid growth and changing career decisions on the part of students. This issue is also complex and difficult to assess quantitatively. However, some measures that can assist in assessing changes in quality are trends in the proportion of doctoral level S/E's in the labor force, aptitude test scores of prospective graduate students in science and engineering, and trends in the continuing education of S/E's.

Related to this second theme is the status of young investigators, both at educational institutions and in industry, because the continued vitality of science depends ultimately on the infusion of new personnel.

Increasing attention is being focused on equity concerning the participation of women and minorities in science and engineering. Comparisons between men and women and between majority and minority groups place the roles of women and minorities in perspective and provide information with which to assess progress toward achieving greater equity.

The interpretation of the statistical indicators used in this chapter has some limitations. For example, one cannot always infer causal relationships from observed statistical associations. To illustrate, if one observes a disparity in average wage rates between employed males and females, one cannot assume that the disparity is necessarily due to sex discrimination. Similarly, while wages are influenced by the interaction of market forces (i.e., personnel requirements on the one hand and the available supply of personnel on the other), wages, in turn, influence both the magnitude of the supply and the extent of the utilization of manpower. These limitations suggest that care should be exercised in drawing conclusions from these indicators. However, the data presented here do illuminate the current status of scientists and engineers and suggest future changes.

Differences in concepts, data collection techniques, and statistical reporting procedures exist for some of the statistics presented in this chapter. For example, some statistics on S/E's engaged in R&D are reported in terms of the primary work activity of the individual scientists (that activity in which the individual spends the greatest proportion of work time). Studies suggest, however, that the concept of primary work activity understates the numbers in R&D since S/E's at universities and colleges may have teaching as their primary work activity and research as a secondary activity. Readers wishing to understand the indicators and their limitations more fully are urged to consult the primary data sources listed in the appropriate references and Appendix tables. Finally, no single indicator can adequately describe the current status or even a major aspect of the S/E personnel scene. Thus, conclusions should generally not be based on single indicators, but rather on a series of indicators grouped under each major theme.

Estimates of the number of scientists and engineers in the United States are derived by integrating elements from several sources representing the following three groups:

> Group 1—Experienced scientists and engineers (excluding holders of doctorates), defined, first, as having worked as a scientist or engineer or in a related occupation, at the time of the 1970 Decennial Census of Population; second, must have passed two of the following three criteria to have been included in estimates subsequent to 1970: (a) occupation in science or engineering, (b) highest degree held in science or engineering, (c) professional identification as scientist or engineer.
>
> Group 2—New entrants to science and engineering, defined as having received, after 1970, a master's degree in mathematics, biological science, psychology, economics, sociology, or other social science; or held a bachelor's degree in any of these fields and was employed in S/E; or held a baccalaureate in any of the other S/E fields.
>
> Group 3—Doctoral scientists and engineers, defined as having received a doctorate in science or engineering, or having received a doctorate in non-S/E fields but employed in an S/E position.

SUPPLY AND UTILIZATION

This section deals with the current utilization of scientists and engineers, and the projected utilization and supply of scientists and engineers.

Several indicators can be used to assess, in normative terms, the adequacy of current utilization patterns of S/E's. These include comparisons of S/E employment with the growth of total U.S. employment and economic activity, the priority of scientific and technical activities in industry as measured by the ratios of S/E's to total industrial support staff, and the work activities of S/E's—especially data on the number and proportion engaged in R&D and the number working outside of science and engineering. The indicators do not include an assessment of the level of scientific and technical (S&T) activity because there is no consensus on what constitutes an adequate level of such activity. In principle, the current S/E workforce probably is not adequate, since there are many worthwhile S&T activities that could be carried out if both the financial and the personnel resources were available.

Assessment of the current supply of scientists and engineers can be based on such empirical evidence as unemployment rates, while projections of the future supply of S/E's are related to anticipated requirements.

The following indicators suggest that S/E utilization is rising vis a vis total U.S. employment and total economic activity. The employment of S/E's in R&D, however, has not kept pace with the increases in total S/E employment. Private industry seems to be devoting a declining proportion of its human resources to scientific and technological activities. It appears that the current number of scientists is more than adequate to meet demand, but that requirements for engineers equal, or exceed somewhat, the current supply. NSF and others project that the aggregate future supply of S/E's will generally be adequate to meet anticipated requirements through the 1980's.

Comparisons of S/E employment with other employment trends and with changes in national economic indicators are useful in that they can reflect whether de facto national priorities are changing. However, such comparisons cannot determine whether national priorities are "correct." If S/E employment increases less rapidly than total employment or other economic indicators, the comparison suggests that society is giving higher priority to nonscientific activities at the expense of scientific ones. If S/E employment increases less rapidly than national economic indicators, a possible explanation to be explored is whether or not the productivity of scientific and engineering work is increasing.

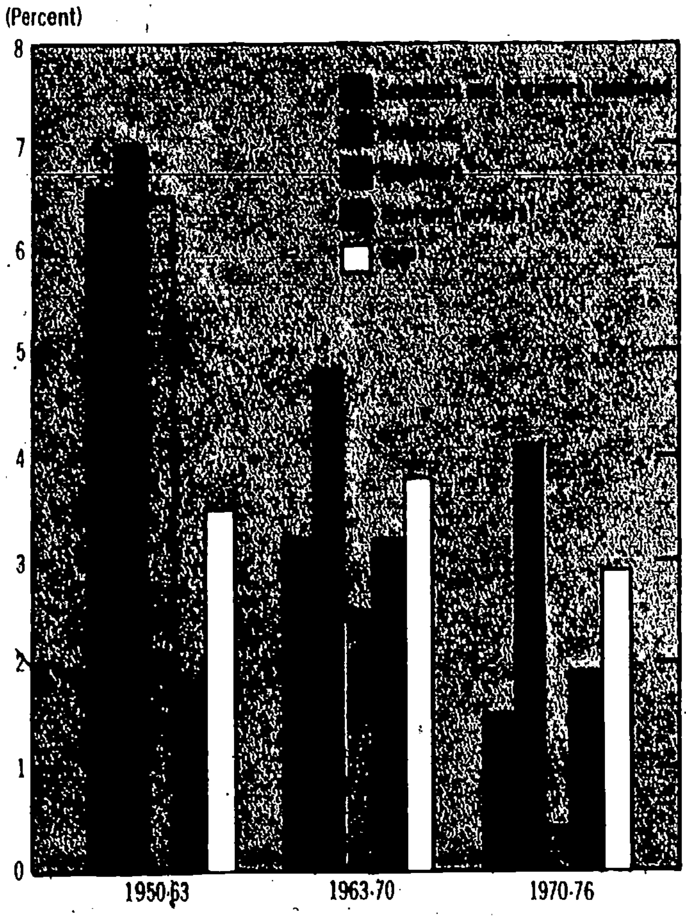
Growth in S/E Employment

From 1970 to 1976, employment of scientists and engineers grew at about the same rate as overall economic activity and more rapidly than total employment. During this period, employment of S/E's increased at an average annual rate of 2.7 percent (6.2 percent for scientists and 0.4 percent for engineers), while total employment increased only 1.9 percent per year. Real gross national product—another indicator of overall economic activity—increased at an average annual rate of 2.9 percent (figure 5-1). The relatively rapid growth in scientific employment was strongly influenced by the rapid growth in employment of social scientists (including psychologists) and of computer specialists; these two groups accounted for approximately 60 percent of the growth in scientific employment over the 1970-76 period.

Excluding the social scientists and computer specialists, scientific employment increased at an average annual rate of 4.1 percent, while combined S/E employment inceased by 1.5 percent per year. This combined scientist and engineer employment growth rate is below those recorded for total employment and overall economic activity over the 1970-77 period.

Figure 5-1

Average annual percent increases in science and engineering employment and in other economic and manpower variables: 1950-76



[1] Excludes data for psychologists, social scientists, and computer specialists.
[2] Nonfarm wage and salary workers.
[3] Gross national product (in constant 1972 dollars).
REFERENCE: Appendix table 5-1.

Science Indicators—1978

Employment of S/E's reached almost 2.4 million in 1976, about 5.7 percent above 1974 levels[1] (see Appendix table 5-2). Scientific employment in this period grew significantly faster than engineering employment, 9.7 percent and 2.3 percent, respectively, continuing a general trend since the 1950's. The slower growth of the number of engineers employed, compared to scientists, largely reflects relatively slow growth or declines in those industries employing significant numbers of engineers.[2] Employment increases for S/E's between 1974 and 1976 reflect primarily the economic recovery that started in 1975. However, the fact that R&D funding in 1976 (as measured in constant dollars) was slightly above 1974 levels probably also contributed to the employment gains.[3] More recent data suggest that a turning point may have been reached for engineers, since the employment of engineers increased by 6 percent between 1976 and 1977.[4]

Not all fields of science shared equally in the recent overall growth in employment (see figure 5-2). Physical and life scientists, who constitute about 45 percent of all scientists, contributed almost 65 percent of the total growth in science employment betwen 1975 and 1976.

Priority of Scientific and Technical Activities in Industry

Private industry, the sector employing by far the largest number of S/E's in the U.S. economy, accounts for three-fifths of all persons working in science and engineering. Of these, about 7 out of every 10 are engineers. Available data indicate that since 1967, nontechnical activities[5] have been growing at a faster rate than technical activities. This conclusion is based on comparisons between employment of S/E's[6] and total employment of persons not directly engaged in

[1] Scientist and engineer population and employment estimates for 1974 have been revised substantially from those appearing in earlier editions of *Science Indicators* reports.

[2] See, for example, various issues of *Employment and Earnings*, U.S. Department of Labor, for trends in industrial employment. Information on engineering employment, by industry, can be found in "Scientific and Technical Personnel in Private Industry, 1960-70 and 1975," *Reviews of Data on Science Resources*, National Science Foundation (NSF 78-302), p. 9.

[3] *National Patterns of R&D Resources, 1953-1978-79*, National Science Foundation (NSF 78-313), p. 36.

[4] *Employment and Training Report of the President*, U.S. Department of Labor, 1978, p. 230.

[5] Nontechnical activities include management, sales, accounting, clerical, and similar functions.

[6] Excluding social scientists and psychologists, for whom data are unavailable.

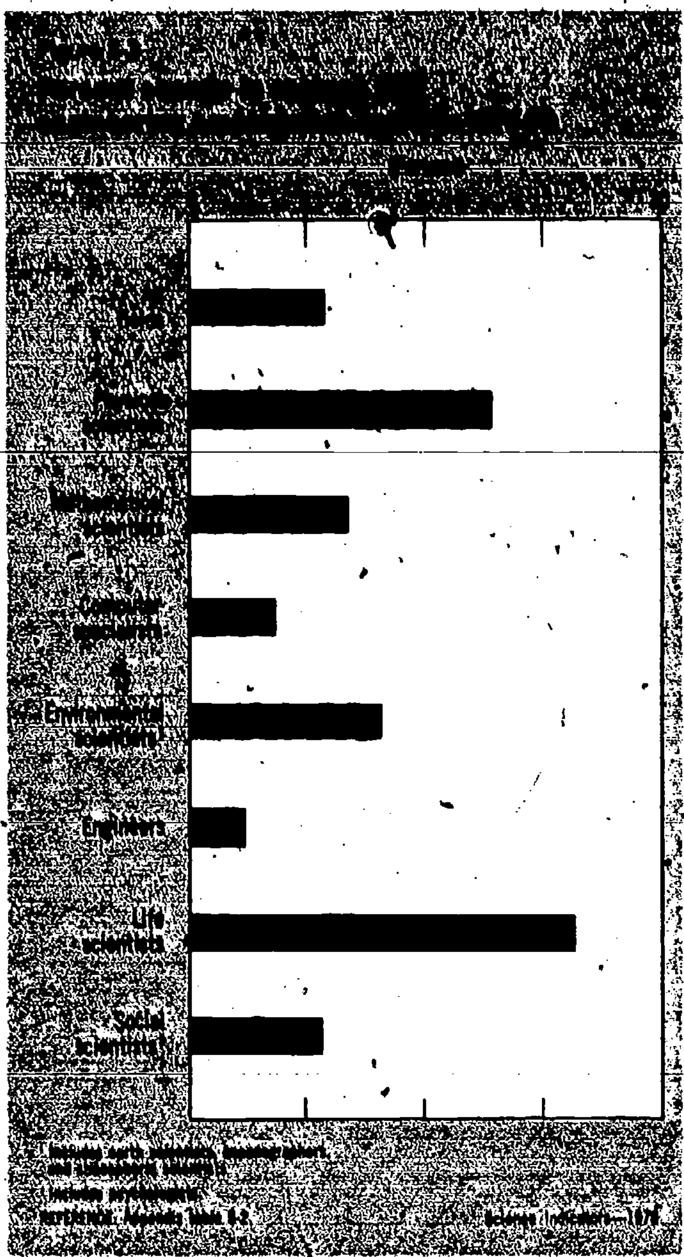
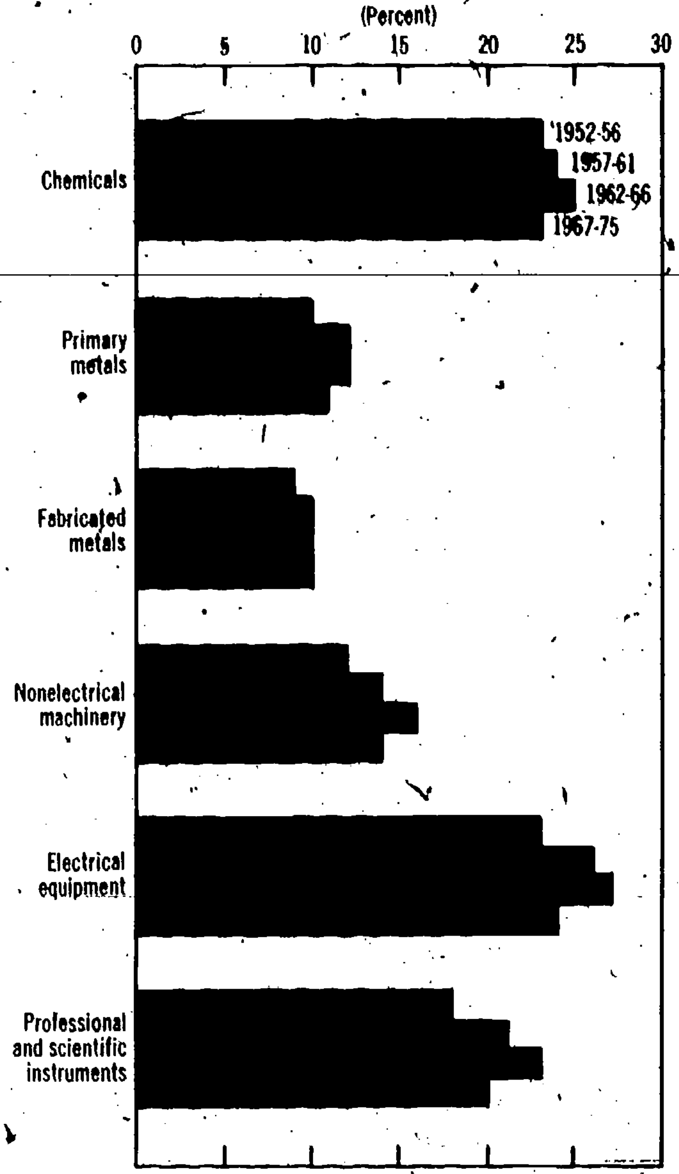


Figure 5-3

Employment of scientists and engineers as an average percent of total nonproduction workers, for selected industries: 1952-75



REFERENCE Appendix table 5 3 Science Indicators—1978

production work in six industries that are major employers of S/E personnel, and for which consistent estimates are available over time (see figure 5-3). In each industry except fabricated metals, the proportion of scientists and engineers showed a significant increase through the mid-1960's, after which each industry showed a decline to 1975. Thus the number of employed S/E's, while generally increasing for these industries, apparently is not growing as rapidly as the support staff, and more resources are going for nontechnical activities and relatively less for technical endeavors. This trend could have negative consequences since S/E's contribute significantly to general economic growth and to increases in productivity in the U.S. economy.

Activities of Scientists and Engineers

The work being done by scientists and engineers, including the number, proportion, and distribution of those doing R&D, indicates the level of current science and technology activities. The number of R&D personnel may be a leading indicator of the Nation's overall science and technology effort that depends heavily on innovation which, in turn, is frequently based on R&D. Another indicator of current effort is the proportion of employed scientists and engineers holding jobs outside of science and engineering fields. A growth in this proportion may indicate that the Nation is not adequately utilizing these highly trained personnel. On the other hand, the activities of these S/E's outside of science and engineering may be productive from a social viewpoint, resulting in no social loss but a loss to science and technology.

R&D Activities. Although FTE (full-time-equivalent) employment of S/E's in R&D has increased each year since 1973, the 1969 level was not exceeded until 1977 when a new high of 571,000 was reached (see figure 5-4). Between 1974 and 1976, FTE employment of S/E's in R&D increased by almost 5 percent, while total S/E employment grew by 5.7 percent.[7] Thus, the proportion of S/E's in R&D declined slightly between 1974 and 1976.

Work Activities of Doctoral-Level Scientists and Engineers. The professional work activities of all S/E's can indicate the human resources input to the American scientific and technical enterprise; yet the work activities of S/E doctorate holders are of special interest, because doctoral-level S/E's provide much of the leadership in scientific endeavors.

The work patterns of doctoral S/E's are undergoing change (figure 5-5), but these overall patterns differ significantly among employment sectors.[8] In educational institutions, there has been a relative decline in teaching activities, with corresponding gains in R&D and other activities. In contrast, other employment sectors have seen

[7] *Detailed Statistical Tables. U.S. Scientists and Engineers: 1976*, National Science Foundation (NSF 79-305), pp. 33, 50.

[8] "Work Activities of Doctoral Scientists and Engineers Show Substantial Change Between 1973 and 1977," *Science Resources Studies Highlights*, National Science Foundation (NSF 78-316).

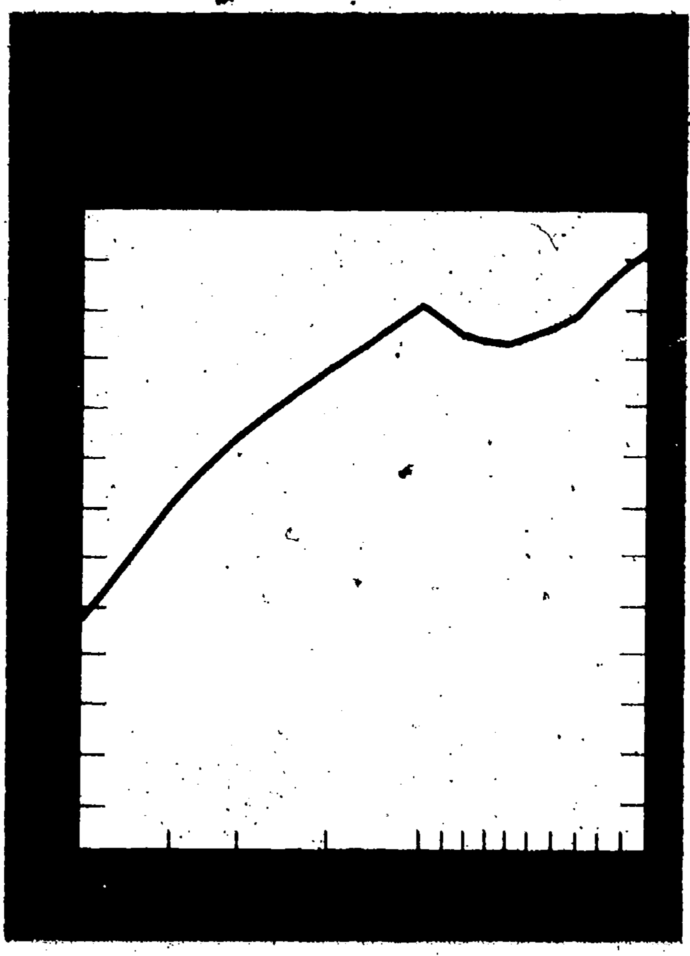
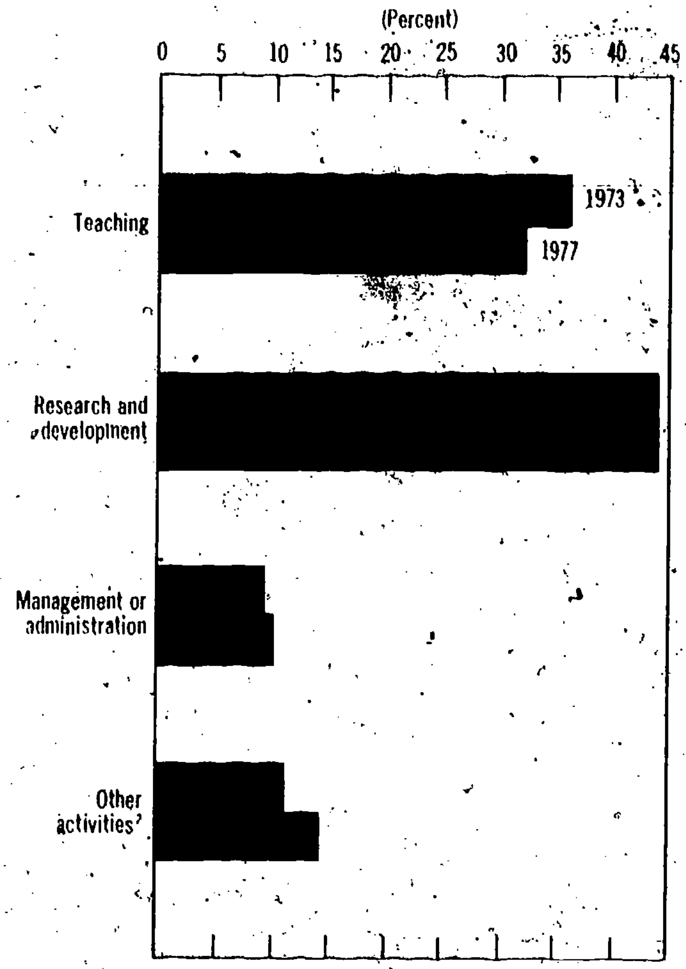


Figure 5-5

Distribution of employed doctoral scientists and engineers by primary work activity:[1] 1973 and 1977



[1] Primary work activity is defined as that type of work occupying the largest portion of time

[2] Includes consulting, sales, and other professional service activities

REFERENCE Appendix table 5-5 Science Indicators 1978 a relative shift from R&D to non-R&D work activities. These shifts are somewhat compensatory, so that the overall proportion of doctoral S/E's primary engaged in R&D activities remained stable between 1973 and 1977.

Although the proportion of doctoral-level S/E's primarily engaged in R&D remained constant, some changes did occur in the character of the R&D work over the 1973-77 period (see text table 5-1). The number of doctoral S/E's in development activities increased at a substantially greater rate than that for basic and applied research (59 percent between 1973 and 1977 for development, compared to 27 percent each for basic and applied research). To some extent, this shift to development reflects the growing number of doctoral-level S/E's in private industry, where development activities predominate.

The amount of R&D participation by the growing work force of doctoral-level S/E's assumes added significance when R&D expenditures during this 4-year time frame are examined. Thus, while the number of doctoral S/E's primarily engaged in all aspects of R&D work increased substantially, R&D expenditures in constant dollars showed much smaller increases between 1973 and 1977.[9] Also, between 1973 and 1977, the number of full-time-equivalent scientists and engineers in R&D, at all degree levels, increased by about 10 percent, a growth rate considerably below that of doctoral-level S/E's in R&D. The increasing participation of this level of S/E's in R&D suggests that employers are enriching their R&D staff by taking advantage of the greater availability of S/E's holding the doctorate.

The number of employed doctoral-level S/E's in the United States increased by 29 percent between 1973 and 1977. This overall increase was accompanied by little change in the distribution among types of employers (see Appendix table 5-6). Educational institutions continued to provide the greatest number of jobs for doctoral S/E's (see figure 5-6). However, the proportion of these S/E's shifted slightly from academic to nonacademic employment over the 1973-77 period. Small incremental changes in the proportion of S/E's in different employing sectors may be significant, inasmuch as a fairly substantial absolute change is required to affect proportions in the short run.

As would be expected, the movement into nonacademic employment was most noticeable among new doctoral recipients. For example, while about one out of six new S/E doctorates of the 1972 class obtained industrial employment, this ratio rose to about one out of five for the 1976 class. About 70 percent of the new 1976 doctoral recipients who entered industrial employment were involved primarily in R&D activities. However, the proportion of all industrially employed, doctoral-level S/E's engaged in R&D declined from 71 percent in 1973 to 66 percent in 1977.[10] The largest component of this decline was

[9] During the period, total R&D expenditures increased by 5 percent, as did basic research expenditures. *National Patterns of R&D Resources. 1953-1978-79,* National Science Foundation (NSF 78-313), pp. 36, 38.

[10] "Work Activities of Doctoral Scientists and Engineers Show Substantial Change between 1973 and 1977," *Science Resources Studies Highlights,* National Science Foundation (NSF 78-316).

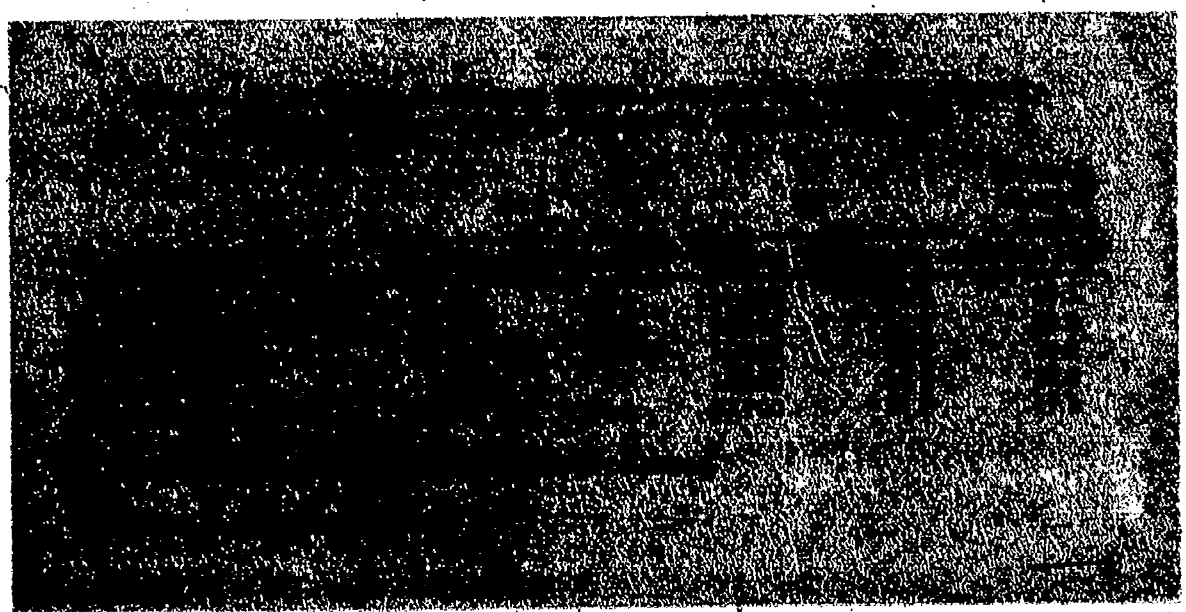
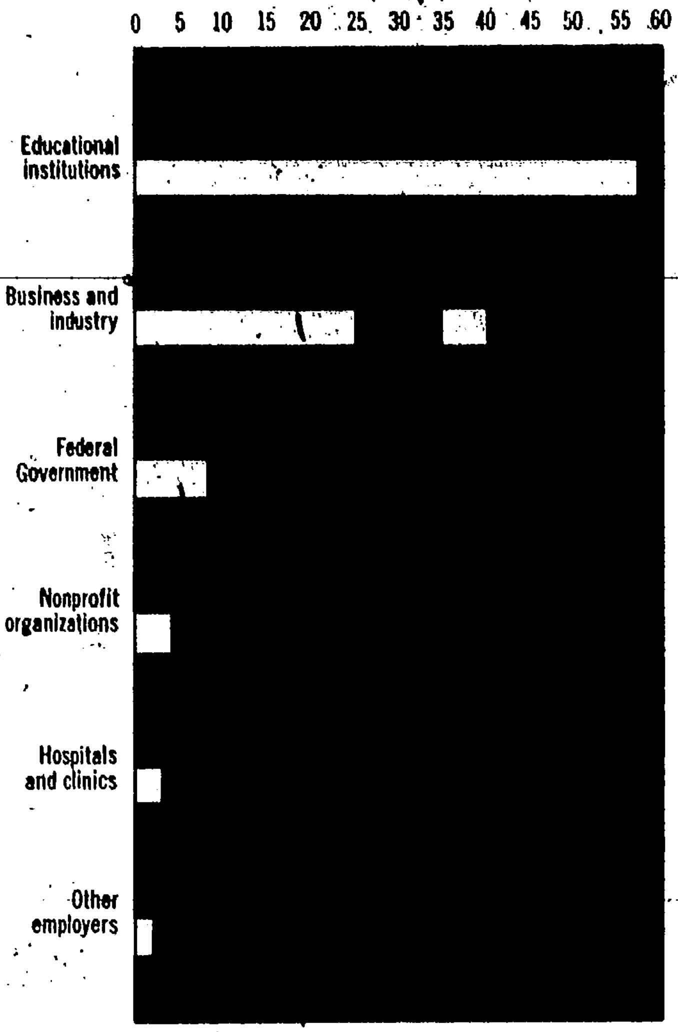


Figure 5-6

Distribution of doctoral scientists and engineers by type of employer: 1973 and 1977



REFERENCE: Appendix table 5-6. Science Indicators—1978

the management of R&D. The proportion primarily engaged in the management of non-R&D activities and sales/professional services increased substantially.[11] These changes suggest that in industry, new doctoral-level S/E's are relatively more active in R&D than their more senior colleagues, who are moving out of R&D activities. The increased hiring of young doctorates by industry has not produced any significant problems in underutilization as judged by some employers,[12] according to NSF's Industrial Panel on Science and Technology.

Is the shift in the proportion of doctoral-level S/E's, especially new degree recipients, from academia to other employing sectors good from a national point of view? The answer depends, in part, upon shifts in the work activities of these S/E's. Within R&D, for example, applied research and development predominate in industry, whereas basic research predominates in universities and colleges.

S/E's Working Outside S/E Fields. Not all employed S/E's are working in science and engineering jobs. For many reasons, some take jobs not only outside their fields of training, but also outside of science and engineering altogether. Of the S/E's employed in 1976, 12 percent reported that they were in non-S/E jobs. By field, the proportion in non-S/E jobs ranged from about 3 percent of the mathematical scientists to 30 percent of the environmental scientists (see figure 5-7). Some S/E's choose to work in non-S/E jobs, for higher pay or for other personal reasons. For example, only about 10 percent of those experienced S/E's who were in the labor force in 1970 and who were in non-S/E jobs in 1976 indicated that they believed that S/E jobs were not available. About three-fifths, on the other hand, indicated they were in non-S/E jobs because of personal preference, promotions, or higher pay. The proportion of the experienced S/E's "involuntarily" employed outside of science and engineering varies somewhat by field (see text table 5-2).

As might be expected, employment outside of science and engineering occurred to a lesser extent among S/E's holding the doctorate than among all employed S/E's. In 1977, about 8 percent of the employed doctoral-level S/E's were in nonscience jobs, up from about 5.5 percent in 1973.[13] Fields with an above-average proportion of S/E's in nonscience jobs in both 1973 and 1977 include the physical and social sciences.[14] Physical and social scientists represented about 55 percent of all doctoral-level S/E's employed in nonscience

[11] *Detailed Statistical Tables, Characteristics of Doctoral Scientists and Engineers in the United States, 1977*, National Science Foundation (NSF 79-306), p. 5.

[12] "Utilization of Science and Engineering Doctorates in Industrial Research and Development," *Science Resources Studies Highlights*, National Science Foundation (NSF 78-301).

[13] "Work Activities of Doctoral Scientists and Engineers Show Substantial Change between 1973 and 1977," *Science Resources Studies Highlights*, National Science Foundation (NSF 78-316).

[14] *Characteristics of Doctoral Scientists and Engineers in the United States, 1973*, Appendix B, National Science Foundation (NSF 75-312-A), pp. 14, 23.

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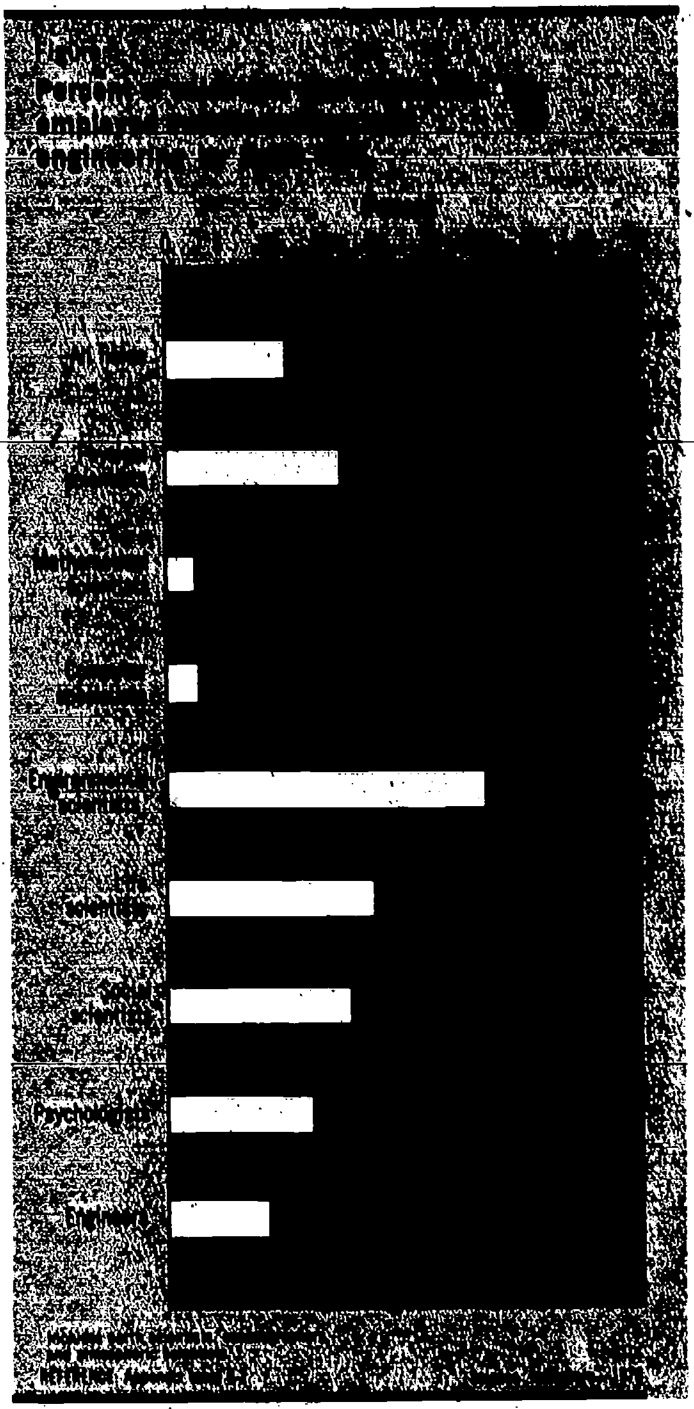


jobs in 1977, but they accounted for only about 35 percent of all employed doctoral-level S/E's.[15]

The Current Supply of Scientists and Engineers.

Recent concern about the lack of suitable job opportunities and past concerns about shortages of scientists and engineers suggests a need for indicators for assessing the supply/demand balance. Such assessment depends on several factors, including the perspective of those concerned with the condition (employers, the Government, and individual scientists and engineers); the definitions used; and the methods used in the assessment analyses.[16]

The work "shortage" requires careful consideration. Some would say that there is a shortage of S/E's if the number available for employment is less than the number required to meet some social goals. From an economic viewpoint, however, this definition is not viable, because there is no demand unless employers are willing to pay for the services of as many S/E's as are needed to meet such social goals. A more realistic definition of an S/E shortage is that the quantity demanded at prevailing salaries exceeds the available quantity supplied. A frequently used definition implies that there is a shortage of S/E's when the number available (supply) increases less rapidly than the number demanded at salaries paid in the recent past.[17]

Several labor market indicators frequently are used to assess the relative overall "balance" in the market for scientific and technical personnel—a shortage or surplus situation for S/E's. These indicators include unemployment rates; the experience of recent graduates seeking to enter the labor force, and relative salaries. Furthermore, special studies shed light on the situation in selected areas of concern, such as energy. The indicators examined suggest a possible surplus of scientists in general; they also suggest that the supply of engineers is in approximate balance with demand.

Unemployment Rates. Unemployment rates, one indicator of possible problems in the labor market, only partially measure the supply/demand balance. These rates do not indicate the degree of possible underutilization of S/E's in positions requiring skills below those that the jobholders actually possess. In addition, unemployment rates in most instances do not measure the difficulty or length of time required to obtain employment for those S/E's first entering the job market or by those changing jobs. Also, "hidden unemployment" may exist; for example, qualified persons may have involun-

[15] See Appendix table 5-10.

[16] See W. Lee Hansen, "The Economics of Scientific and Engineering Manpower," *Journal of Human Resources*, vol. 2 (Spring, 1967), pp. 191-219.

[17] See, for example, David M. Blank and George J. Stigler, *The Demand and Supply of Scientific Personnel*, (New York: National Bureau of Economic Research, Inc., 1957), p. 24.

Field	Total in non-S/E	Prefer non-S/E	Promoted out	Better pay	Locational preference	Job not available	Other reasons	No reason reported
All S/E's	100	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Physical scientists	100	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Mathematical scientists	100	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Computer specialists	100	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Environmental scientists[1]	100	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Life scientists	100	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Psychologists	100	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Social scientists	100	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Engineers	100	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[1] Includes earth scientists, oceanographers, and atmospheric scientists.
[2] No data reported.

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

REFERENCE: Appendix table 5-7.

tarily accepted jobs outside of science or engineering. However, data indicate that only about 1 percent of the S/E's who were in the labor force in 1970 were involuntarily employed in non-S/E positions in 1976.[18]

Relative to both the general labor force and to all professional and technical workers, scientists and engineers have shown a relatively strong labor market position (see figure 5-8). In 1971, the unemployment rate for engineers was similar to that for all professional and technical workers. By 1977, the rate for engineers had fallen to less than half that for all professional and technical workers (see figure 5-9).

In 1976, the unemployment rate for S/E's was 3.0 percent—2.1 percent for engineers and 4.0 percent for scientists (see figure 5-10).[19] In general, natural scientists had lower unemployment rates than did social scientists. Economists, with an unemployment rate of only about 1 percent, were a noticeable exception among social scientists. It is noteworthy that many of the scientific occupations showing below-average unemployment rates—economists, computer specialists, and medical scientists—are those that are less dependent for employment opportunities on faculty appointments and levels of R&D funding.

Unemployment rates for doctoral-level S/E's generally are lower than those for all scientists and engineers. As with all S/E's, unemployment rates for those with doctorates vary considerably by field (see figure 5-10).

These unemployment rates suggest some imbalances in the supply/demand condition for scientists below the doctoral level. At about 4 percent in 1976, the unemployment rate for all scientists suggests that the supply may exceed demand, especially in such fields of science as psychology and sociology. The rate for engineers (about 2 percent in 1976) suggests a rough balance, although demand probably exceeds supply; unemployment generally cannot be reduced to zero because of "frictional unemployment" resulting from people changing jobs and entering and reentering the labor force.[20] For doctoral-level S/E's as a group, the unemployment rates indicate no significant problems in

[18] Based on data from the NSF-sponsored Survey of Experienced Scientists and Engineers.

[19] *Detailed Statistical Tables, U.S. Scientists and Engineers: 1976.* National Science Foundation (NSF 79-305), p. 14.

[20] The lowest overall national unemployment rate recorded since 1940 was 1.1 percent (seasonally adjusted) in April 1944, when the Nation was experiencing an extremely tight labor market during wartime.

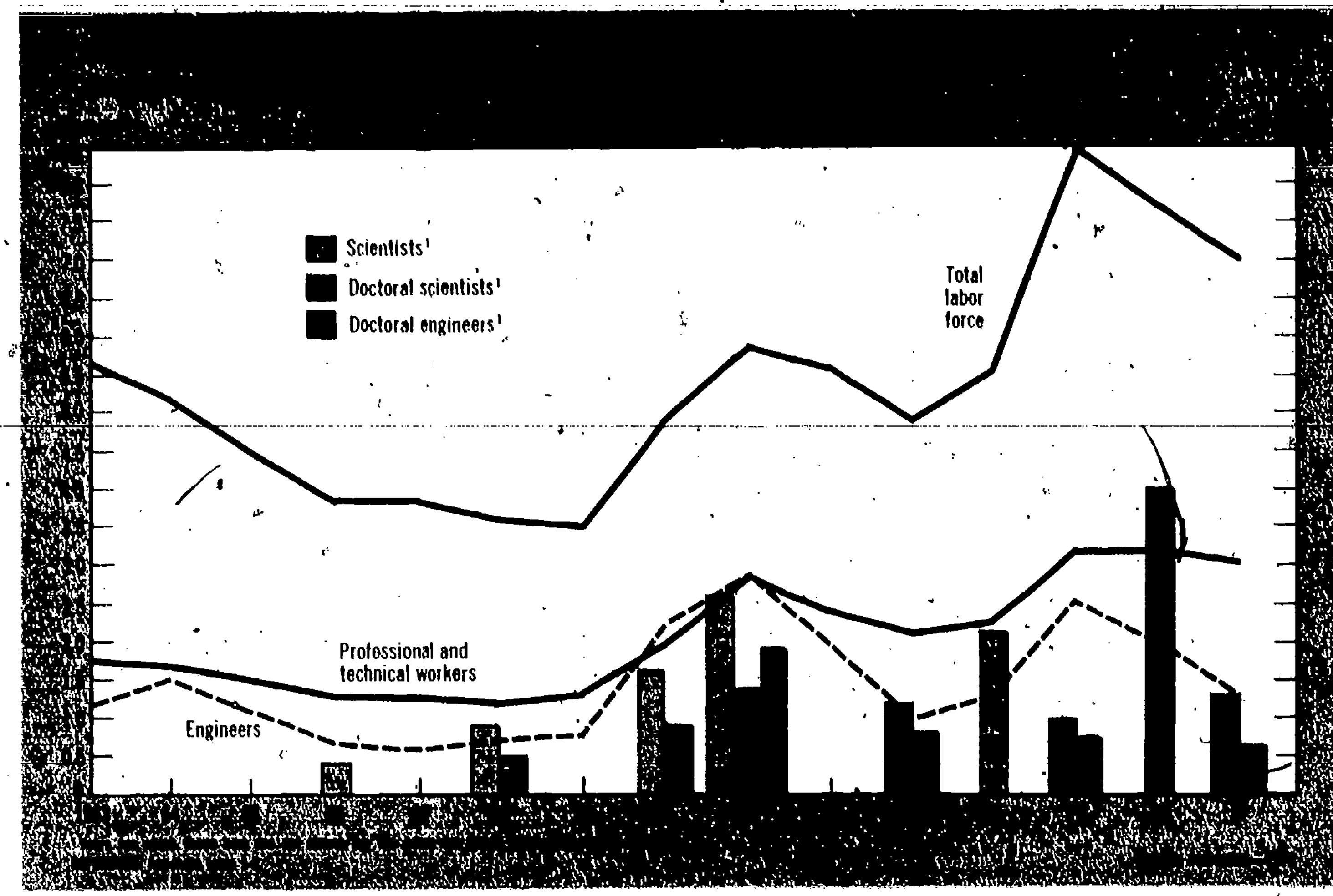
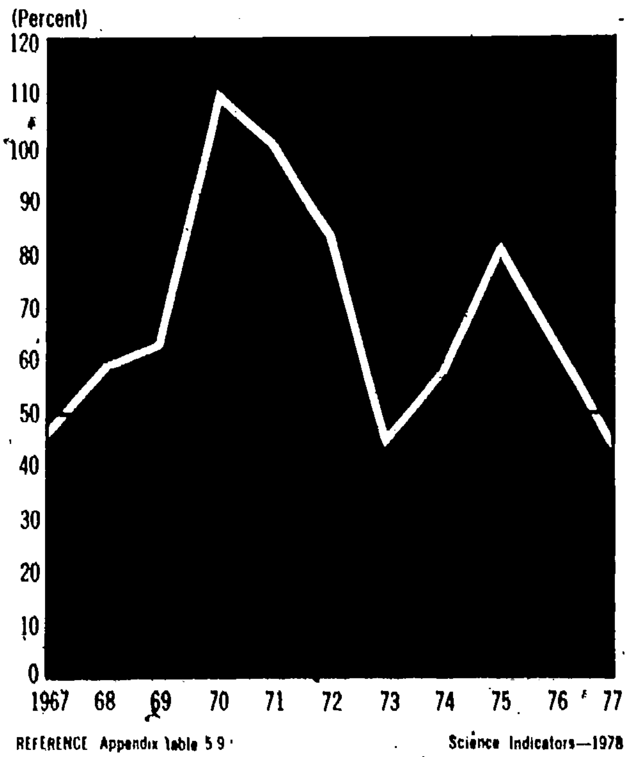


Figure 5-9
Unemployment rates for engineers as a percent of the rates for professional and technical workers: 1967-77



terms of supply/demand balance. Nevertheless, the individual unemployed scientist or engineer, of course, undergoes considerable hardship.

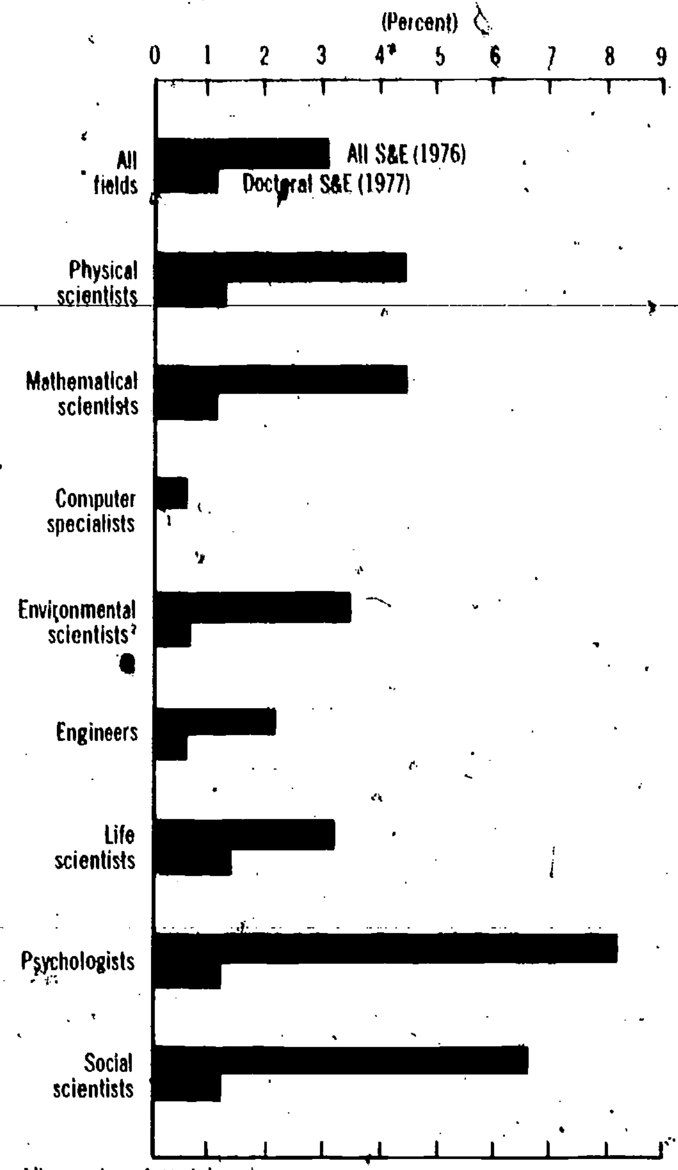
Experience of Recent Science and Engineering Graduates. The experience of recent S/E graduates is another indicator of the degree of market balance. In general, if the demand for S/E's is greater than the supply at existing salary levels, the proportion of recent graduates who obtain jobs in science or engineering will be relatively high. Those proportions, however, could vary considerably by degree levels.

Only 30 percent of those who earned baccalaureates in science and engineering in 1974 and 1975 were employed in S/E jobs in 1976, while 36 percent held jobs outside of science and engineering (see figure 5-11).[21] However, a significant proportion (24 percent) of these new graduates were attending graduate school on a

[21] "Employment Patterns of Recent Entrants into Science and Engineering," *Reviews of Data on Science Resources*, National Science Foundation (NSF 78-310), p. 5.

Figure 5-10

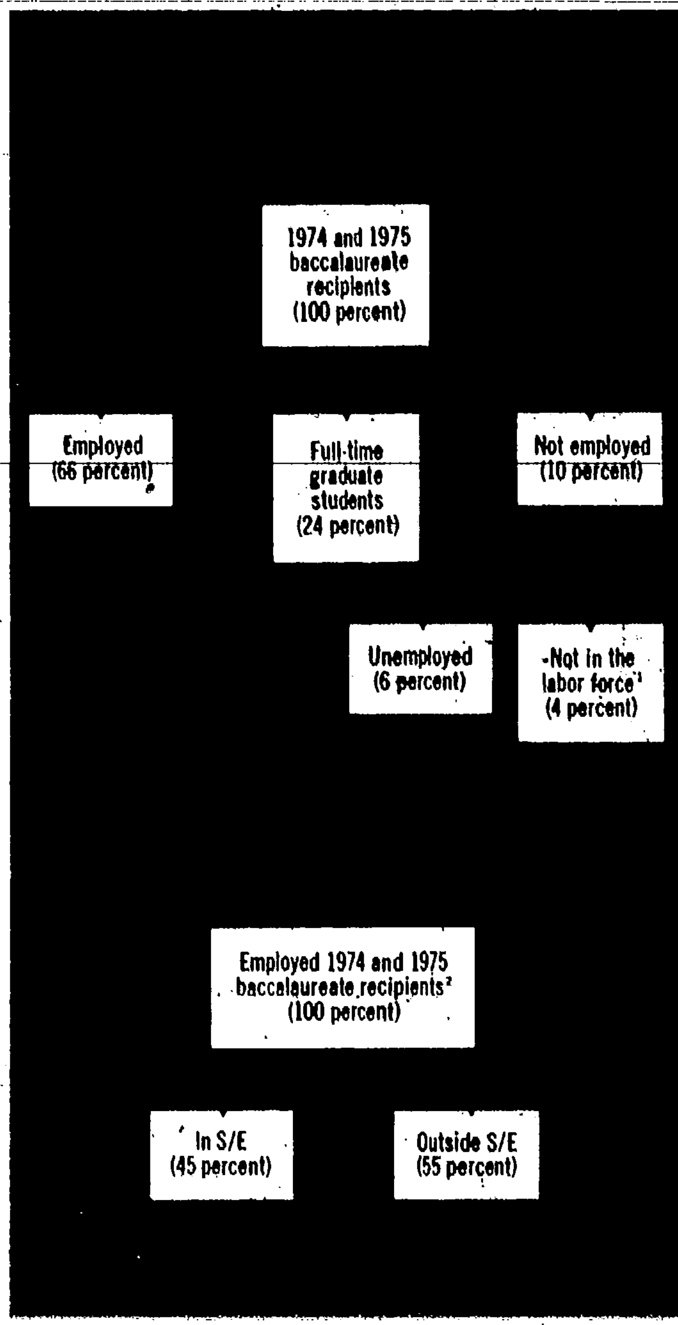
Science and engineering unemployment rates by field: 1976-77



¹ No unemployment reported

² Includes earth scientists, oceanographers, and atmospheric scientists.

REFERENCE: Appendix tables 5-2 and 5-10. Science Indicators - 1978



full-time basis. When these students are excluded from the analysis, a somewhat different picture develops; for those employed, about 45 percent had jobs in science and engineering, with wide variations among fields of science. Those with degrees in the natural sciences and engineering showed a significantly greater propensity to obtain jobs in science and engineering fields than those with degrees in the social sciences.

These data clearly indicate the degree of relative supply/demand balance. They also suggest that, for some fields in today's job market, the baccalaureate may not be considered sufficient for entry into scientific employment. The decline of the baccalaureate as an entry degree is consistent with two alternative explanations. First, the nature of scientific work may have become more complex, requiring advanced degrees for those entering such work. Second, there may be "overcredentialing"; that is, employers may be requiring advanced degrees, not because of the complexity of the work but because those with advanced degrees may be more readily available.

The proportion of recent graduates with master's degrees who found work in science or engineering is higher than those with the bachelor's degree. Overall, more than three-fourths (78 percent) of employed master's degree holders were working in S/E jobs, and the variation by field was not as great as that for those with only the baccalaureate (see figure 5-12). By way of comparison, about 92 percent of new S/E doctorates are employed in science and engineering positions.

The data on recent graduates who are new entrants into the labor market suggest that, in general, the quantity of scientists is more than adequate to meet the current quantity demanded. For some of the science occupations, such as social scientists, demand could increase substantially before shortage situations would develop. For engineers, however, demand and supply seem to be roughly in balance.

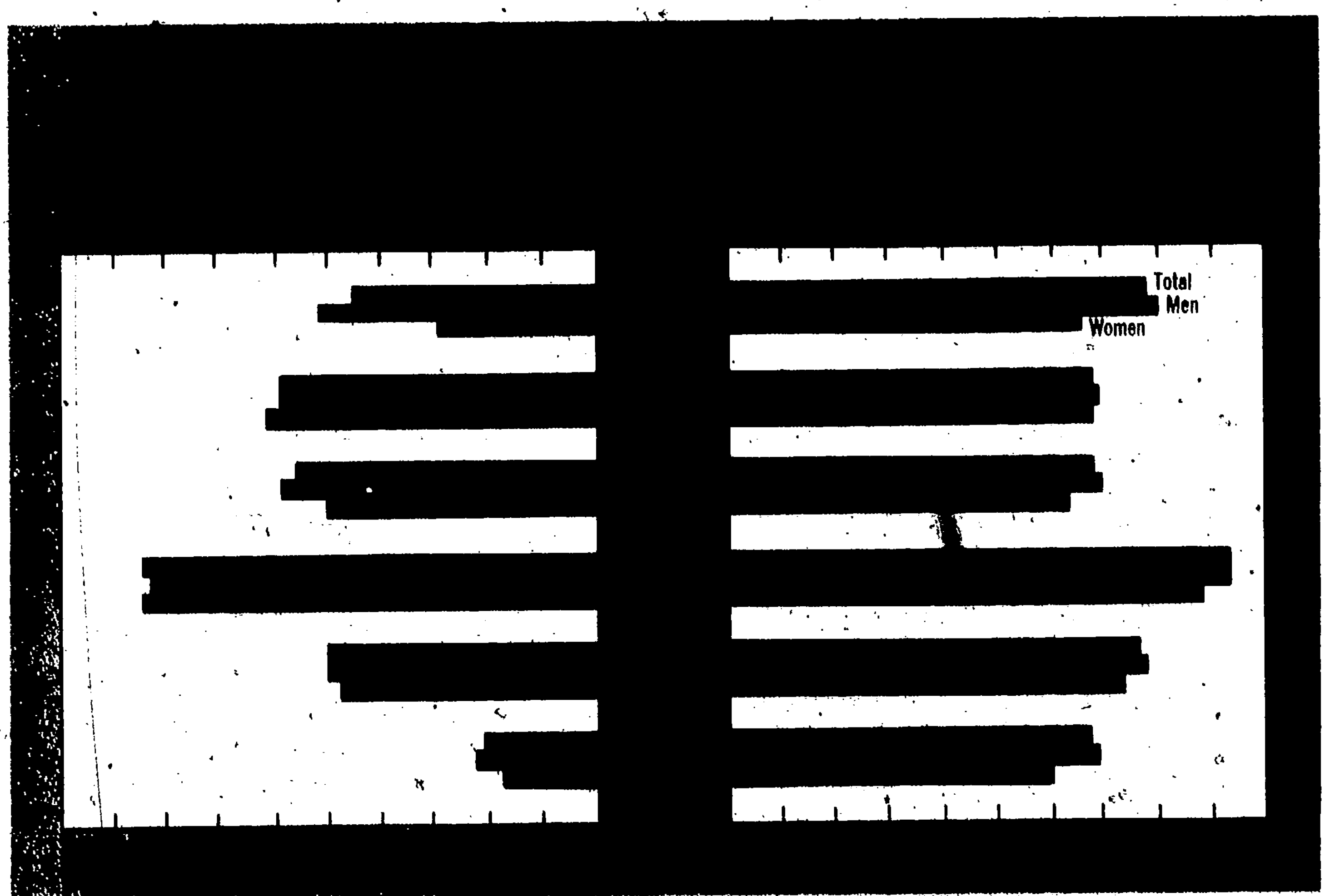
Relative Salaries. Another indicator of labor market balance is salary trends. If S/E's are in short supply, their salaries would be expected to increase relative to some general salary measure,[22] as employers increase their salary offers to attract the available supply. If salaries of S/E's increase at the same or lower rates than do general salary levels, the inference is that the available supply is equal to or greater than current demand.

Care must be exercised in using relative salary data as indicators of labor market balance since the earnings of professional and technical workers in general have not kept pace with those for other workers. Nonprofessional wages have increased more rapidly for a variety of reasons, including increases in the minimum wage and union efforts to obtain pay raises for production and related workers. As a result, for example, the earnings of male operatives[23] increased by 65 percent between 1970 and 1977, while those for male professional and technical workers increased by 49 percent.[24]

[22] Hourly or weekly earnings of production workers are frequently used as indicators of general wage trends.

[23] Includes transportation and semiskilled metalworking occupations.

[24] Based on earnings of year-round, full-time workers. See *Current Population Reports*, Series P-60, U.S. Department of Commerce, Bureau of the Census, No. 80 (1971), pp. 117-118, and No. 116 (1978), p. 13.



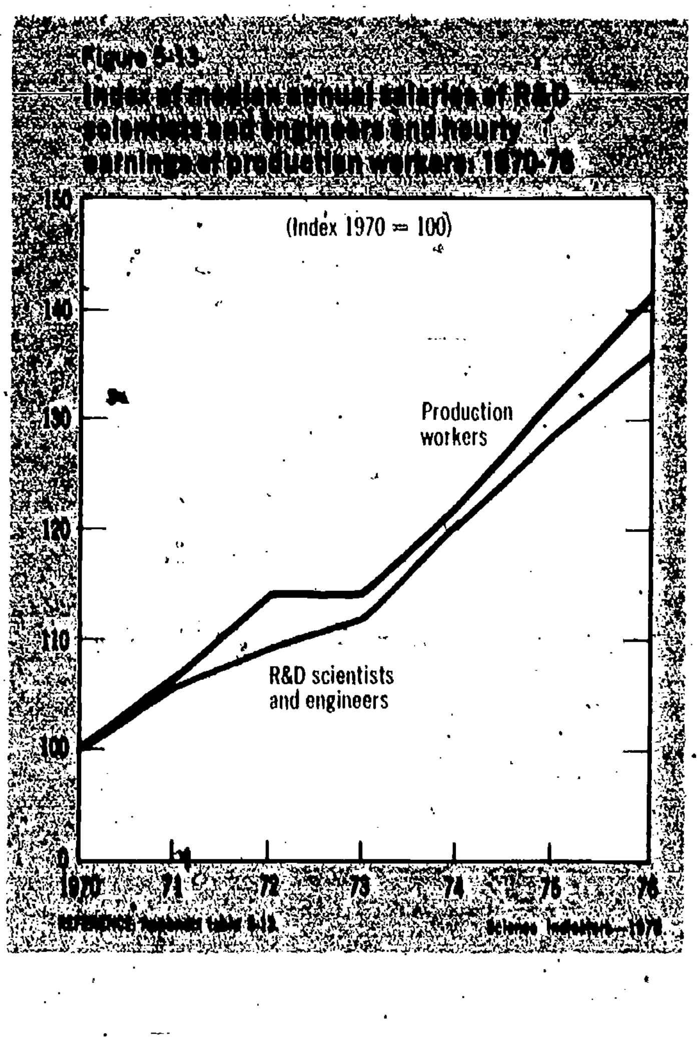
The median monthly salaries of R&D scientists and engineers did not keep pace with increases in the hourly earnings of production workers in the 1970's (see figure 5-13). Salaries of S/E's in R&D (measured in current dollars) rose by about 37 percent between 1970 and 1976, earnings of all male professional workers increased by 38 percent, but production workers' salaries increased 42 percent. Salaries of doctoral-level S/E's in R&D increased by about 36 percent over the same period. While indicating stronger demand for doctoral-level S/E's than for scientists and engineers with less education, the data also indicate a rough balance in the supply/demand condition for doctoral-level S/E's in R&D.

Starting salaries for new hires of inexperienced engineers (and presumably scientists) may reflect the market situation for that occupation.[25] Data developed by the College Placement Council indicate that starting salary offers for scientists and engineers have increased since the 1973-74 recruiting period. However, caution must be exercised in inferring that a "shortage" situation is developing for S/E's from the moderate increase in starting offers (29 percent for engineers from 1973-74 to 1976-77).[26] When adjusted for inflation, little increase in starting salaries is indicated. The data suggest, however, that the market for natural scientists and engineers is improving relative to that for graduates in business and the humanities and social sciences (see figure 5-14).

Special Areas. Special situations concerning S/E supply may exist in specific occupations. For example, one study[27] has indicated current shortages of energy-related personnel in selected fields such as mining, petroleum engineering, and chemical engineering at the doctoral level. The market, however, appears to be responding to this situation—1978 bachelor's degrees in these fields are up sharply from mid-1970 levels.

[25] See, for example, W. L. Hansen, "The Shortage of Engineers," *Review of Economics and Statistics*, vol. 43 (August, 1961), pp. 251-56; and Richard Freeman, *The Overeducated American* (New York: Academic Press, 1976), pp. 10-16.

Figure 5-13.
Index of median annual salaries of R&D scientists and engineers and hourly earnings of production workers: 1970-76



Projected Supply and Utilization of Scientists and Engineers

Doctoral Scientists and Engineers. Projections are indicators of possible futures which are generally used as planning tools to anticipate potential problems and to develop a better understanding of the dynamics of the systems that are being analyzed. Since projections are sensitive to assumptions about behavioral relationships and future values of critical variables, they should be used with caution and several caveats are pertinent.

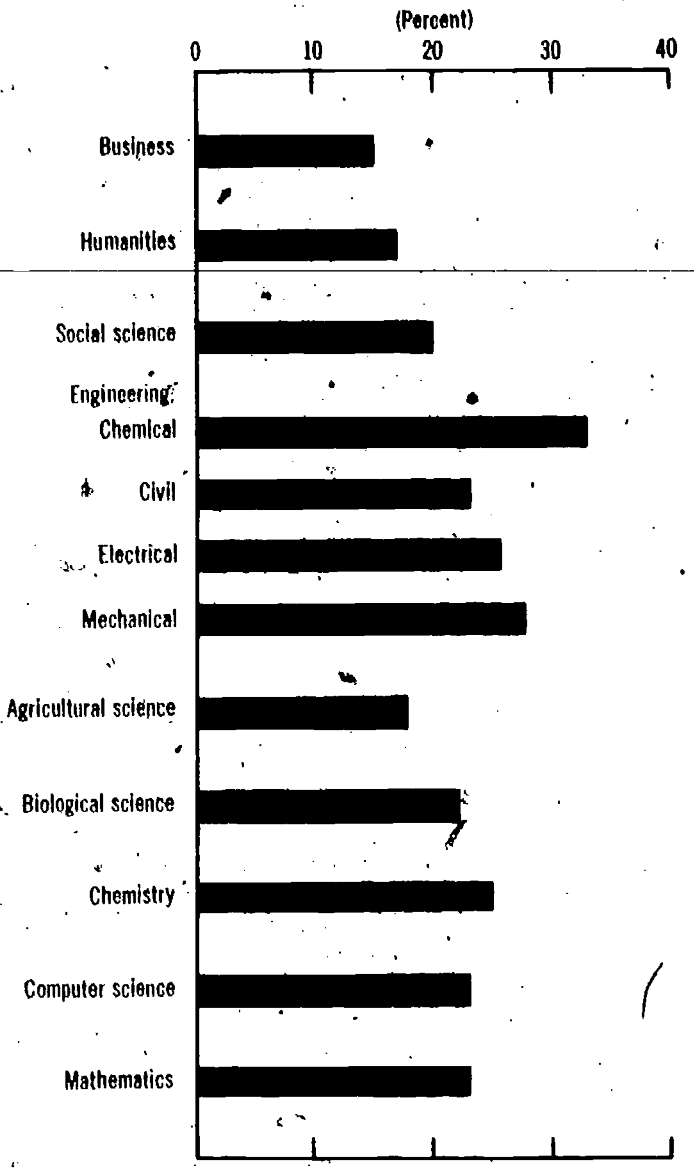
Projections are conditional forecasts incorporating a number of assumptions about the future. If these assumptions are changed, the results of the projections will be altered. In addition, all projection techniques are subject to inherent difficulties. For example, an obvious hazard of trend extrapolation is that tendencies may be altered by unexpected events. Similarly, in projections based on econometric models, pertinent factors that may have been omitted, either through oversight or because of data limitations, are assumed to have stable relationships with factors that have been con-

[26] See *CPC Salary Survey Final Report* (Bethlehem, Pa.: College Placement Council, July 1976 and 1978), p. 3.

[27] Hugh Folk, *et al.*, *Scientific and Technical Personnel in Energy-Related Activities: Current Situation and Future Requirements* (Urbana/Champaign, Ill.: Center for Advanced Computation, University of Illinois, 1977), pp. 73-76. See also "Current and Future Utilization of Scientific and Technological Personnel in Energy-Related Activities," *Reviews of Data on Science Resources*, National Science Foundation (NSF 77-315).

Figure 5-14

Percent change in average monthly salary offers to bachelor's degree candidates, by selected curricula: 1973-74 to 1976-77



REFERENCE: Appendix table 5-14. Science Indicators—1978

sidered. These relationships could be altered in the future. In view of these limitations, a false sense of precision should not be attributed to the numerical forecasts. Instead, attention should be focused on broad features of the projections.

A final caveat concerns the level of aggregation of projections. Each major area of science and engineering includes specific disciplines (e.g., physics, economics, electrical engineering) that can differ from the aggregate in its supply and utilization balance. Thus, it must not be assumed that the projections for broad areas of science (e.g., physical sciences) are necessarily applicable to their individual disciplines.

The annual number of doctorates awarded in science and engineering has declined slightly each year since 1973, the first such declines experienced since the mid-1950's. These declines, coupled with reduced employment opportunities for scientists and engineers in the academic sector, raise policy issues regarding future supply/demand relationships, market adjustments to imbalances, and potential implications of these for the future vitality of scientific research and development in the United States—particularly in the academic sector.

Independent projections—prepared by the National Science Foundation (NSF) and the Bureau of Labor Statistics (BLS), which are discussed more fully in Appendix I—indicate that, in general, the supply of doctorate scientists and engineers is likely to be more than ample to meet anticipated demand.[28] Depending on the model examined, from 185,000 to 210,000 students are projected to receive science and engineering doctorates from American universities roughly over the next decade.[29] Based on these projections and estimates of attrition, an S/E doctoral labor force of 410,000 to 420,000 is projected for the mid-1980's, as compared to 340,000 to 350,000 projected to be in S/E-related (or traditional) activities.

The difference between supply and utilization in the mid-1980's is projected by BLS and NSF to be in the 60,000-to-80,000 range. This difference represents an estimate of doctoral S/E's who are likely to find it necessary to accept non-S/E or nontraditional employment. Based on historical evidence, it is likely that only a small proportion of

[28] For models of supply and utilization covering scientists and engineers, see *Projections of the Supply and Utilization of Science and Engineering Doctorates, 1982 and 1987*, National Science Foundation (NSF 79-303); Douglas Braddock, "Oversupply of Ph.D.'s to Continue Through 1985," *Monthly Labor Review* (October 1978). Other models related to more general markets for highly trained labor, or to particular sectors of this market (such as the academic sector) can be found in Richard Freeman, *The Overeducated American* (New York: Academic Press, 1976); *Projections of Educational Statistics to 1986-87*, U.S. Department of Health, Education and Welfare, National Center for Education Statistics; Roy Radner and Charlotte V. Kuh, *Preserving a Lost Generation: Policies to Assure a Steady Flow of Young Scholars Until the Year 2000* (Berkeley, Calif.: Carnegie Council on Policy Studies in Higher Education, 1978).

[29] These projections are adjusted to reflect the international flows of migrating scientists and engineers. The BLS projection (185,000) is for the period 1976-1985; the NSF projection (210,000) is for the period 1977-1987.

this group will actually be unemployed. By contrast, only about 23,000 doctoral S/E's were in full-time, non-S/E positions in 1977.

However, the models produce some differences in projected supply/utilization findings when the data are classified by broad S/E fields. Mathematics is expected to encounter the largest imbalance, with anywhere from 21 to 30 percent of its doctoral S/E's projected to be engaging in non-S/E activities. Social sciences follows closely behind mathematics, with anywhere from 19 to 27 percent of its doctorates projected in non-S/E activities. Problems are expected to be somewhat less severe in the life sciences (with 16 to 20 percent projected to be in non-S/E activities) and in the physical sciences (where only 9 to 10 percent are projected in non-S/E activities). The projections for engineers are more divergent. The NSF model projects 19 percent of the engineering doctorates employed in non-S/E activities, whereas the BLS model projects a shortage of roughly 8 percent in the labor market for doctoral engineers. This difference is primarily due to considerably lower projections of doctorate degrees by BLS. The congruence of the projection findings in the aggregate thus appear to result from offsetting differences in findings among major fields.

These projections suggest that, strictly on the basis of the availability of human resources with scientific and engineering training at the doctoral level, the United States may not be constrained from engaging in new initiatives in R&D and other technological efforts. The projected growing disparity between supply and utilization for doctoral scientists and engineers, however, may cause for concern since there may be some direct loss for the next several years of the substantial resources invested in the specific skill training of these scientists and engineers by virtue of their working in nonscience or nonengineering activities.

All Scientists and Engineers. In general, the Bureau of Labor Statistics estimates that the supply of scientists through the mid-1980's will be more than adequate to meet demand in most fields. For engineers, supply and demand are expected to be in rough balance. Projections developed by BLS indicate that engineering graduates in most specialities will face good employment opportunities through the mid-1980's.[30] In the Bureau's terminology, the phrase "good employment opportunities" means that demand and supply will be roughly balanced.

The outlook for scientists varies considerably by field and level of training. Favorable employment opportunities are projected for geologists and geophysicists, reflecting increasing exploration for petroleum and other minerals. However, the number qualified to enter the geophysics field may fall short of requirements if current trends continue. In the physical sciences, favorable opportunities are projected in the nonacademic sectors for chemists and physicists. The situation is expected to be less favorable for those seeking employment as astronomers. The number of degrees granted in astronomy will probably continue to exceed available openings. Approximately three-fourths of total employment of chemists is expected to be in private industry, primarily in development of new products. The generally favorable outlook for nonacademic physicists reflects primarily an anticipated decline in the number of graduate degrees in physics rather than a significant increase in demand.

Those seeking employment as mathematicians are likely to face keen competition throughout the mid-1980's. Opportunities, however, are expected to be best for advanced degree holders in applied mathematics seeking jobs in government and in private industry. Employment opportunities for life scientists are expected to be good for those with advanced degrees through the mid-1980's, but those with lesser degrees may experience more competition for available jobs. In the social sciences, anthropologists are expected to face keen competition for jobs, while economists with masters and doctoral degrees are expected to have favorable nonacademic opportunities. Those with training in sociology at all degree levels may expect keen competition for available jobs. For doctoral psychologists, prospects will be brightest for those trained in applied areas such as clinical counseling and industrial psychology.

QUALITY

Recently, there has been increasing speculation on a possible decline in quality of the scientific and technical work force. Such speculation is difficult to deal with, since no direct measures of overall work force quality yet exist. However, several indicators may be used to assess the quality of the S/E work force. These include changes in the proportion of doctorates held by persons in the S/E work force, aptitude test scores of prospective graduate students, data

[30] See "The Job Outlook in Brief," *Occupational Outlook Quarterly* (Spring 1978), U.S. Department of Labor, Bureau of Labor Statistics.

on nonformal training activities of experienced S/E's, and distribution of researchers by age. Though limited, the data presented below indicate that the quality of the S/E workforce has not declined, and by some measures quality has actually improved. For example, the proportion of scientists and engineers holding the doctorate has increased, and the proportion of experienced scientists and engineers obtaining further training has remained stable through the 1970's. Also, test scores of prospective graduate students in science and engineering continue high and unchanged relative to the scores of graduate students in non-S/E fields. The relative decline in the proportion of the S/E doctoral workforce which is under 35 years of age may produce some dimunition in the vitality of science. However, a change in the age distribution may reflect a return the normal after an unusual situation produced by the rapid expansion of the system in the 1960's. The changing situation is already producing a considerably slower infusion of new investigators into the academic sector.

Rising Proportion of Doctorates in the S/E Work Force

From 1960 to 1976, the number of doctoral degrees awarded in S/E fields increased at an average annual rate of 6.8 percent, slightly faster than the annual rate of 5.7 percent for baccalaureates. The number of persons in the S/E work force who had earned doctoral degrees grew by 3.3 percent a year, somewhat faster than the 2.8 percent annual growth of the total S/E work force over the 1974-76 period. Consequently, the proportion of S/E workers who hold doctorates also increased. For natural scientists,[31] the proportion doubled from 1960 to 1976, and for all S/E workers it increased from 10.6 percent in 1974 to 11.4 percent in 1976. The higher percentage of workers having more advanced education implies higher average quality. As pointed out earlier, some increase may have resulted from hiring new entrants with doctoral degrees simply because they were available, and not because their positions had previously required that level of education.

Test Scores of Prospective Graduate Students

From 1970 to 1977, the quality of prospective S/E graduate students, as measured by test scores on the verbal and quantitative components of the Graduate Record Examination (GRE) remained high and unchanged with respect to the actual scores and relative to the average scores of graduate students in nonscience fields (Appendix table 5-15).

The mean scores are available for the years 1970 to 1977 for five broad S/E fields (see figure 5-15). In verbal ability, scores for science and nonscience candidates did not differ significantly, but engineering candidates' scores averaged noticeably lower than science candidates'. In quantitative ability, candidates for admission to S/E fields averaged more than one standard deviation above candidates in nonscience fields, but there were large differences separating candidates in engineering, mathematics, and physics from those in the life and social sciences.

The absence of any significant decline in average scores may seem surprising in view of the expansion in numbers, and in view of the decline in average scores of students seeking admission as college freshmen. However, from the 1930's until well into the 1960's, a very large increase in the percentage of young people attending college was accompanied by an increase in average scores on tests of intellectual aptitude;[32] as colleges expanded their enrollments, they also became more selective. This situation could not continue indefinitely, and it is widely known that the average aptitude scores of high school seniors seeking admission to college have declined in recent years.

However, the applicants for admission to graduate school, whose average scores are plotted in figure 5-15, are from an earlier college generation; many of them entered college before the recent decline in scores, and through 1977 there has been no drop in this measure of the quality of graduate students in science and engineering. Not only has the quality of prospective graduate students remained constant, but the proportion of doctorates granted by top-rated departments for selected fields has been relatively stable from 1967 to 1977. Although the number of doctorates granted in S/E has declined since the early 1970's, the downward trend in the number of doctorates awarded by those departments with a "distinguished" Roose-Anderson rating has proceeded at a slower rate than the trend in lesser rated departments.[33]

[31] Excluding social scientists and psychologists, for whom data are not available for the earlier years.

[32] Paul Taubman and Terence Wales, *Mental Ability and Higher Educational Attainment in the 20th Century.* (New York: National Bureau of Economic Research, 1972).

[33] *Summary Report 1977: Doctorate Recipients From United States Universities* (Washington, D.C.: National Academy of Sciences, 1978), p. 9.

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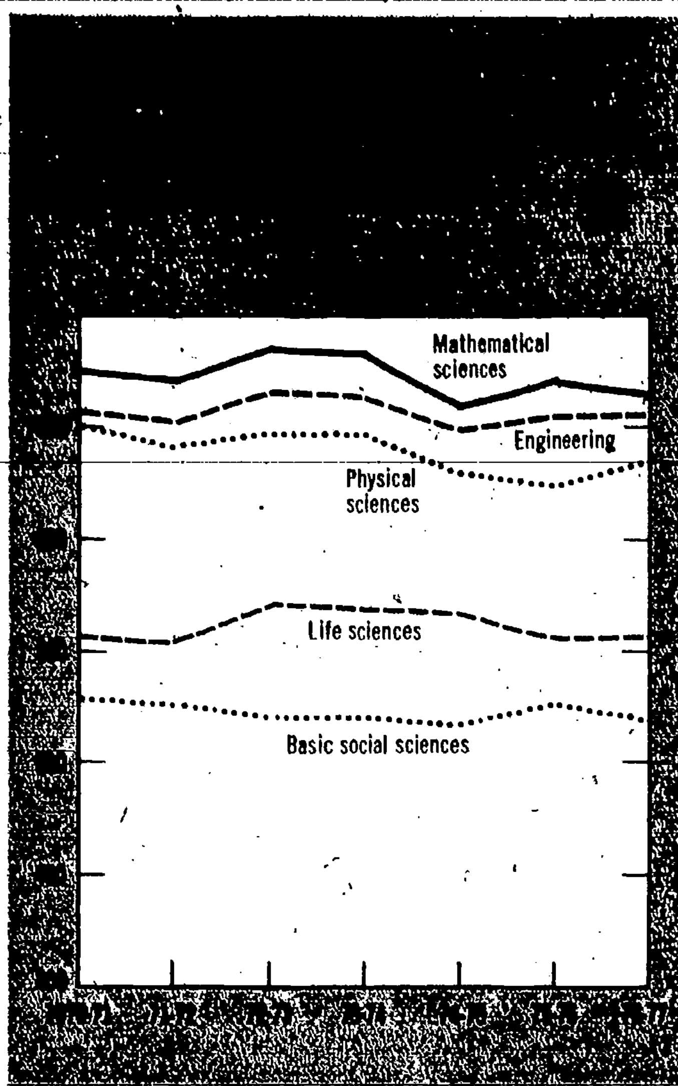
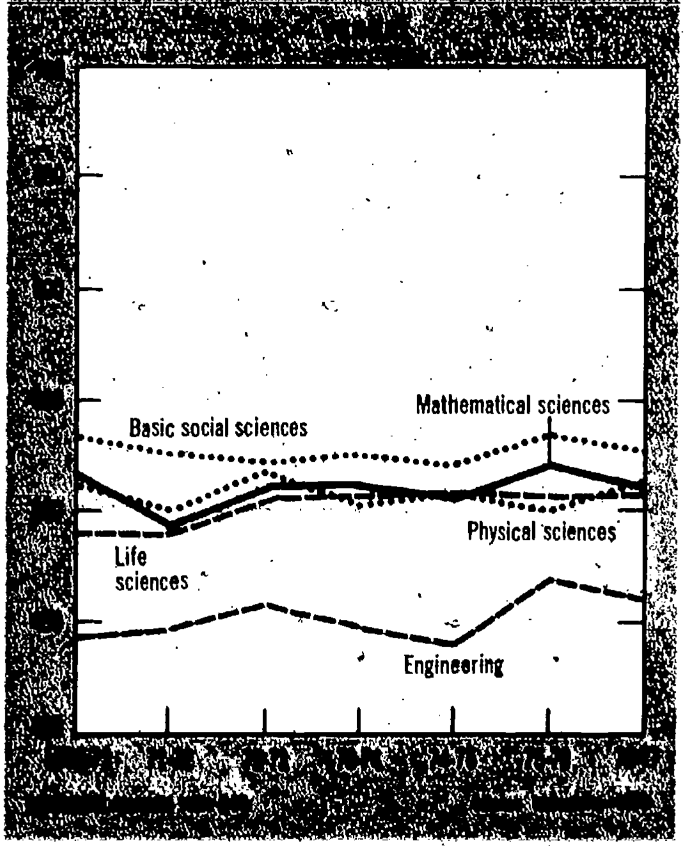




Continuing Training

Another indication of the quality of experienced S/E's is the proportion who participate in training programs, both formal and informal. Surveys sponsored by the NSF[34] permit study of individuals who were employed in science and engineering at the time of the 1970 Decennial Census of Population. Data from these surveys show that experienced scientists and engineers continue to participate in education and training programs. For example, the proportion of doctorate-holders receiving this training climbed from 14 percent in 1972 to 18 percent in 1976. Over the same period, however, the proportion of master's degree holders remained relatively constant at about 22 to 23 percent. The proportion of S/E's obtaining nonformal training remained high—over 35 percent—for each of the years 1972 through 1975. "On-the-job training" and "courses at employer's training facilities" were the two most frequent types of supplementary training cited by participants in the study.[34] Thus, the established S/E community is taking advantage of opportunities to maintain and improve its level of competence.

Young Scientists and Engineers

One indicator of the vitality of the science and engineering work force is the age distribution of active S/E's and, in particular, the status of "young" investigators. Frequently, research activities in the years immediately following the doctorate are characterized by innovative approaches.[35] Three indicators of this aspect of quality are the age distribution of doctoral-level S/E's, the number and proportion of university faculty who are "young," and the flow of recent doctoral-level recipients into R&D.

Age Distribution of Doctoral-Level S/E's. In 1977, about 22 percent of the employed doctoral-level S/E's were under 35 years of age, compared to 25 percent in 1975 and 27 percent in 1973. The age distribution of doctoral-level S/E's varies

[34] *Characteristics of the National Sample of Scientists and Engineers 1974, Part I: Demographic and Educational,* National Science Foundation (NSF 75-333), pp. 42-45; and *Characteristics of Experienced Scientists and Engineers, 1976. Detailed Statistical Tables,* National Science Foundation (NSF 78-305).

[35] See, for example, *Report of the National Science Board to the Subcommittee on Science, Research and Technology of the Committee on Science and Technology, U.S. House of Representatives Regarding Peer Review Procedures at the National Science Foundation,* (NSB 77-468), November 1977, p. II-2; and "Decline in Recent Science and Engineering Doctoral Faculty Continues into 1978", *Science Resources Studies Highlights,* National Science Foundation (NSF 79-301).

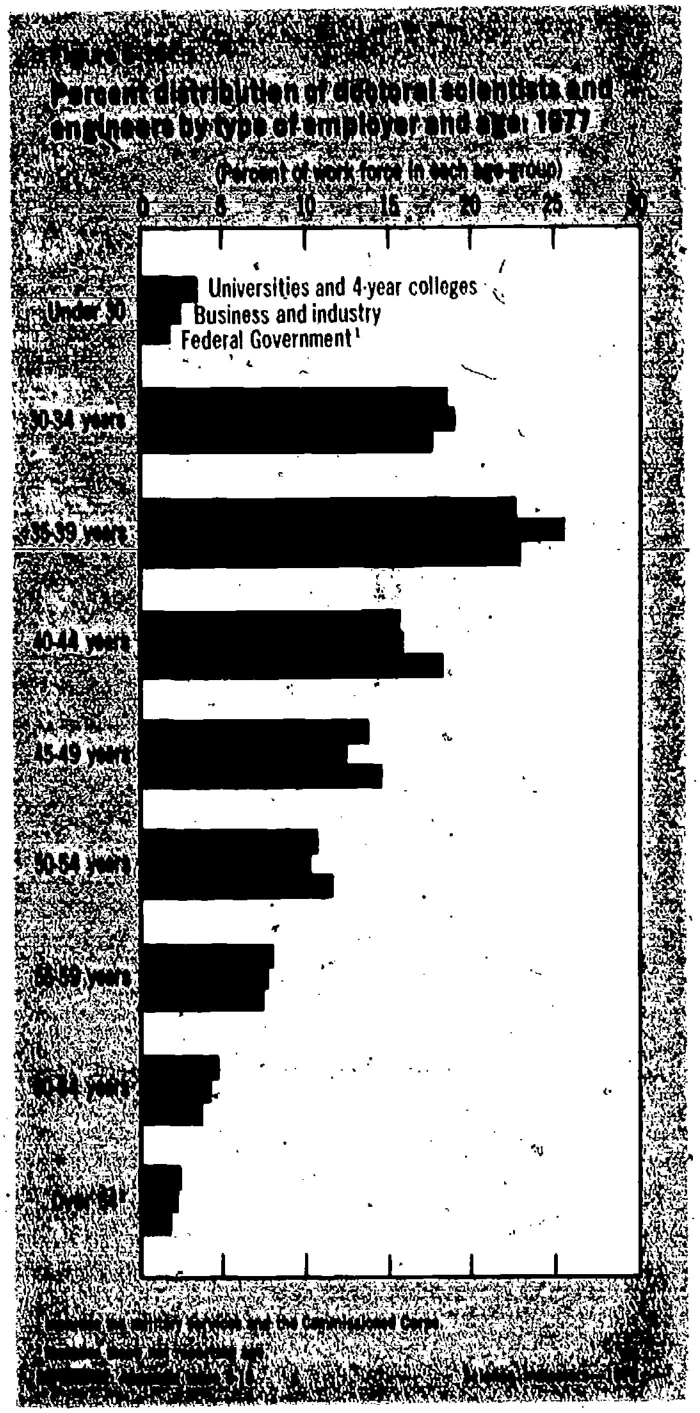
somewhat by type of employer and by primary work activity, e.g., R&D and teaching (see figures 5-16 and 5-17). In 1977, for example, about 22 percent of the doctoral-level S/E's in 4-year colleges and universities and in industry were under age 35, while in the Federal Government the comparable figure was about 19 percent. A significant fraction of those under 35 years of age in colleges and universities hold postdoctoral appointments.[36]

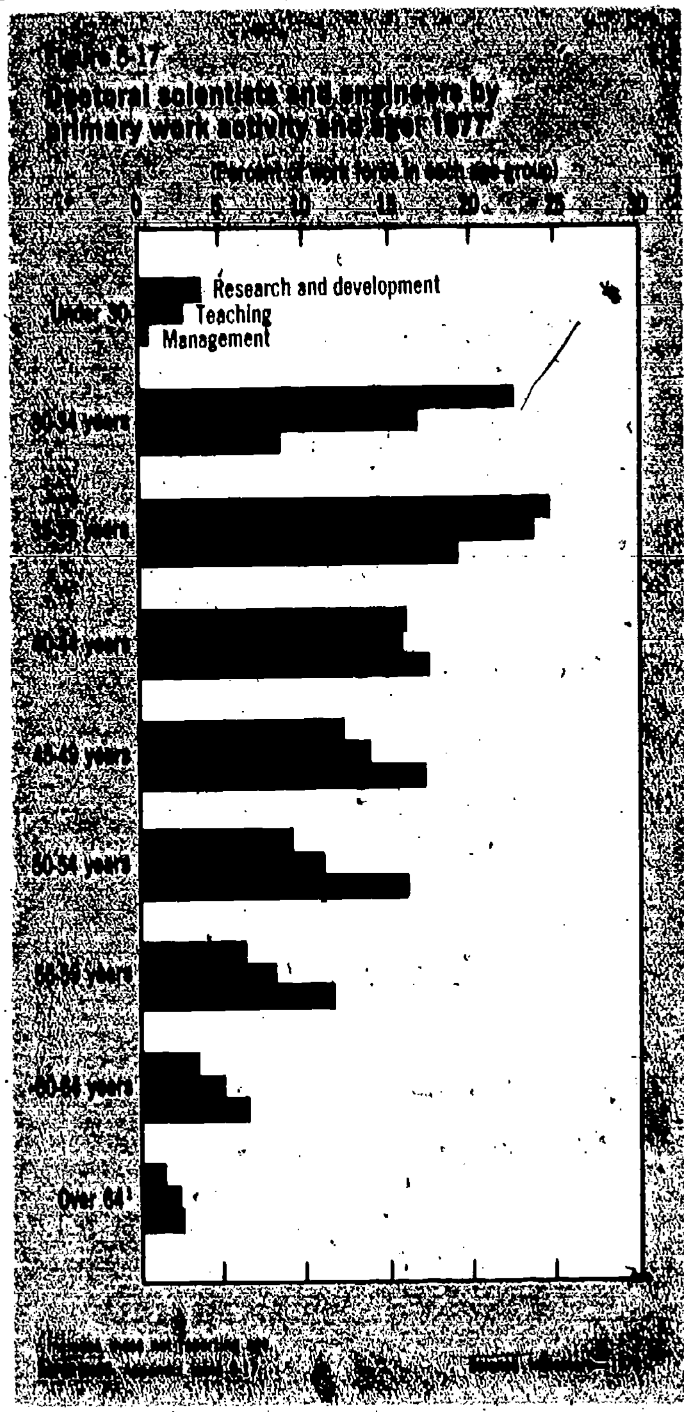
[36] National Science Foundation, unpublished data.

The relatively high proportion of young people holding doctorates and working in industry reflects, in part, the large number hired for R&D activities between 1973 and 1977.[37] Projections developed by NSF indicate that young people with doctorates increasingly will find jobs in industry, but not necessarily in R&D.[38]

[37] "Utilization of Science and Engineering Doctorates in Industrial Research and Development," *Science Resources Studies Highlights*, National Science Foundation (NSF-301).

[38] *Projections of the Supply and Utilization of Science and Engineering Doctorates, 1982 and 1987*, National Science Foundation (NSF 79-303).



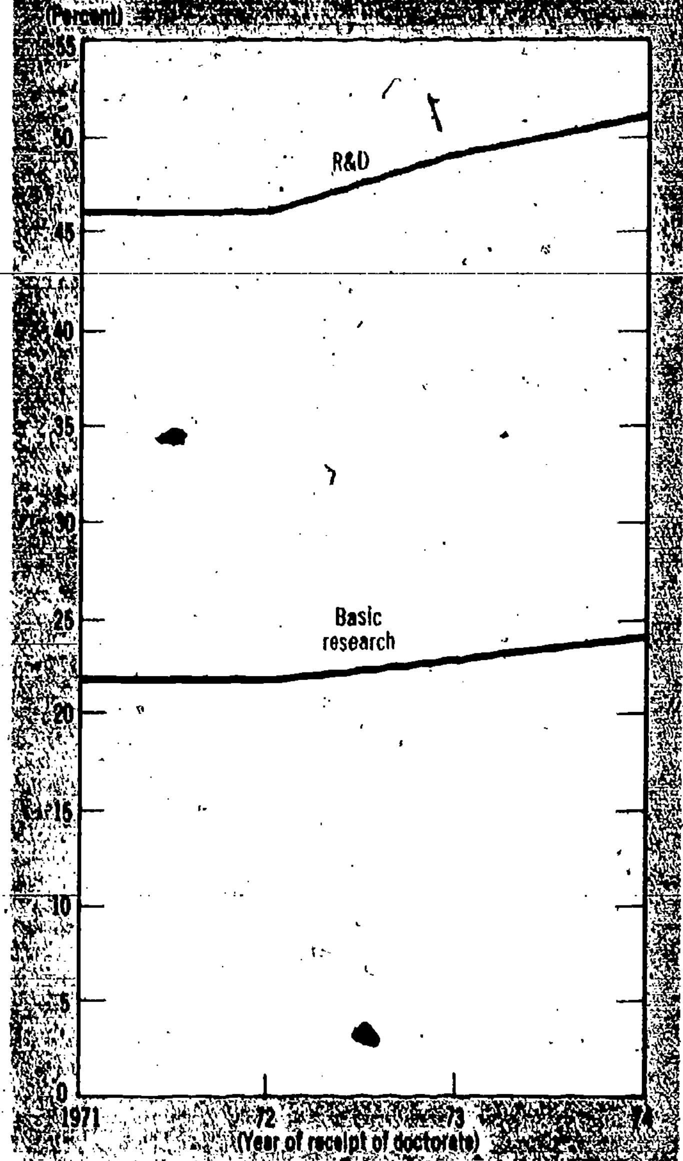


Young Investigators. The continued vitality of research depends on many factors, and the steady infusion of new investigators is particularly important. Universities, which perform much of the Nation's basic research, have experienced recent marked reductions in the numbers of young doctorate-holding faculty[39] (i.e., 7 or fewer years from receipt of the doctoral degree). Over the 11-year period 1968-1978, while the total number of doctorates held by faculty in selected science and engineering fields increased by 14 percent, the number of young people with doctorates has dropped and their total percentage has declined from 42 percent to 24 percent.[40] In the opinion of department heads, 30 percent of the full-time doctoral faculty should be in the young category.[41] In 1978-79, doctoral-level departments in 16 representative science and engineering fields expect to hire 2,980 full-time doctorate-holding faculty, of whom 70 percent are expected to be of assistant professor rank. At most universities new doctorate holders enter the faculty as assistant professors.[42]

The research activity of full-time science and engineering faculty in universities, expressed as the proportion spending 20 percent or more of their time in research, increased slighty between 1968 and 1974. In both years, about 91 percent of the young doctorate-holding faculty were included in the research-active group.[43]

Flow of S/E's Recently Awarded Doctorates into R&D. Available data show that almost half of the S/E's recently awarded doctoral degrees are engaged in R&D in the years immediately following receipt of their degrees (see figure 5-18). This concentration, in large part, reflects two factors. First, to capitalize on the most advanced concepts and techniques, industry often employs young doctoral-level S/E's in the laboratory for their first assignments. Many will move out, however, into management and other non-R&D positions. Second, increasing numbers of those newly awarded doctorates do not take permanent positions after graduation but stay at universities in postdoctoral positions. Not all who hold postdoctoral appointments, however, seek or find permanent jobs in R&D.

Figure 5-18
Proportion of 1971-74 Ph.D. recipients primarily employed in R&D and in basic research[1]



[1] Employment status in the Spring following the receipt of the doctorate.
REFERENCE: Appendix table 5-18. Science Indicators—1978

EQUITY

Women and minorities in science and engineering are receiving increasing attention, reflecting

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[39] Although not all scientists are young when they receive the doctorate, most of those who have held the doctorate for 7 years or less are in fact young. In recent years, the median age for new science doctorates has been about 30 years.

[40] "Decline in Recent Science and Engineering Doctoral Faculty Continues into 1978," *Science Resources Studies Highlights*, National Science Foundation (NSF 79-301).

[41] Frank J. Atelsek and Irene L. Gomberg, *Young Doctorate Faculty in Selected Science and Engineering Departments, 1975 and 1980* (Washington, D.C.: American Council on Education, 1976), p. 9.

[42] Frank J. Atelsek and Irene L. Gomberg, *Young Doctorate Faculty in Science and Engineering: Trends in Composition and Research Activity* (Washington, D.C.: American Council on Education, 1979).

[43] *Young and Senior Science and Engineering Faculty, 1974*, National Science Foundation (NSF 75-307), p. 31.

two separate but related concerns: to attract the best students into science and engineering regardless of sex, racial group, or ethnic status in order to maintain and improve the quality of scientific and technical effort; and to ensure equity of opportunity for women and minorities to participate in science and engineering.

The concept of equity (or fairness) can be defined as equal treatment of equals. In the labor market, this means equal treatment with respect to employment and salary practices for individuals with comparable skills. A separate but related issue involves equity in the acquisiton of skills. Inequities in employment and salary practices in the labor market have different policy implications from inequities in skill acquisition, particularly in labor markets requiring substantial amounts of formal (as opposed to on-the-job) training.

Labor market and training inequities are issues that merit serious policy concern because of the resource costs they impose on society (as a result of maldistribution of resources they produce) and because of the financial and psychic costs they impose on the individuals who are subject to these inequities.

Disparities—between men and women and between racial minorities and others—in labor market variables (such as employment and/or salaries) or in skill acquisition variables (such as enrollments in science and engineering programs at colleges and universities) can be indications of such inequities. However, such indicators, although necessary, may not be sufficient to justify an inference of inequity. In principle, observed disparities among these groups in labor market variables can also reflect voluntary differences in labor market behavior among groups (such as career choices, occupational preferences, etc.) or differences among groups in sociodemographic characteristics (such as age, work experience). To the extent that these nonequity-related factors are operating in labor markets, they mean that observed disparities can overstate the degree of inequity that exists.

The indicators presented below suggest that both women and minorities are underrepresented in the science and engineering workforce. But women may be improving their representation, as evidenced by their increasing fraction of the degrees granted in science and engineering. This increased relative "flow" of new women entrants is slowly altering the sex composition of the stock of scientists and engineers. In contrast, among minorities, blacks appear to be making little progress in improving their representation.

Women in Science and Engineering

Population and Labor Force Participation. Of the approximately 2.7 million in the 1976 S/E population, about 9 percent were women. Only about 3 percent of these women were in engineering fields, and about three-fifths were in the life and social sciences, and psychology. In contrast, more than half the men were engineers rather than scientists. The concentration of women in science rather than engineering may partially reflect occupational stereotyping, on the part of both society and women themselves. The distribution of women among the various science fields may in part reflect society's "traditional" expectation of women. For example, the general public may view life sciences as health-related, and they may see health, along with psychology, as a helping occupation. Following their traditional roles as wives and mothers, women might be encouraged and/or pressured into helping fields. The current occupational distribution within science may also reflect limited opportunities for women in the physical sciences in the past, and few female role models.

Between 1974 and 1976, the number of women S/E's increased at a pace almost twice that for men (15 percent versus 8 percent).[44] The more rapid increases for women, both in the stock of the S/E population and in the number of degrees granted, may partly be attributed to affirmative action programs and increasing female awareness of opportunities in science and engineering. The number of science and engineering degrees awarded to women has increased more rapidly than those awarded to men recently, and an increasing proportion of women so trained are seeking careers in science and engineering. These indicators suggest that employers may be more willing to hire women for S/E jobs.

About 85 percent of all female S/E's were in the labor force in 1976—that is, employed or seeking employment. Of those S/E women not in the labor force, almost one-quarter were social scientists. Ninety-one percent of the males were in the labor force in 1976. The participation of both male and female S/E's in the labor force is greater than the participation rates of all males and all females of working age.[45] The labor force participation rate for all working-age women was 47 percent in 1976, and for working-age men, 78

[44] *Detailed Statistical Tables. U.S. Scientists and Engineers: 1976*, National Science Foundation (NSF 79-305), pp. 14, 46.

[45] *Employment and Training Report of the President, 1978*, U.S. Department of Labor, 1978, p. 182. Working age is defined as 16 years of age and older.

ERIC

percent. The difference between S/E women and all women is striking and suggests a much stronger labor force commitment by S/E women.

Women constituted 10.4 percent (31,673) of the doctoral-level S/E's in 1977, up from 9.5 percent in 1975 and 8.7 percent in 1973. The representation of women in the different fields of science varies considerably. Of all doctoral-level women S/E's, 34 percent were in the life sciences and another 27 percent were in psychology.[46]

As might be expected, the labor force participation rate of women holding the doctorate in S/E fields (90 percent) was somewhat above the rate of all female S/E's (85 percent).[47] The relatively high labor force participation of women holding S/E doctorates (and women S/E's in general) reflects more interest in S/E careers, favorable job opportunities for women in science and engineering, and the general tendency for labor force participation to increase with educational attainment.

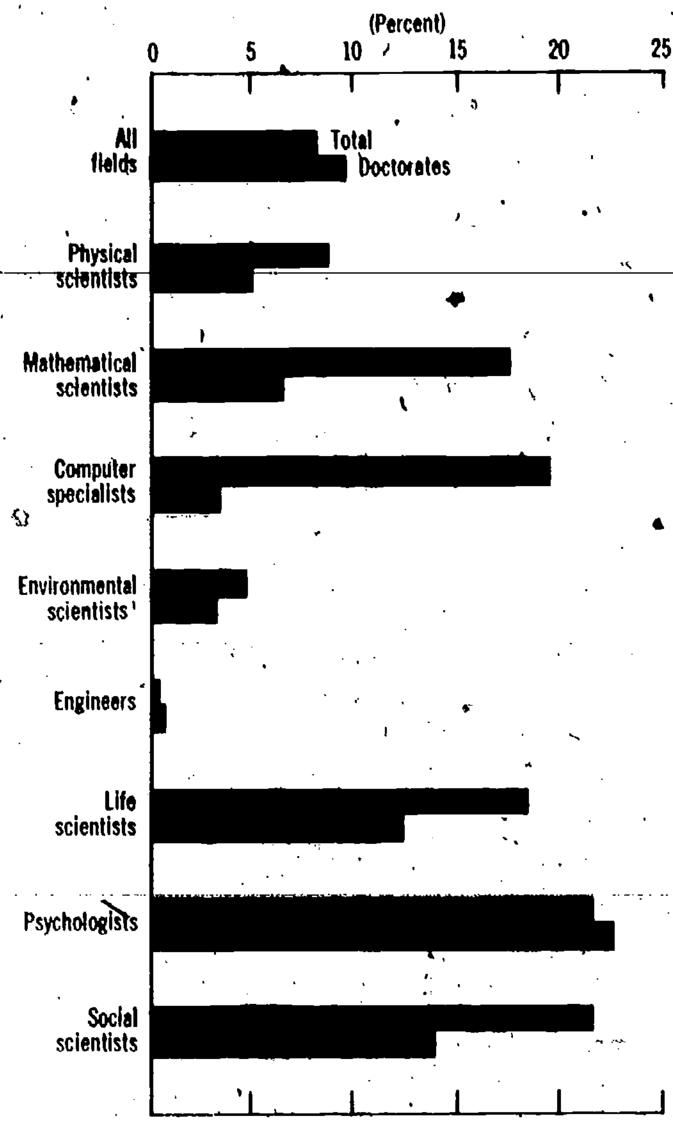
Employment. The number of employed female S/E's in 1976 (197,200) represented about 8.3 percent of all employed S/E's, up from 7.8 percent in 1974. Between 1974 and 1976, the employment of women scientists and engineers increased at a much faster rate (12 percent) than that for men (5 percent). Among science occupations, employment of women increased by about 11 percent, while the number of employed male scientists increased by almost 10 percent. In 1976, women represented about 17 percent of all employed scientists, up from about 8 percent in 1968.[48]

Women are still underrepresented in S/E jobs. In 1976, women represented about 40 percent of all employed persons, and a slightly higher proportion of all professional and technical workers (42 percent).[49] This latter group includes occupations, such as nursing and teaching, that traditionally employ large numbers of women. The various science and engineering fields vary widely in the proportions accounted for by women (see figure 5-19).

Of the 284,200 employed doctoral-level S/E's in 1977, 9.7 percent were women. The employment of women doctoral-level S/E's has been increasing, both absolutely and in comparison to that of men. Between 1973 and 1977, for example, the employment of women doctoral-level S/E's increased by 62 percent, and the comparable increase for men was 26 percent. Thus, the female portion of the employed doctoral S/E's went from 7.7 percent in 1973 to 9.7 percent in 1977.

Figure 5-19

Employed women scientists and engineers as percent of total S&E's: 1976
Employed women doctorate scientists and engineers as percent of total doctorates: 1977



[1] Includes earth scientists, oceanographers, and atmospheric scientists

REFERENCE: Appendix table 5-19. Science Indicators—1978

Unemployment Rates. Unemployment rates are one indicator of potential labor market problems. Higher unemployment rates for women suggest that they face labor market

[46] *Detailed Statistical Tables. Characteristics of Doctoral Scientists and Engineers in the United States, 1977*, National Science Foundation (NSF 79-306), pp. 24-25.

[47] *Detailed Statistical Tables. U.S. Scientists and Engineers: 1976*, National Science Foundation (NSF 79-305), p. 14.

[48] *American Science Manpower, 1968*, National Science Foundation (NSF 69-38), pp. 69, 253.

[49] *Employment and Training Report of the President, 1978*, U.S. Department of Labor, 1978, pp. 179-180, 205.

problems different from those of males in the scientific and technical work force. The unemployment rate for female S/E's in 1976 was 6.8 percent, in contrast to the 2.7 percent unemployment rate for male S/E's,[50] and almost double the 3.5 percent rate for women in the overall labor force with 4 or more years of college education.[51] The latter comparison should be treated with caution, since the S/E unemployment rate is not strictly comparable to the unemployment rate for all women with 4 years or more of college. For the latter population, persons who report they are not working and looking for work must indicate specific actions taken to find employment; otherwise they are counted as not being in the labor force. NSF surveys, however, do not contain this screening step. Hence, more S/E women would be counted as unemployed than would be the case if they had had to indicate specific job-seeking activity.

Approximately 35 percent of all women with 4 or more years of college were not in the labor force in 1976, whereas only about 15 percent of women S/E's were so classified. Also, a significant proportion of employed women with 4 or more years of college are not in professional occupations. In 1976, for example, almost one-third of the employed women with 4 or more years of college were in nonprofessional jobs; of these women, about half were in clerical occupations.[52] Higher unemployment rates for women S/E's, as compared to their male colleagues, also reflect to some extent the concentration of women in the behavioral and social sciences, fields which usually have above-average unemployment rates. In general, however, women have had higher unemployment rates than men regardless of field of science. Excluding psychology and the social sciences, the unemployment rate for women scientists was 4.1 percent in 1976 compared with 2.4 percent for males in the same fields. The sex difference in unemployment rates remains even after years of schooling are taken into account.

Among doctoral-level S/E's, the unemployment rate in 1977 for women (3.4 percent) was considerably above that for men (0.9 percent). With the exception of economists, the unemployment rates for women were higher than for men across all fields of science.

The above data suggest that considerable improvements are needed to achieve parity with respect to unemployment rates. However, as mentioned earlier, lack of parity does not necessarily imply inequity. No one knows to what extent the observed lack of parity reflects voluntary decisions on the part of women to forsake particular employment opportunities for more attractive opportunities. For example, if some of the women S/E's reported as unemployed have strong location preferences, because of their husbands, or because they have young children and cannot find satisfactory child-care arrangements, the inferences about equity that might be drawn from the observed disparity in unemployment rates would be weakened considerably.

Salaries. Salary similarities between men and women S/E's could be another indicator of equity in the S/E work force. However, differences do not necessarily imply inequity. Salary differentials can reflect many differences in variables including field, type of employer, higher degree, age, work activity, and years of work experience. Thus, for example, in 1977 the median age for male doctorate holders in S/E was 41 years and for women, 39 years. More importantly, in 1977, men with doctorates averaged 13.6 years of professional experience, while the average for women with doctorates was 9.2 years. In addition, a greater proportion of men than women were engaged in management, the work activity generally paying the highest salary.

Among doctoral S/E's, women had lower average salaries than men in 1977. Thus, for all fields, men with S/E doctorates earned $26,000 annually; the comparable figure for women was $20,700. This same general pattern shows across all S/E occupations (see figure 5-20) and across types of employer and work activity (see Appendix tables 5-20 and 5-28 through 5-31).[53]

Part of the overall difference in salaries is attributable to differences in average age and experience, the different fields in which men and women have tended to concentrate, and other differences. The salary gap narrows when comparisons are made between men and women with the same educational level, of the same age, in the same field, or holding similar jobs. For example, among doctoral S/E's, women under 30 years of age had salaries only about 7 percent below those

[50] *Detailed Statistical Tables, U.S. Scientists and Engineers: 1976*, National Science Foundation (NSF 79-305), p. 14.

[51] *Educational Attainment of Workers, March, 1976*, Special Labor Force Report 193, U.S. Department of Labor, Bureau of Labor Statistics, 1976.

[52] *Ibid.*

[53] Appendix tables 5-28 and 5-29 show salaries for all doctoral S/E's rather than for men only. However, from Appendix table 5-21 it can be seen that salaries for men are quite similar to the combined data for men and women.

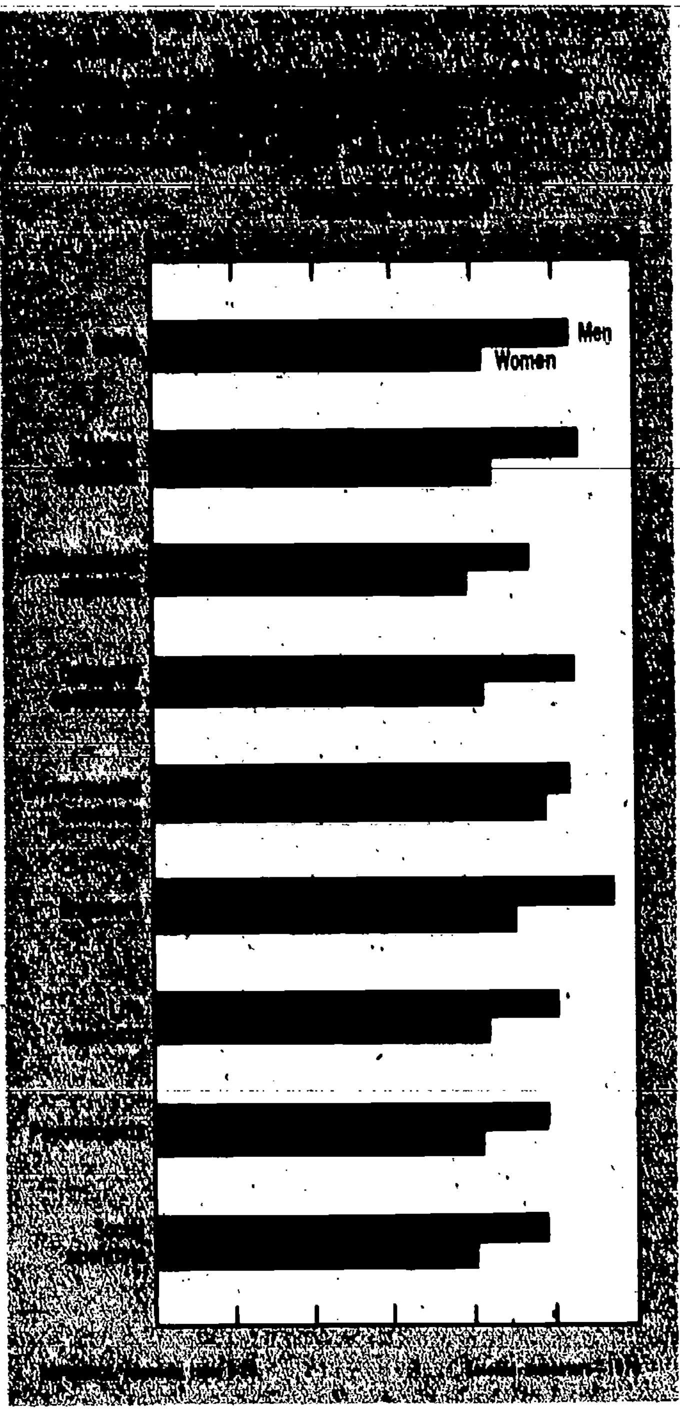
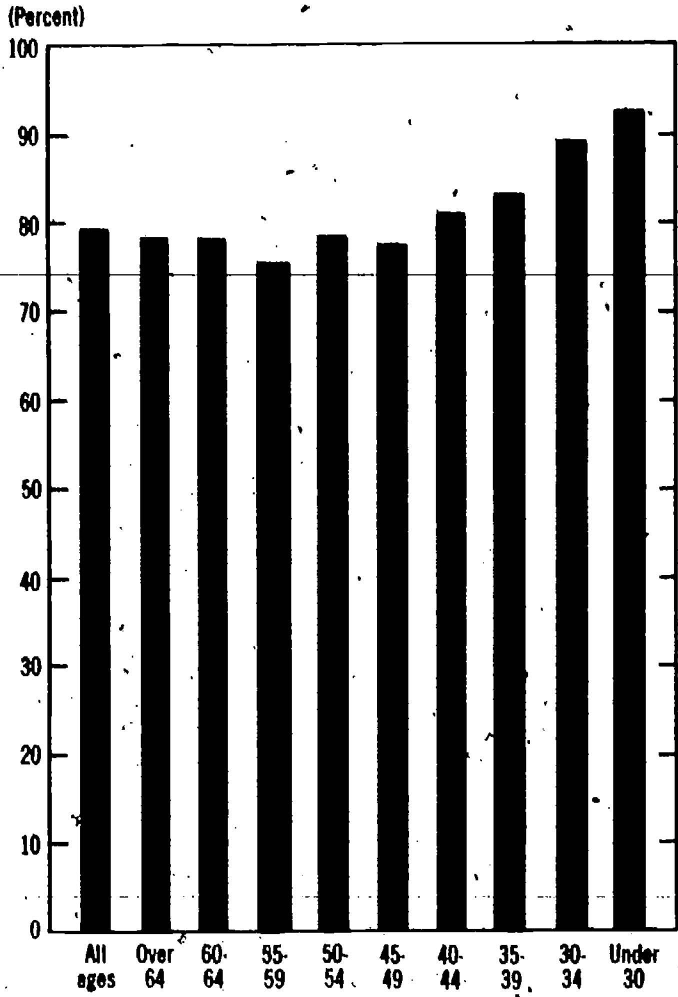


Figure 5-21
Median annual salaries of women doctoral scientists and engineers as a percent of those for men: 1977



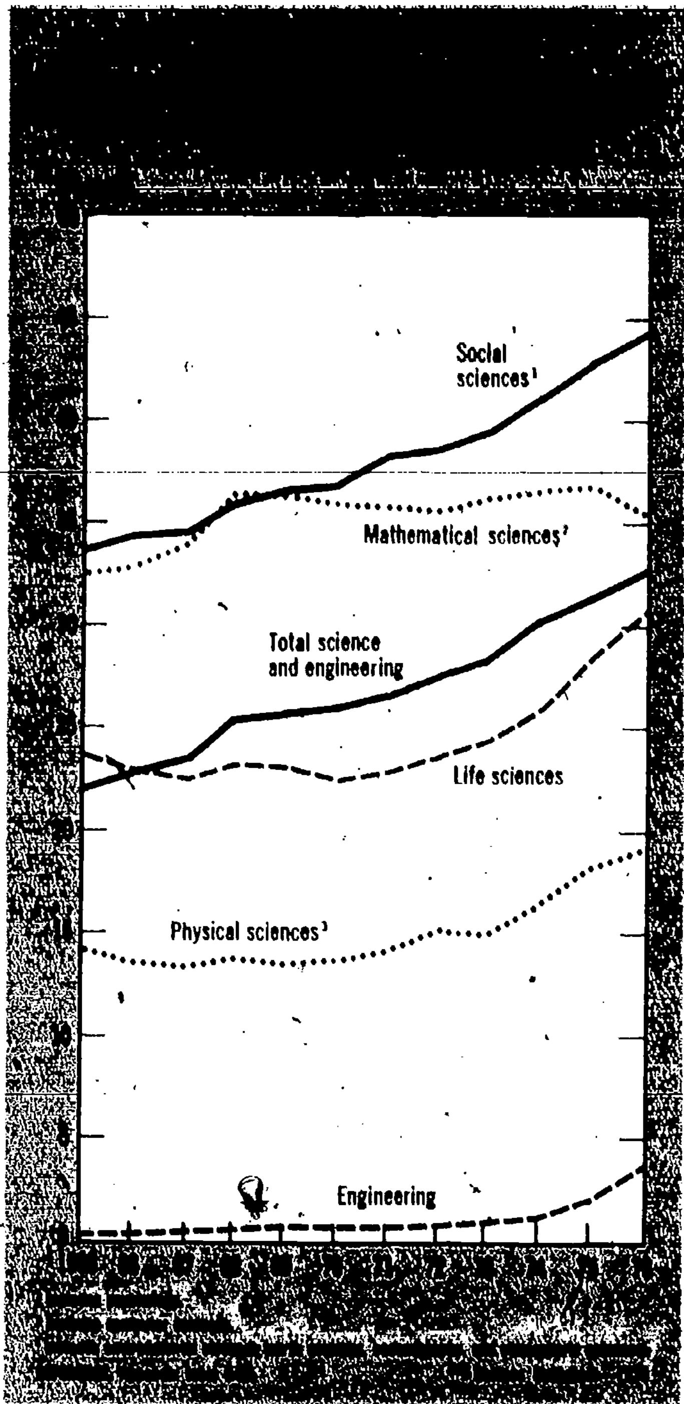
REFERENCE: Appendix table 5-21.

Science Indicators—1978

for men of the same age, while for all ages combined the difference was approximately 20 percent (see figure 5-21). As the career paths of men and women scientists become more similar, salary differentials should continue to narrow.

Science and Engineering Majors. Significant increases have occurred in both the number and proportion of women receiving degrees in the sciences and engineering. For example, between 1970 and 1976, the number of women receiving bachelor's degrees in science and engineering increased by almost 40 percent, from 69,000 to 96,000. For men, the increase was less than 1 percent (195,200 to 196,600). As a proportion of all bachelor's degrees in S/E, those awarded to women increased from 26 percent in 1970 to 33 percent in 1976 (see figure 5-22).

Doctoral degrees in science and engineering awarded to men declined by 11 percent (or about 1,800) between 1970 and 1977, primarily in the physical sciences and engineering. In contrast, the number of women receiving doctoral degrees in science and engineering increased by more than 90 percent over the 1970-77 period, with increases noted in all the major fields of science and engineering. As a proportion of all S/E doctoral degrees, those awarded to women



increased from almost 9 percent in 1970 to 18 percent in 1977 (see figure 5-23).

Transition from School to Work. Do the relatively immediate posteducational labor force experiences of men and women with science education differ? Data from a 1976 survey of 1973-74 and 1974-75 graduates at the bachelor's and master's degree levels help illuminate this issue.[54] The labor force participation rate for recent male S/E baccalaureates was 96 percent; for women, the rate was 91 percent. The labor force participation rate for women was considerably higher than the 65 percent reported for all working-age women with 4 years of college in 1976.[55] Clearly, women S/E graduates do seek employment and are a significant factor in the supply of new scientists and engineers.

The women baccalaureates, however, had a higher unemployment rate (10.9 percent) than men (7.4 percent) in 1976. The higher unemployment rate for women may be related to the fields of study in which they major. Two-thirds of the women S/E baccalaureates received their degrees in the social sciences (including psychology), in which the unemployment rate was 11.4 percent. In contrast, only 1 percent of the women majored in engineering (compared to 27 percent of the men), which had an unemployment rate of 3.5 percent. Of the recent S/E graduates who found employment, the proportion of men finding jobs in science and engineering was significantly greater than that for women—51 percent for men but only 29 percent for women. This disparity reflects, to large degree, the fields in which women major. In the physical sciences, roughly the same proportion of women (61 percent) and men (59 percent) found jobs in science and engineering. A similar finding was noted for engineering graduates (see figure 5-24).

The indicators presented above suggest that there has been an underutilization of women in science and engineering. Sex differentials in unemployment rates and salaries may be evidence of continuing problems, especially for older women S/E's. However, the increasing proportion of S/E degrees awarded to women, the increasing proportion of women in the S/E work force, and the narrowing of the male-female gap in starting salaries suggest that the problems may gradually be diminishing.

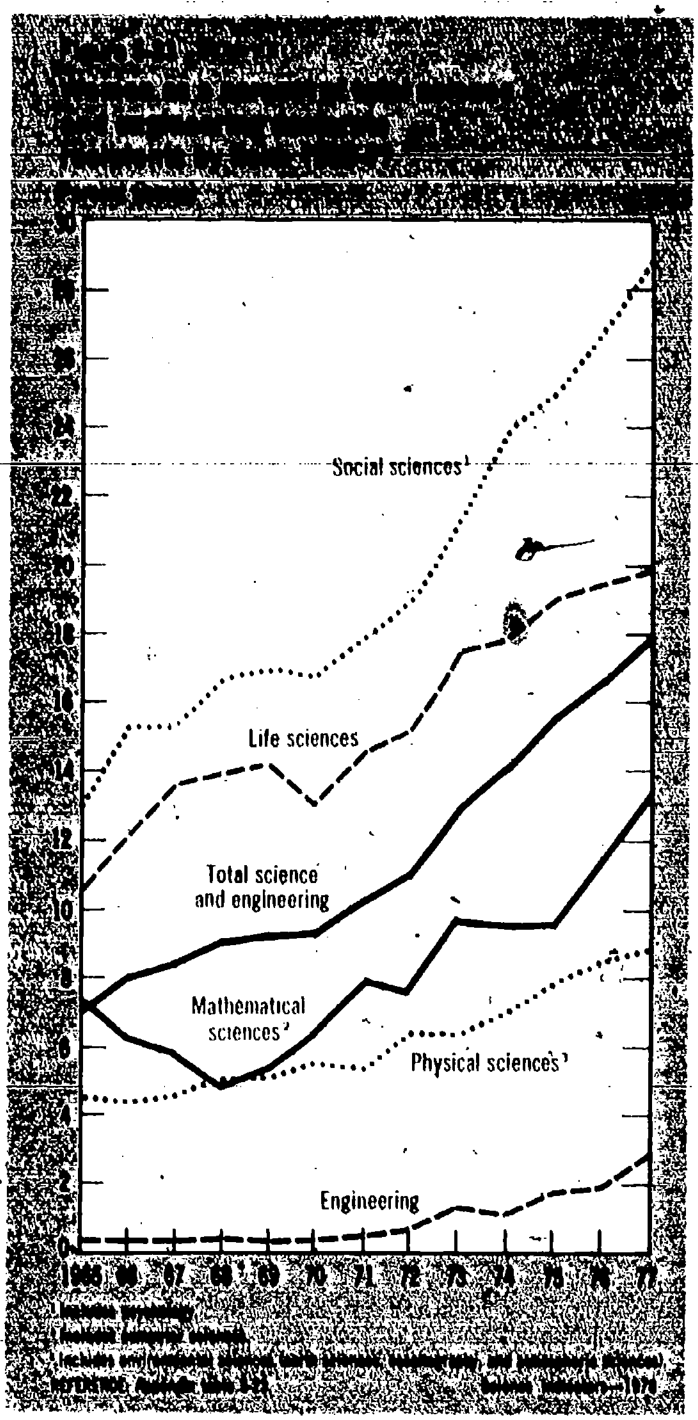
Minorities in Science and Engineering

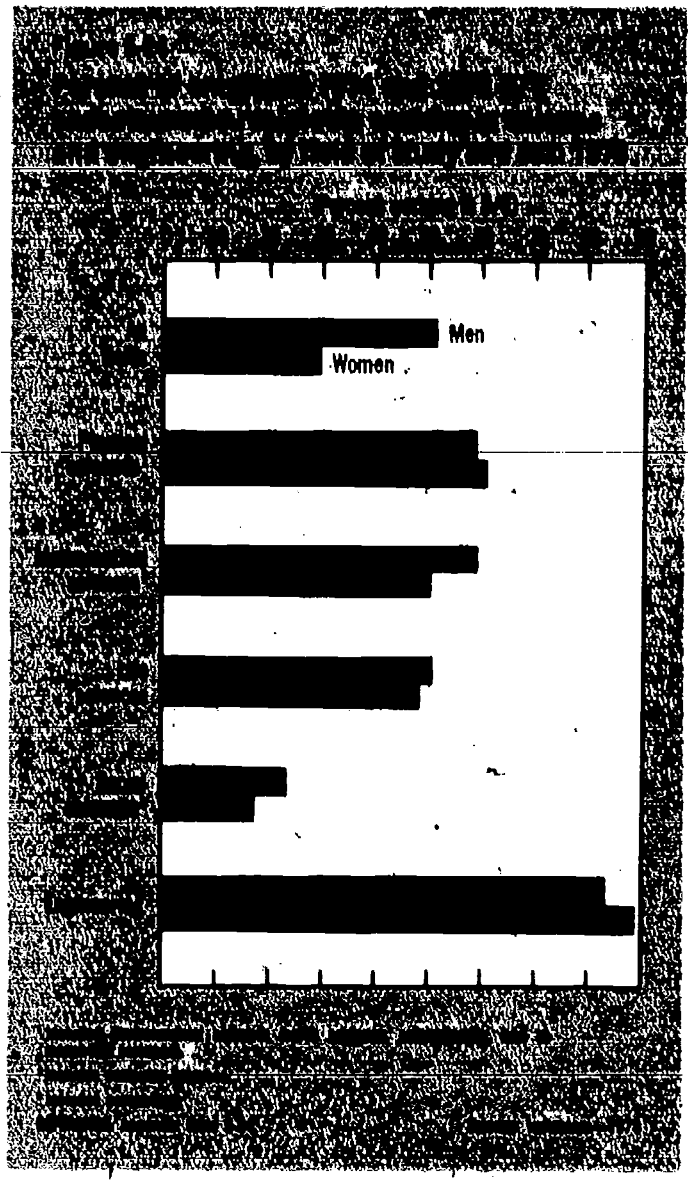
Population and Labor Force Participation. Only about 4 percent of all S/E's in 1976 were members of racial minority groups.[56] By way of contrast, about 8 percent of all professional and

[54] "Employment Patterns of Recent Entrants into Science and Engineering," *Reviews of Data on Science Resources*, National Science Foundation (NSF 78-310).

[55] *Educational Attainment of Workers, March 1976*, Special Labor Force Report 193, U.S. Department of Labor, Bureau of Labor Statistics, 1976.

[56] Includes blacks, American Indians, Asian-Americans, and all other minority groups, as well as those not reporting race. Of the estimated 112,000 members of racial minority groups reported in 1976, about 9,500 or 8 percent were those who had not reported their race.

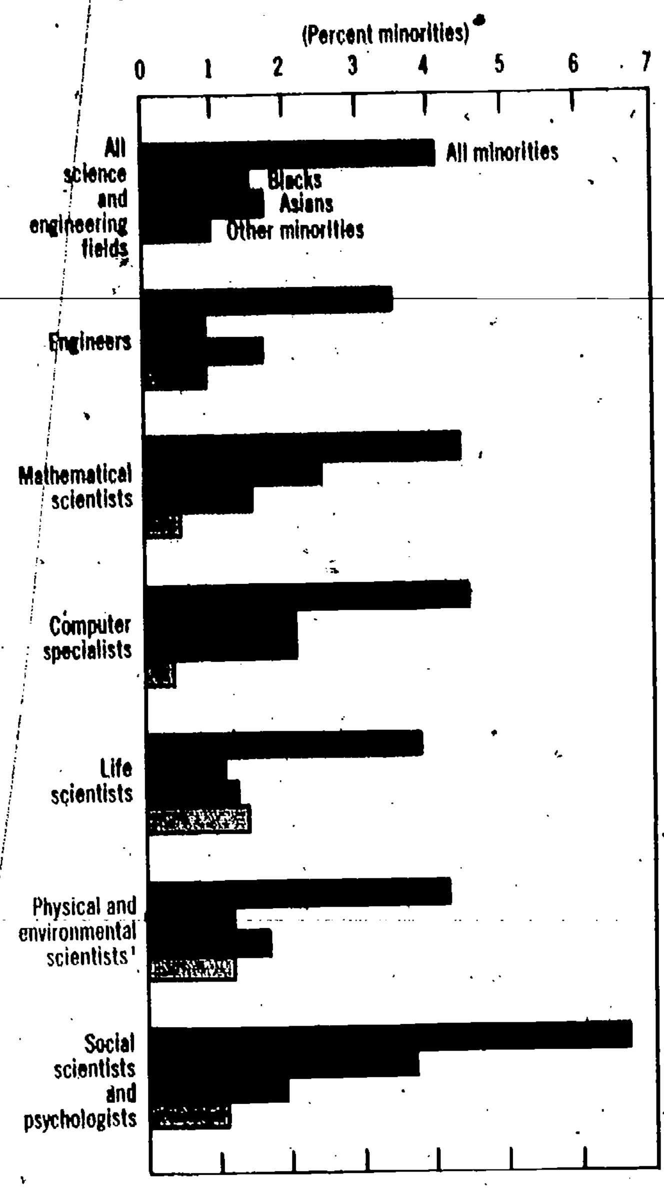




related workers in 1976 were members of racial minority groups. About 40 percent of the minority S/E's were of Asian extraction, while blacks represented about 36 percent of all minority S/E's. Because of differences in distribution by field and educational attainment among blacks, Asian-Americans, and other minorities, treating racial minorities as a single total may be quite misleading (see figures 5-25 and 5-26). Any analysis of minorities in science and engineering should distinguish, whenever possible, between blacks and persons of Asian extraction.

The need for separate treatment is clear; the scientists and engineers of Asian extraction include a distinctly higher proportion with doctorates than is found among the white majority, while the proportion of blacks with doctorates is somewhat lower than that of whites (see text table 5-3). In recent additions to the doctoral-level S/E work force, the number of blacks grew more rapidly than the number of whites from 1973 to 77—35 percent increase versus 26 percent—but these increases were far below the 70 percent increase for Asians. These and other data show that Asian-Americans are well represented in the S/E work force and need no special attention. Because of data limitations, however, it is not known whether or not this general statement applies to all the subgroups within the Asian-American category.

Figure 5-25
Minority representation among scientists and engineers: 1976



[1] Includes earth scientists, oceanographers, and atmospheric scientists
REFERENCE: Appendix table 5-25.
Science Indicators—1978

Blacks present a quite different picture. Although blacks who become S/E's fare about as well as their white colleagues, the number acquiring the qualifications to enter the S/E labor force lags badly. The 1976 labor force participation rate of black S/E's (89 percent) was quite similar to that for their white counterparts (91 percent)[57] and was considerably above the 1976 rate for all blacks in the general population (about 59 percent).[58] Of those black S/E's not in the labor force, about two-fifths were social scientists. At the doctoral level, the labor force participation rate for black scientists and engineers in 1977 was somewhat above that for their white colleagues (97 percent versus 95 percent).[59]

Unemployment Rates. Unemployment among black S/E's is significantly higher than among whites. In 1976, black S/E's had an 8.3 percent unemployment rate; whites, 3.0 percent; and Asian-Americans, 2.8 percent. It is interesting that more than half of the unemployed blacks were social scientists, primarily sociologists and anthropologists. Thus, the relatively high unemployment among black scientists and engineers reflects to some extent the distribution of blacks among the various fields of science. When psychology and the social sciences are excluded from the analysis, black S/E's show an unemployment rate of 4.9 percent versus 2.5 percent for whites.

At the doctoral level, black S/E's in 1977 showed an unemployment rate (0.7 percent), somewhat lower than that for whites (1.1 percent), while Asian-Americans reported a rate (1.5 percent) somewhat higher than that for whites. This general pattern was noted across most major fields of science.

Salaries. Among doctoral-level S/E's, both blacks and Asian-Americans reported 1977 salaries that averaged 7 percent lower than those for their white colleagues. With some exceptions, this general pattern held across the major fields of science. Black biological scientists and sociologists/anthropologists reported higher salaries than both whites and Asian-Americans in the same fields. Among psychologists, the highest annual salaries were reported by Asian-Americans (see Appendix table 5-20).

As previously stated, salary differences can reflect many variables including age, years of experience, field, type of employer (industry, government, academia, etc.), and primary work activity (R&D, teaching, etc.).

Science and Engineering Majors. In 1977, only about 350 blacks received the doctorate in science and engineering fields, up from about 265 in

[57] *Detailed Statistical Tables, U.S. Scientists and Engineers, 1976*, National Science Foundation (NSF 79-305), p. 15.

[58] *Employment and Training Report of the President, 1978*, U.S. Department of Labor, 1978, p. 193.

[59] *Detailed Appendix Tables, Characteristics of Doctoral Scientists and Engineers in the United States, 1977*, National Science Foundation (NSF 79-306), p. 24.

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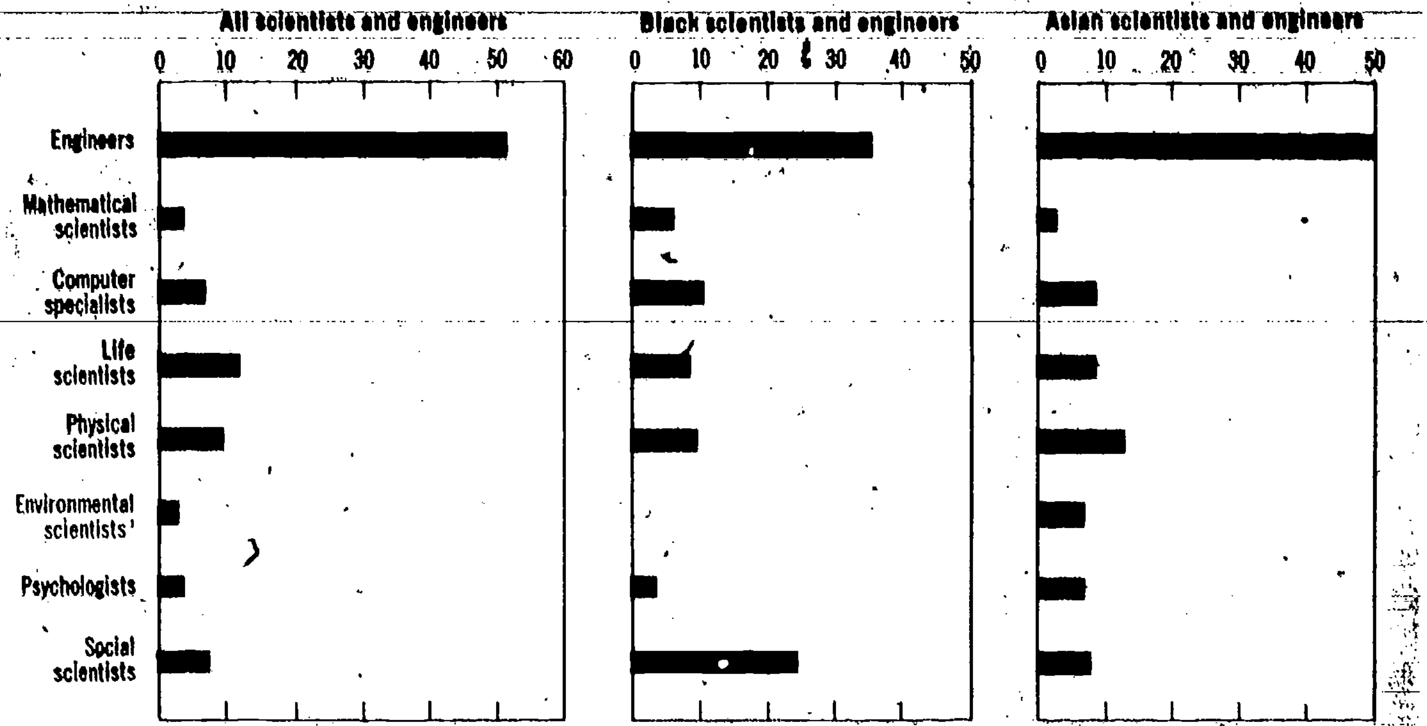
Figure 5-26

Percent distribution of employed scientists and engineers by field, for selected minority groups: 1976



[1]Includes earth scientists, oceanographers, and atmospheric scientists.
[2]Less than 0.5 percent.
REFERENCE: Appendix table 5-26.

Science Indicators—1978

Table 5-3. Percent distribution of scientists and engineers by highest degree and minority group: 1976

Level	Total	White	Black	American Indian	Asian	Other minorities
Total	100	100	100	100	100	100
Doctorate	11	10	7	15	33	7
Masters	24	24	24	15	27	21
Baccalaureate	62	63	68	58	40	70
Other[1]	3	3	2	12	1	1

[1]Includes professional medical degrees, associate degrees, and others.

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

REFERENCE: Appendix table 5-27.

1974. In 1977, blacks constituted about 11 percent of the total U.S. population but received only about 2.3 percent of all doctorates in science and engineering awarded to U.S. citizens.[60] Moreover, black doctorate recipients are concentrated in the social sciences and psychology. In 1977, for example, about two-thirds of the blacks who received doctorates in science and engineering earned their degrees in social sciences and psychology; in contrast, the social sciences and psychology proportion of S/E doctorates earned by all U.S. citizens was about 38 percent.

In 1976, blacks represented about 9 percent of all students enrolled in institutions of higher education. Among science and engineering fields, however, black representation was below average. For example, blacks represented 6.6 percent of those enrolled in the biological sciences, 5 percent of those in engineering, and 4.3 percent of those in the physical sciences.[61]

The indicators presented above reveal that blacks are underrepresented in science and engineering. The data also show that blacks have made progress toward achieving equity in the S/E work force. Nevertheless, substantially increased representation will require considerable time since it depends on more extensive development of the background skills needed for science activities prior to college entry.[62]

[60] Including noncitizens on permanent visas. Of the 350 blacks earning S/E doctoral degrees in 1977, about 40 were noncitizens on permanent visas.

[61] *Fall Enrollment in Higher Education, 1976*, U.S. Department of Health, Education and Welfare, National Center for Education Statistics, 1978.

[62] See *Women and Minorities in Science and Engineering*, National Science Foundation (NSF 77-304), p. 14.

Appendix I
Statistical Tables

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Table 1-1. National expenditures for performance of R&D as a percent of gross national product (GNP) by country: 1961-78

Year	France	West Germany	Japan	United Kingdom	United States	U.S.S.R.
			Ratio of R&D expenditures to Gross National Product[1]			
1961	1.38	NA	1.39	2.39	2.74	NA
1962	1.46	1.25	1.47	NA	2.73	2.64
1963	1.55	1.41	1.44	NA	2.87	2.80
1964	1.81	1.57	1.48	2.30	2.97	2.87
1965	2.01	1.73	1.54	NA	2.91	2.85
1966	2.03	1.81	1.48	2.32	2.90	2.88
1967	2.13	1.97	1.53	2.33	2.91	2.91
1968	2.08	1.97	1.61	2.29	2.83	NA
1969	1.94	2.05	1.65	2.23	2.74	3.03
1970	1.91	2.18	1.79	NA	2.64	3.23
1971	1.90	2.38	1.84	NA	2.50	3.29
1972	1.86	2.33	1.85	2.06	2.43	3.58
1973	1.77	2.32	1.89	NA	2.34	3.66
1974	1.81	2.26	1.95	NA	2.32	3.64
1975	1.82	2.39	1.94	2.05	2.30	3.69
1976	1.78	2.28	1.94	NA	2.27	3.55
1977	1.79	2.26	NA	NA	2.27	3.47
1978	NA	2.28	NA	NA	2.25	NA
			Index of R&D/GNP (1961 = 1.00)			
1961	1.00	NA	1.00	1.00	1.00	NA
1962	1.06	1.00	1.06	NA	1.00	1.00
1963	1.12	1.13	1.04	NA	1.05	1.06
1964	1.31	1.26	1.06	.96	1.08	1.09
1965	1.46	1.38	1.11	NA	1.06	1.08
1966	1.47	1.45	1.06	.97	1.06	1.09
1967	1.54	1.58	1.10	.97	1.06	1.10
1968	1.51	1.58	1.16	.95	1.03	NA
1969	1.41	1.64	1.19	.93	1.00	1.15
1970	1.38	1.74	1.29	NA	.96	1.22
1971	1.38	1.90	1.32	NA	.91	1.25
1972	1.35	1.86	1.33	.86	.89	1.36
1973	1.28	1.78	1.36	NA	.85	1.39
1974	1.31	1.81	1.40	NA	.85	1.38
1975	1.32	1.91	1.40	.86	.84	1.40
1976	1.30	1.82	1.40	NA	.83	1.34
1977	1.30	1.81	NA	NA	.83	1.31
1978	NA	1.82	NA	NA	.82	NA

(continued)

Table 1-1. (Continued)

Year	France	West Germany	Japan	United Kingdom	United States	U.S.S.R.
			R&D expenditures (national currency in billions)[2]			
1961	4.5	NA	275.5	0.66	14.3	NA
1962	5.4	4.5	319.3	NA	15.4	5.2
1963	6.4	5.4	368.3	NA	17.1	5.8
1964	8.3	6.6	438.1	.77	18.9	6.4
1965	9.8	7.9	508.6	NA	20.0	6.9
1966	10.8	8.8	576.6	.89	21.8	7.5
1967	12.2	9.7	702.5	.94	23.2	8.2
1968	13.1	10.6	877.5	1.00	24.6	9.0
1969	14.2	12.2	1,064.7	1.05	25.6	10.0
1970	15.0	14.8	1,355.5	NA	25.9	11.7
1971	16.6	18.0	1,532.4	NA	26.6	13.0
1972	18.3	19.2	1,791.9	1.31	28.4	14.4
1973	19.8	20.5	2,215.8	NA	30.6	15.7
1974	23.0	22.3	2,716.0	NA	32.7	16.5
1975	26.2	24.6	2,974.6	2.14	35.2	17.4
1976	29.8	25.7	3,320.7	NA	38.6	17.7
1977	33.5	27.1	NA	NA	42.8	18.3
1978	NA	29.2	NA	NA	47.3	18.9
			Gross National Product (national currency in billions)			
1961	328.3	333.0	19,852.8	27.5	523.3	NA
1962	367.2	360.5	21,659.5	28.9	563.8	197.2
1963	412.0	382.1	25,592.1	30.8	594.7	206.8
1964	456.7	419.6	29,661.9	33.6	635.7	223.2
1965	489.8	458.2	32,985.8	36.0	688.1	242.1
1966	532.0	487.4	38,876.0	38.4	753.0	260.1
1967	574.8	493.7	45,901.3	40.4	796.3	282.0
1968	630.0	535.2	54,582.1	43.6	868.5	NA
1969	734.0	597.7	64,520.8	46.8	935.5	329.6
1970	783.6	679.0	75,529.5	51.5	982.4	362.6
1971	873.1	756.0	83,167.9	57.5	1,063.4	394.8
1972	981.8	827.2	96,888.4	63.6	1,171.1	401.8
1973	1,115.1	920.1	117,277.3	73.6	1,306.6	429.4
1974	1,274.3	986.9	139,256.5	83.4	1,412.9	453.1
1975	1,441.0	1,032.9	153,118.7	104.1	1,528.8	471.8
1976	1,675.4	1,127.9	171,342.7	123.5	1,700.1	498.6
1977	1,870.3	1,198.7	190,134.5	139.8	1,887.2	527.6
1978	NA	1,278.3	NA	NA	2,100.0	NA

[1] Calculated from unrounded figures.

[2] Gross expenditures for performance of R&D including associated capital expenditures except for the United States where total capital expenditure data are not available. U. S. estimates for the period 1972-77 show that the inclusion of capital expenditures would have an impact of less than one tenth of one percent on the R&D/GNP ratio.

NA = not available.

NOTE: The latest data may be preliminary or estimates. The French gross domestic product is provided in place of the GNP for 1977.

SOURCES: Organisation for Economic Co-operation and Development, *International Survey of the Resources Devoted to R&D by Member Countries, International Statistical Years, 1963/64, 1967, 1969, 1971, 1973 and 1975. International Financial Statistics*, Vol. 30 (May, 1977); Vol. 31 (May, 1978); Vol. 31 (August, 1978); and Vol. 32 (January, 1979).

France: Delegation Generale a la Recherche Scientifique et Technique, unpublished statistics.
Japan: Scientific Councelor Embassy of Japan, Washington, D. C., unpublished statistics.
United Kingdom: Science and Technology Department, The British Embassy, Washington, D. C., unpublished statistics.
West Germany: Bundesministerium fur Forscheng und Technologie, unpublished statistics.
United States: Science Resources Studies, National Science Foundation, unpublished statistics.
U.S.S.R.: Robert W. Campbell, *Reference Source on Soviet R&D Statistics, 1950-1978*, 1978.

See figure 1-1.

Table 1-2. G.E.R.D. in national currency by source of funds: 1967-75

	National currency (in millions)				Percent			
	1967	1971	1973	1975	1967	1971	1973	1975
France	12,375.8	16,006.4	19,788.8	26,203.1	100.0	100.0	100.0	100.0
Total domestic	11,965.0	15,427.1	19,116.0	24,847.4	96.7	96.4	96.6	94.8
Business enterprise	3,896.5	5,728.1	7,583.7	10,234.0	31.5	35.8	38.3	39.1
Government and other	8,068.5	9,699.0	11,532.3	14,613.4	65.2	60.6	58.3	55.8
From abroad	410.8	579.3	672.8	1,355.7	3.3	3.6	3.4	5.2
Japan	606,293.0	1,345,919.0	2,147,726.0	2,974,573.0	100.0	100.0	100.0	100.0
Total domestic	605,841.0	1,344,929.0	2,146,344.0	2,972,591.0	99.9	99.9	99.9	99.9
Business enterprise	380,794.0	893,380.0	1,318,670.0	1,706,861.0	62.8	66.4	61.4	57.4
Government and other	225,047.0	451,549.0	827,674.0	1,265,730.0	37.1	33.5	38.5	42.6
From abroad	452.0	988.0	1,381.0	1,981.0	.1	.1	.1	.1
United Kingdom[1]	941.8	1,081.9	1,322.6	2,152.2	100.0	100.0	100.0	100.0
Total domestic	905.5	1,042.4	1,251.4	2,047.1	96.2	96.4	94.6	95.1
Business enterprise	405.2	461.9	571.7	873.0	43.0	42.7	43.2	40.6
Government and other	500.3	580.5	679.7	1,174.1	53.1	53.7	51.4	54.6
From abroad	36.3	39.4	71.3	105.1	3.8	3.6	5.4	4.9
United States[2]	22,453.0	27,527.6	30,410.6	36,695.0	100.0	100.0	100.0	100.0
Total domestic	22,453.0	27,527.6	30,410.6	36,695.0	100.0	100.0	100.0	100.0
Business enterprise	7,356.0	10,813.0	12,890.4	15,985.8	32.8	39.3	42.4	43.0
Government and other	15,097.0	16,714.6	17,520.2	20,909.2	67.2	60.7	57.6	57.0
From abroad	NA	NA	NA	NA	NA	NA	NA	NA
West Germany	8,337.3	15,609.0	19,232.0	22,969.0	100.0	100.0	100.0	100.0
Total domestic	8,297.4	15,470.0	19,019.0	22,461.0	99.5	99.1	98.9	97.8
Business enterprise	4,794.0	8,572.0	9,357.0	11,514.0	57.5	54.9	48.6	50.1
Government and other	3,503.4	6,898.0	9,661.0	10,947.0	42.0	44.2	50.2	47.7
From abroad	39.9	139.0	213.0	508.0	.5	.9	1.1	2.2

[1] All 1971 United Kingdom figures are from 1970, and 1973 figures from 1972.
[2] United States' 1967 figures are from 1966.

NA = not available.

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

SOURCE: Organisation for Economic Co-operation and Development, *International Survey of the Resources Devoted to R & D by Member Countries, International Statistical Years* 1967, 1971, 1973, and 1975.

See figure 1-2.

Table 1-3. Scientists and engineers[1] engaged in R&D per 10,000 labor force population, by country: 1965-78

Country	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
	Scientists and engineers[1] engaged in R&D per 10,000 labor force population													
France	21.0	23.0	25.3	26.4	27.2	27.3	27.8	28.1	28.4	28.8	29.3	29.9	NA	NA
West Germany	22.6	22.3	23.9	25.9	28.8	30.8	33.5	35.7	37.4	38.2	39.4	40.0	40.5	NA
Japan	24.6	26.4	27.8	31.1	30.8	33.4	37.5	38.1	42.5	44.9	47.9	48.4	49.9	NA
United Kingdom	21.4	NA	NA	17.2	NA	NA	NA	27.8	NA	NA	30.6	NA	NA	NA
United States	64.1	66.1	66.1	66.9	66.1	63.6	60.6	58.3	56.8	56.3	56.4	56.7	57.4	58.0
U.S.S.R. (low est)	44.8	47.1	50.7	53.5	56.5	58.4	63.0	66.5	73.5	74.5	78.2	80.7	81.9	NA
U.S.S.R. (high est)	48.2	51.4	55.3	58.8	62.1	64.2	69.1	73.2	81.5	82.9	87.5	90.9	92.7	NA
	Scientists and engineers engaged in R&D (in thousands)													
France	42.8	47.9	52.4	54.7	57.2	58.5	60.1	61.2	62.7	64.1	65.3	67.0	NA	NA
West Germany	61.0	60.0	63.0	68.0	76.3	82.5	90.2	96.0	101.0	102.5	103.9	104.5	105.5	NA
Japan	117.6	128.9	138.7	157.6	157.1	172.0	194.3	198.1	226.6	238.2	255.2	260.2	272.0	NA
United Kingdom	54.6	NA	NA	43.6	NA	NA	NA	77.1	NA	NA	78.8	NA	NA	NA
United States	494.5	521.1	534.4	550.4	556.6	546.5	526.4	518.5	517.5	525.4	534.8	549.9	571.1	595.0
U.S.S.R. (low est)	521.8	556.5	607.8	650.8	698.8	733.3	804.2	862.5	966.7	995.8	1,061.2	1,113.7	1,147.8	NA
U.S.S.R. (high est)	561.4	607.6	662.6	715.2	767.5	806.9	881.8	950.1	1,072.1	1,108.0	1,187.6	1,254.5	1,299.1	NA
	Total labor force (in thousands)													
France	20,381	20,522	20,676	20,744	20,996	21,465	21,638	21,817	22,083	22,282	22,310	22,440	22,468	NA
West Germany	27,034	26,962	26,409	26,291	26,535	26,817	26,910	26,901	26,985	26,797	26,397	26,148	26,051	NA
Japan	47,870	48,910	49,830	50,610	50,980	51,530	51,860	52,000	53,260	53,100	53,230	53,780	54,520	NA
United Kingdom	25,498	25,632	25,490	25,378	25,370	25,300	25,123	25,194	25,545	25,602	25,795	26,093	26,327	NA
United States	77,178	78,893	80,793	82,272	84,239	85,903	86,929	88,901	91,040	93,240	94,793	96,917	99,534	102,537
U.S.S.R.	116,494	118,138	119,893	121,716	123,584	125,612	127,672	129,722	131,610	133,600	135,767	137,987	140,140	NA

[1] Includes all scientists and engineers engaged in R&D on a full-time-equivalent basis (except for Japan whose data include persons primarily employed in R&D and the United Kingdom whose data include only the Government and industry sectors).

NA = Not available

NOTE: Estimates are shown for most countries for latest years and for the United States for 1966 and 1967. A range has been provided for the U.S.S.R. because of the difficulties inherent in comparing Soviet scientific personnel data.

SOURCES: Organisation for Economic Co-operation and Development, *Labor Force Statistics, 1965-1976* (Paris: OECD, 1978), p. 23, and August 1978 Quarterly Supplement; Department of Labor, *Employment and Training Report of the President*, 1978, p. 179.

France: Delegation Generale a la Recherche Scientifique et Technique, unpublished statistics.
Japan: Scientific Councelor Embassy of Japan, Washington, D.C., unpublished statistics.
United Kingdom: Science and Technology Department, The British Embassy, Washington, D.C., unpublished statistics.
West Germany: Bundesministerium fur Forschung und Technologie, unpublished statistics.
United States: National Science Foundation, *National Patterns of R&D Resources, 1953-1978-79*, (NSF 78-313), 1979, p. 45.
U.S.S.R.: Dr. Robert W. Campbell, *Reference Source on Soviet R&D Statistics, 1950-1978*, 1978; and Steven Rapawy, *Estimates and Projections of the Labor Force and Civilian Employment in the U.S.S.R., 1950 to 1990*, Foreign Economic Report No. 10, (Washington, D.C.: Department of Commerce, 1976), p. 19.

See figure 1-3.

Table 1-4. Estimated ratio of civilian R&D expenditures[1] to gross national product (GNP) for selected countries: 1961-76

Year	France	West Germany	Japan	United Kingdom	United States
	Estimated civilian R&D expenditures as a percent of GNP				
1961	0.97	NA	1.37	1.48	1.10
1962	1.03	1.14	1.46	NA	.97
1963	1.10	1.26	1.43	NA	.81
1964	1.34	1.38	1.47	1.46	1.02
1965	1.37	1.53	1.53	NA	1.00
1966	1.40	1.62	1.47	1.58	1.10
1967	1.50	1.70	1.51	1.68	1.23
1968	1.54	1.72	1.60	1.70	1.37
1969	1.49	1.81	1.64	1.69	1.47
1970	1.47	1.96	NA	NA	1.52
1971	1.37	2.16	NA	NA	1.41
1972	1.39	2.13	NA	1.49	1.44
1973	1.30	2.01	NA	NA	1.47
1974	1.34	2.27	1.91	NA	1.46
1975	1.41	2.20	NA	1.50	1.42
1976	1.42	2.09	NA	NA	1.39
	Estimated civilian R&D expenditures[2] (national currency in billions)				
1961	3.2	NA	272.3	0.41	5.75
1962	3.8	4.1	316.3	NA	5.49
1963	4.6	4.8	365.7	NA	4.81
1964	6.1	5.8	434.7	.49	6.50
1965	6.7	7.0	504.0	NA	6.90
1966	7.4	7.9	570.5	.61	8.27
1967	8.6	8.4	695.4	.68	9.82
1968	9.7	9.2	871.9	.74	11.89
1969	10.9	10.8	1,056.1	.79	13.74
1970	11.5	13.3	NA	NA	14.91
1971	12.0	16.3	NA	NA	14.98
1972	13.6	17.6	NA	.95	16.81
1973	14.5	18.5	NA	NA	19.16
1974	17.1	20.4	2,663.1	NA	20.60
1975	20.3	22.7	NA	1.56	21.68
1976	23.7	23.6	NA	NA	23.66

(continued)

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Table 1-4. (Continued)

Year	France	West Germany	Japan	United Kingdom	United States
	Gross national product (national currency in billions)				
1961	328.3	333.0	19,852.8	27.5	523.3
1962	367.2	360.5	21,659.5	28.9	563.8
1963	412.0	382.1	25,592.1	30.8	594.7
1964	456.7	419.6	29,661.9	33.6	635.7
1965	489.8	458.2	32,985.8	36.0	688.1
1966	532.0	487.4	38,876.0	38.4	753.0
1967	574.8	493.7	45,901.3	40.4	796.3
1968	630.0	535.2	54,582.1	43.6	868.5
1969	734.5	597.7	64,520.8	46.8	935.5
1970	783.6	679.0	75,529.5	51.5	982.4
1971	873.1	756.0	83,167.9	57.5	1,063.4
1972	981.3	827.2	96,888.4	63.6	1,171.1
1973	1,115.1	920.1	117,277.3	73.6	1,306.6
1974	1,274.3	896.9	139,256.5	83.4	1,412.9
1975	1,441.0	1,032.9	153,118.7	104.1	1,528.8
1976	1,669.3	1,127.9	171,342.7	123.5	1,700.1

[1] National expenditures for R&D, excluding Government funds for defense and space.

[2] Gross expenditures for performance of R&D including associated capital expenditures, except for the United States, where total capital expenditure data are not available.

NA = Not available

NOTE: The latest data from these sources may be preliminary or estimates.

SOURCES: Calculated from Appendix table 1-1 and Organisation for Economic Cooperation and Development, *Changing Priorities for Government R&D* (Paris: OECD, 1975), and OECD, *International Survey of the Resources Devoted to R&D by Member Countries, International Statistical Year — 1973: The Objectives of Government R&D Funding 1970-76* Vol. 2B (Paris: OECD, 1977).

See figure 1-4.

Table 1-5. Estimated distribution of Government R&D expenditures among selected national objectives[1] by country: 1961-77

	National defense	Space	Energy production	Economic development	Health	Community services	Advancement of knowledge[2]
France				National currency in millions			
1961	1,310.0	16.5	735.0	231.6	13.0	12.7	592.3
1967	3,082.0	522.8	1,723.2	1,381.0	116.1	81.0	1,758.1
1972	3,050.0	730.0	1,600.0	2,200.0	200.0	170.0	2,800.0
1975	5,000.0	942.2	1,453.0	4,329.4	680.2	328.7	4,072.2
1976	5,200.0	907.4	1,505.2	4,031.1	755.9	398.4	4,432.6
				Percent distribution			
1961	44	1	25	8	(3)	(3)	20
1967	35	6	20	16	1	1	20
1972[4]	28	7	15	20	2	2	26
1975	30	6	9	26	4	2	24
1976	30	5	9	23	4	2	26
Japan				National currency in millions			
1961-62	3,162.0	—	5,881.0	25,446.0	724.0	1,071.0	47,321.0
1965-66	4,495.0	141.0	4,944.0	44,898.0	3,679.0	2,818.0	103,163.0
1969-70	6,523.0	2,083.0	22,539.0	69,987.0	5,492.0	7,254.0	185,376.0
1974-75	15,809.0	37,090.0	59,409.0	161,796.0	21,424.0	18,129.0	388,700.0
				Percent distribution			
1961-62	4	—	7	30	1	1	56
1965-66	3	(3)	3	27	2	2	63
1969-70	2	1	8	23	2	2	61
1974-75	2	5	8	23	3	3	55
United Kingdom				National currency in millions			
1961-62	248.6	2.7	56.6	37.9	5.7	0.7	26.0
1966-67	260.4	21.4	65.2	70.9	13.3	2.2	58.4
1972-73	336.8	15.3	69.6	182.8	39.1	8.3	121.8
1974-75	503.1	22.5	68.6	230.6	22.6	13.1	214.9
1975-76	553.5	27.0	87.0	283.3	31.8	17.9	237.1
				Percent distribution			
1961-62	65	1	15	10	2	(3)	7
1966-67	52	4	13	14	3	(3)	12
1972-73	43	2	9	23	5	1	15
1974-75	47	2	6	21	2	1	20
1975-76	46	2	7	20	3	2	20

(continued)

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Table 1-5. (Continued)

	National defense	Space	Energy production	Economic development	Health	Community services	Advancement of knowledge[2]
United States[5]				National currency in millions			
1961-62	7,338.5	1,225.9	755.0	339.1	500.6	99.9	118.2
1966-67	8,264.8	5,307.0	875.0	792.3	968.8	321.1	308.6
1971-72	8,584.7	2,957.6	838.0	1,322.1	1,379.8	729.2	465.4
1974-75	9,620.9	2,511.3	1,163.9	1,784.2	2,247.4	954.6	761.9
1976-77	11,987.1	2,940.3	2,097.9	2,058.5	2,351.9	1,097.1	954.7
				Percent distribution			
1961-62	71	12	7	3	5	1	1
1966-67	49	32	5	5	6	2	2
1971-72	53	18	5	8	9	5	3
1974-75	51	13	6	9	12	5	4
1976-77	51	13	9	9	10	5	4
West Germany				National currency in millions			
1961	381.0	—	267.0	NA	NA	NA	639.0
1966	803.0	177.0	693.0	NA	NA	NA	1,488.0
1971	1,180.0	[illegible]22.0	1,230.0	1,057.0	195.0	133.0	3,190.0
1975	1,405.0	539.9	1,342.9	1,729.5	414.6	748.7	6,430.7
1976	1,490.5	600.8	1,411.9	1,721.7	448.1	670.8	6,614.5
				Percent distribution			
1961	22	—	16	NA	NA	NA	37
1966	1[illegible]	4	16	NA	NA	NA	35
1971	15	6	16	13	3	2	41
1975	11	4	11	14	3	6	51
1976	12	5	11	13	3	5	51

[1] See Appendix table 1-6 for the components of these objectives.
[2] Excludes general university funds for the United States.
[3] Less than 0.5 percent.
[4] Later estimates indicate that French defense-related R&D expenditures in 1972 were about 32 percent and space R&D, 6 percent of the total government expenditures.
[5] Function categories are not the same as those of Appendix table 2-16; e.g., "Advancement of knowledge" does not equal "Science and technology base."

NA – Not available.

NOTE: Percents may not total 100 because of exclusion of the category "Not specified" and/or due to rounding.

SOURCE: Organisation for Economic Co-operation and Development, *Changing Priorities for Government R&D* (Paris: OECD, 1975), and OECD, *International Survey of the Resources Devoted to R&D by Member Countries, International Statistical Year — 1973: The Objectives of Government R&D Funding, 1970-76* Vol. 2B (Paris: OECD, 1977).

See figure 1-5.

Table 1-6. Classification of Government R&D expenditures shown in Appendix table 1-6.

Category	Components
National defense	R&D directly related to military purposes, including space and nuclear energy activities of a military character.
Space	Civilian space R&D such as manned space flight programs and scientific investigations in space.
Energy production	R&D activities aimed at the supply, production, conservation, and distribution of all forms of energy except as means of propulsion for vehicles and rockets.
Economic development	R&D in a wide range of fields including: agriculture, forestry, and fisheries; mining and manufacturing; transportation, telecommunications (including satellite communications), construction, urban and rural planning, and utilities.
Health	R&D in all of the medical sciences, and in health service management directed toward the protection and improvement of human health.
Community services	R&D for such purposes as environmental protection, educational methods, social and development services, fire and other disaster prevention, planning and statistics, recreation and culture, law and order.
Advancement of knowledge	R&D of a general nature or spanning several fields which cannot be attributed to specific objectives; it consists of R&D expenditures of science councils and private nonprofit institutes. General university funds are included for all countries except the United States.

Table 1-7. Industrial R & D expenditures as a percentage of the domestic product of industry: 1967-75

(National currency in millions)

Country	BERD[1]	DPI[2]	BERD/DPI (in percent)
United States			
1967	$16,385.0	$659,200	2.49
1971	18,314.0	862,700	2.12
1975	24,164.0	1,223,200	1.98
United Kingdom			
1967	604.5	30,212	2.00
1971	697.4	NA	NA
1975	1,340.0	76,739	1.75
West Germany			
1967	5,682.9	444,070	1.28
1971	10,521.0	682,350	1.54
1975	14,469.0	912,660	1.59
France			
1967	6,292.0	442,700	1.42
1971	8,962.1	695,297	1.29
1975	15,617.0	1,140,204	1.37
Japan			
1967	378,969.0	45,315,500	.84
1971	895,020.0	80,914,400	1.11
1975	1,684,846.0	141,173,000	1.19

[1] Business enterprise R & D (total industrial R & D expenditure.)
[2] The domestic product of industry.

NA = Not available

NOTE: The industrial R & D expenditures (BERD) and the domestic industrial product (DPI) figures are shown in millions of national currency.

SOURCE: Organisation of Economic Co-operation and Development, *International Survey of the Resources Devoted to R & D by Member Countries, International Statistical Year, 1971*, and special tabulations, 1978, unpublished.

See figure 1-6.

Table 1-8. R & D performed in the business enterprise sector by source of funds: 1967-75.

Country	National currency (in millions) 1967	1971	1975	Percent 1967	1971	1975
France	6,713.6	8,962.1	15,616.5	100.0	100.0	100.0
Total domestic	6,422.5	8,439.9	14,393.5	95.7	94.8	92.2
Business enterprise	3,819.1	5,525.6	9,965.8	56.9	61.7	63.8
Government	2,602.3	2,939.9	4,376.8	38.8	32.8	28.0
Private non-profit	1.1	21.0	47.2	(1)	.2	.3
Higher education	—	7.4	3.7	—	0.1	—
Foreign	291.1	468.2	1,223.0	4.3	5.2	7.8
Japan	378,970.0	895,020.0	1,684,847.0	100.0	100.0	100.0
Total domestic	378,890.0	894,192.0	1,683,201.0	100.0	99.9	99.9
Business enterprise	375,112.0	876,607.0	1,651,984.0	99.0	97.9	98.0
Government	3,288.0	17,585.0	28,649.0	.9	2.0	1.7
Private non-profit	374.0	—	2,514.0	.1	—	.1
Higher education	116.0	—	54.0	(1)	—	(1)
Foreign	80.0	827.0	1,647.0	(1)	.1	.1
United Kingdom[2]	624.4	697.4	1,340.1	100.0	100.0	100.0
Total domestic	601.1	664.8	1,255.4	96.3	95.3	93.7
Business enterprise	387.6	433.8	841.3	62.1	62.2	62.8
Government	200.9	227.7	414.1	32.2	32.6	30.9
Private non-profit	12.6	3.3	—	2.0	.5	—
Higher education	—	—	—	—	—	—
Foreign	23.3	32.6	84.7	3.7	4.7	6.3
United States[3,4]	15,541.0	18,314.0	24,164.0	100.0	100.0	100.0
Total domestic	15,541.0	18,314.0	24,164.0	100.0	100.0	100.0
Business enterprise	7,254.0	10,643.0	15,559.0	46.7	58.1	64.4
Government	8,287.0	7,671.0	8,605.0	53.3	41.9	35.6
Private non-profit	—	—	—	—	—	—
Higher education	—	—	—	—	—	—
Foreign	—	—	—	—	—	—
West Germany	5,682.9	10,521.0	14,469.0	100.0	100.0	100.0
Total domestic	5,654.1	10,383.0	14,005.0	99.5	98.7	96.8
Business enterprise	4,652.3	8,449.0	11,397.0	81.9	80.3	78.8
Government	986.8	1,915.0	2,596.0	17.4	18.2	17.9
Private non-profit	15.0	19.0	12.0	.3	.2	.1
Higher education	—	—	—	—	—	—
Foreign	28.8	138.0	464.0	.5	1.3	3.2

[1] Less than 500,000.
[2] United Kingdom 1971 figures are from 1969/70.
[3] U.S. 1967 figures are from 1966.
[4] Current expenditures plus depreciation only.

NOTE: Details may not add to totals because of rounding.

SOURCE: Organisation of Economic Co-operation and Development, *International Survey of the Resources Devoted to R & D by Member Countries, International Statistical Years,* 1967, 1971, and 1975, Total Tables; (Paris: OECD).

See figure 1-7.

Table 1-9. U.S. and world scientific and technical articles[1] by field: 1973-77

Field[2]	1973	1974	1975	1976	1977
	U.S. articles as a percent of all articles				
All fields	39	39	38	38	38
Clinical medicine	43	43	43	43	43
Biomedicine	39	38	39	39	39
Biology	46	46	45	44	42
Chemistry	23	22	22	22	22
Physics	33	33	32	31	30
Earth and space sciences	47	47	44	46	45
Engineering and technology	42	42	41	41	40
Psychology	76	75	75	74	74
Mathematics	48	46	44	43	41
	Number of U.S. articles[3]				
All fields	109,317	105,760	102,432	105,262	102,955
Clinical medicine	32,638	31,691	31,334	32,920	33,516
Biomedicine	16,115	15,607	15,901	16,271	16,197
Biology	11,150	10,700	10,400	10,573	9,904
Chemistry	10,474	9,867	9,222	9,337	8,852
Physics	11,721	11,945	11,363	11,502	10,995
Earth and space sciences	5,591	5,371	4,975	5,537	5,197
Engineering and technology	11,955	11,088	10,431	10,346	10,081
Psychology	5,540	5,694	5,155	5,292	5,102
Mathematics	4,134	3,797	3,652	3,484	3,112
	Number of all articles				
All fields	278,819	272,679	267,783	274,525	270,576
Clinical medicine	76,209	74,509	73,485	76,599	77,597
Biomedicine	41,155	40,632	41,244	41,891	41,388
Biology	24,047	23,414	23,260	23,905	23,757
Chemistry	45,004	44,529	42,502	42,773	40,734
Physics	35,864	35,708	35,104	36,902	36,057
Earth and space sciences	11,977	11,479	11,356	12,011	11,531
Engineering and technology	28,617	26,600	25,664	25,146	25,063
Psychology	7,306	7,549	6,875	7,171	6,877
Mathematics	8,639	8,259	8,293	8,127	7,573

[1] Based on the articles, notes, and reviews in over 2,100 of the influential journals carried on the 1973 *Science Citation Index* Corporate Tapes of the Institute for Scientific Information.

[2] See Appendix table 1-10 for the subfields included in these fields.

[3] When an article is authorized by scientists and engineers from more than one country, that article is prorated across the countries involved. For example, if a given article has several authors from France and the United States, it is split ½ to France and ½ to the United States, regardless of the number of actual authors from these countries.

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

SOURCE: Computer Horizons, Inc., unpublished data.

See table 1-1 in text.

Table 1-10. Fields and subfields of international scientific literature

- Clinical medicine
  - General and internal medicine
  - Allergy
  - Anesthesiology
  - Cancer
  - Cardiovascular system
  - Dentistry
  - Dermatology & venereal diseases
  - Endocrinology
  - Fertility
  - Gastroenterology
  - Geriatrics
  - Hematology
  - Immunology
  - Obstetrics & gynecology
  - Neurology & neurosurgery
  - Ophthalmology
  - Orthopedics
  - Arthritis & rheumatism
  - Otorhinolaryngology
  - Pathology
  - Pediatrics
  - Pharmacology
  - Pharmacy
  - Psychiatry
  - Radiology & nuclear medicine
  - Respiratory system
  - Surgery
  - Tropical medicine
  - Urology
  - Nephrology
  - Veterinary medicine
  - Addictive diseases
  - Hygiene & public health
  - Miscellaneous clinical medicine
- Biomedical research
  - Physiology
  - Anatomy & morphology
  - Embryology
  - Genetics & heredity
  - Nutrition & dietetics
  - Biochemistry & molecular biology
  - Biophysics
  - Cell biology, cytology & histology
  - Microbiology
  - Virology
  - Parasitology
  - Biomedical engineering
  - Microscopy
  - Miscellaneous biomedical research
  - General biomedical research
- Biology
  - General biology
  - General zoology
  - Entomology
  - Miscellaneous zoology
  - Marine biology & hybridology
  - Botany
  - Ecology
  - Agriculture & food science
  - Miscellaneous biology
- Chemistry
  - Analytical chemistry
  - Organic chemistry
  - Inorganic & nuclear chemistry
  - Applied chemistry
  - General chemistry
  - Polymers
  - Physical chemistry
- Physics
  - Chemical physics
  - Solid state physics
  - Fluids & plasmas
  - Applied physics
  - Acoustics
  - Optics
  - General physics
  - Nuclear & particle physics
  - Miscellaneous physics
- Earth and space science
  - Astronomy & astrophysics
  - Meteorology and atmospheric science
  - Geology
  - Earth & planetary science
  - Geography
  - Oceanography & limnology
- Engineering and technology
  - Chemical engineering
  - Mechanical engineering
  - Civil engineering
  - Electrical engineering & electronics
  - Miscellaneous engineering & technology
  - Industrial engineering
  - General engineering
  - Metals & metallurgy
  - Materials science
  - Nuclear technology
  - Aerospace technology
  - Computers
  - Library & information science
  - Operations research & management science
- Psychology
  - Clinical psychology
  - Personality & social psychology
  - Developmental & child psychology
  - Experimental psychology
  - General psychology
  - Miscellaneous psychology
  - Behavioral science
- Mathematics
  - Algebra
  - Analysis & functional analysis
  - Geometry
  - Logic
  - Number theory
  - Probability
  - Statistics
  - Topology
  - Computing theory & practice
  - Applied mathematics
  - Combinatorics & finite mathematics
  - Physical mathematics
  - General mathematics
  - Miscellaneous mathematics

Table 1-11. Citation ratios to U.S. scientific and technical articles[1] by field, from U.S. and non-U.S. authors: 1973-77

Field[2]	1973	1974	1975	1976	1977
	Ratios for all articles citing U.S. articles[3]				
All fields	1.28	1.30	1.30	1.29	1.30
Clinical medicine	1.31	1.30	1.29	1.29	1.28
Biomedicine	1.36	1.38	1.36	1.36	1.35
Biology	1.13	1.13	1.12	1.15	1.17
Chemistry	1.54	1.65	1.66	1.58	1.57
Physics	1.40	1.41	1.41	1.40	1.41
Earth and space sciences	1.25	1.25	1.28	1.24	1.28
Engineering and technology	1.11	1.20	1.14	1.18	1.18
Psychology	1.02	1.04	1.01	1.06	1.06
Mathematics	1.14	1.16	1.18	1.18	1.20
	Ratios for U.S. articles citing U.S. articles				
All fields	1.51	1.51	1.50	1.50	1.51
Clinical medicine	1.50	1.47	1.45	1.45	1.44
Biomedicine	1.49	1.49	1.47	1.47	1.45
Biology	1.36	1.35	1.33	1.36	1.41
Chemistry	1.94	2.04	2.06	1.99	1.97
Physics	1.60	1.58	1.59	1.61	1.61
Earth and space sciences	1.38	1.36	1.39	1.35	1.40
Engineering and technology	1.44	1.49	1.42	1.45	1.45
Psychology	1.05	1.07	1.04	1.08	1.08
Mathematics	1.25	1.27	1.28	1.28	1.32
	Ratios for non-U.S. articles citing U.S. articles				
All fields	1.13	1.15	1.15	1.15	1.15
Clinical medicine	1.16	1.15	1.15	1.15	1.15
Biomedicine	1.26	1.28	1.27	1.27	1.26
Biology	.94	.96	.96	.98	1.00
Chemistry	1.38	1.48	1.49	1.42	1.42
Physics	1.28	1.31	1.30	1.29	1.31
Earth and space sciences	1.12	1.14	1.15	1.12	1.16
Engineering and technology	.91	1.00	.97	1.02	1.02
Psychology	.97	.98	.95	1.00	1.01
Mathematics	1.03	1.05	1.08	1.09	1.11

[1] Based on the articles, notes, and reviews in over 2,100 of the influential journals carried on the 1973 *Science Citation Index* Corporate Tapes of the Institute for Scientific Information. When an article is authored by scientists and engineers from more than one country, that article is prorated across the countries involved. For example, if a given article has several authors from France and the United States, it is split ½ to France and ½ to the United States, regardless of the number of actual authors from these countries.

[2] See Appendix table 1-10 for the subfields included in these fields.

[3] A citation ratio of 1.00 reflects no over- or under-citing of the U.S. scientific and technical literature, while a higher ratio indicates a greater influence than would have been expected from the number of U.S. publications alone. In the case of chemistry, for example, the United States received 57 percent more citations from the 1977 literature than could be accounted for by its share of the world's chemistry literature.

SOURCE: Computer Horizons, Inc., unpublished data.

See table 1-2 in text.

Table 1-12. U.S. patents granted to inventors from selected countries, by date of grant and nationality of inventor: 1966-77

Country	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
Total	68,408	65,652	59,103	67,560	64,432	78,320	74,813	74,148	76,281	72,029	70,223	65,218
United States	54,636	51,274	45,783	50,398	47,077	55,979	51,519	51,509	50,648	46,731	44,281	41,452
Foreign	13,772	14,378	13,320	17,162	17,355	22,341	23,294	22,639	25,633	25,298	25,942	23,766
West Germany	3,981	3,766	3,442	4,523	4,434	5,519	5,728	5,588	6,157	6,039	6,178	5,533
Japan	1,122	1,424	1,464	2,152	2,626	4,032	5,153	4,939	5,889	6,353	6,537	6,211
United Kingdom	2,674	2,800	2,481	3,178	2,954	3,468	3,170	2,854	3,145	3,046	2,991	2,651
France	1,435	1,558	1,446	1,808	1,732	2,215	2,231	2,143	2,565	2,367	2,408	2,107
Switzerland	983	948	822	1,058	1,112	1,281	1,305	1,326	1,453	1,457	1,475	1,346
Canada	938	991	897	994	1,065	1,326	1,244	1,345	1,325	1,296	1,192	1,219
U.S.S.R.	66	115	95	159	218	334	355	382	492	421	426	394
Other E.E.C. countries[1]	783	821	744	937	928	1,203	1,194	1,157	1,294	1,073	1,292	1,150

[1] Other European Economic Community (E.E.C.) countries included here are Belgium, Denmark, Ireland, Luxembourg, and the Netherlands. Data for Italy are not comparable for use in this indicator.

SOURCE: Office of Technology Assessment and Forecast, U.S. Patent and Trademark Office, *Special Report: A Profile of U.S. Patent Activity, 1963-77*, 1978.

See figure 1-8.

Table 1-13. Number of U.S. patents granted to selected foreign countries[1] by product field for the period 1963-77.

Country	Total	Product field I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV
Total	1,183,210	11,750	10,887	158,276	20,593	13,661	54,640	24,475	13,370	135,333	316,532	109,441	118,009	63,801	21,642	110,800
United States	849,512	8,399	7,331	103,458	11,977	11,837	41,216	18,409	8,690	104,531	225,057	81,551	87,096	45,379	14,273	80,308
Foreign	333,698	8,351	3,556	54,818	8,616	1,824	13,424	6,066	4,680	30,802	91,475	27,890	30,913	18,422	7,369	30,492
West Germany	83,220	463*	1,018*	15,790*	1,902*	329*	3,038*	1,261*	975*	7,147*	23,967*	6,484*	6,061*	5,141*	2,050*	7,594*
Japan	61,510	1,150*	629*	10,492*	1,299*	233*	2,516*	1,144*	991*	4,189*	13,138*	5,523*	8,606*	2,667*	1,340*	7,593*
United Kingdom	51,822	358*	641*	7,067*	1,075*	443*	2,302*	1,159*	661*	5,321*	14,270*	4,507*	4,986*	3,447*	1,560*	4,025*
France	33,696	236*	276*	5,094*	1,074*	162*	1,308*	653*	451*	3,234*	8,754*	2,952*	3,428*	2,438*	1,015*	2,541*
Switzerland	19,931	164	342*	5,577*	1,072*	38	574	197	202	1,535	5,055*	1,521*	967	690	139	1,858*
Canada	18,251	200*	128*	1,840	322	241*	921*	375*	338*	2,570*	5,803*	1,447*	1,408*	1,136*	289*	1,233*
Sweden	12,737	109	98	734	205	31	616*	304*	242*	1,770*	4,560	1,074	842	839*	231*	1,082
Netherlands	10,614	180*	77	1,664	243	144*	375	178	74	838	2,453	1,197	2,128*	289	102	672
Italy	10,569	94	121	2,352*	435*	36	442	147	123	866	3,194	836	594	497	180	652
Belgium	4,115	32	45	794	105	23	176	146	69	343	953	208	325	131	25	740
U.S.S.R.	4,166	33	16	487	62	40	60	68	119	262	1,593	563	313	114	53	383
Austria	3,506	28	23	314	53	13	168	70	128	411	1,339	211	233	144	53	318
Australia	3,005	36	30	353	46	11	154	67	64	401	1,021	184	158	144	51	285
Denmark	2,377	55	20	253	84	7	124	61	10	328	769	226	132	47	23	238
Mexico	1,335	26	6	415	336	2	38	12	16	96	217	35	18	42	18	68
Other foreign[2]	12,543	185	85	1,348	347	70	526	221	216	1,476	4,356	912	705	651	236	1,209

[1] Countries were selected on the basis of being in the top 10 of at least one of the Standard Industrial Classifications.
* Indicates ranking among the top six foreign countries in this particular product field.
[2] Other foreign includes patents granted to foreign countries not shown separately.

- I Food and kindred products
- II Textile mill products
- III Chemicals, except drugs and medicines
- IV Drugs and medicines
- V Petroleum and gas extraction and petroleum refining
- VI Rubber and miscellaneous plastics products
- VII Stone, clay, glass, and concrete products
- VIII Primary metals
- IX Fabricated metals
- X Nonelectrical machinery
- XI Electrical equipment except communication equipment
- XII Communication equipment and electronic components
- XIII Motor vehicles and other transportation equipment except aircraft
- XIV Aircraft and parts
- XV Professional and scientific instruments

SOURCE: Compiled from information in Office of Technology Assessment and Forecast, U. S. Patent and Trademark Office, *Indicators of the Patent Output of U. S. Industry: Profiles of Patent Activity in 55 Standard Industrial Classification Product Fields, 1963-77,* 1978.

See figure 1-9.

Table 1-14. Patents granted in selected countries by nationality of inventor: 1966-76

Country	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
United States											
Total	68,406	65,652	59,102	67,557	64,427	78,136	74,818	74,139	76,275	71,994	70,236
Granted to nationals	54,634	51,274	45,782	50,395	47,073	55,988	51,515	51,501	50,643	46,603	44,162
Granted to all foreigners	13,772	14,378	13,320	17,162	17,354	22,328	23,293	22,638	25,632	23,391	26,074
Foreign patents granted to U.S.[1]	49,098	47,982	48,229	50,852	48,807	49,849	49,628	43,326	39,990	39,300	34,796
West Germany											
Total	22,598	19,871	21,169	22,623	12,887	18,149	20,600	23,934	20,539	18,290	20,965
Granted to nationals	13,095	11,520	12,143	12,432	6,386	8,295	9,642	11,191	9,793	9,077	10,395
Granted to U.S.	3,733	3,406	3,804	4,483	2,882	4,393	4,575	4,949	3,913	3,140	3,333
Granted to all foreigners	9,503	8,351	9,026	10,191	6,501	9,854	10,958	12,743	10,746	9,213	10,570
U.S. patents as percent of foreigners	39.3	40.8	42.1	44.0	44.3	44.6	41.8	38.8	36.4	34.1	31.5
Japan											
Total	26,315	20,773	27,972	27,657	30,818	36,447	41,454	42,328	39,626	46,728	40,317
Granted to nationals	17,373	13,877	18,576	18,787	21,403	24,795	29,101	30,937	30,873	36,992	32,465
Granted to U.S.	4,688	3,432	4,903	4,657	4,774	5,700	5,948	5,485	4,432	4,918	4,029
Granted to all foreigners	8,942	6,896	9,396	8,870	9,475	11,652	12,353	11,391	8,753	9,736	7,852
U.S. patents as percent of foreigners	52.4	49.8	52.2	52.5	50.4	48.9	48.2	48.2	50.6	50.5	51.3
United Kingdom											
Total	37,272	38,999	43,038	38,790	40,995	41,554	42,794	39,844	37,808	40,689	39,797
Granted to nationals	NA	NA	NA	9,807	10,343	10,376	10,116	9,357	8,971	9,120	8,855
Granted to U.S.	14,117	13,676	12,588	12,678	12,728	12,682	13,001	11,717	10,976	11,497	11,024
Granted to all foreigners	NA	NA	NA	28,893	30,652	31,178	32,678	30,487	28,837	31,569	30,942
U.S. patents as percent of foreigners	NA	NA	NA	43.9	41.5	40.7	39.8	38.4	38.1	36.4	35.6
France											
Total	43,950	46,995	47,990	32,020	26,297	51,456	46,217	27,939	24,725	14,320	29,754
Granted to nationals	14,881	15,246	15,627	10,288	17,758	13,696	10,767	10,817	9,282	4,962	8,420
Granted to U.S.	9,807	10,911	10,794	6,943	5,664	11,973	11,206	5,047	4,719	2,801	6,171
Granted to all foreigners	29,069	31,749	32,363	21,732	8,539	37,760	35,450	17,122	15,443	9,358	21,334
U.S. patents as percent of foreigners	33.7	34.4	33.4	31.9	66.3	31.7	31.6	29.5	30.6	29.9	28.93
Switzerland											
Total	22,507	21,850	17,450	16,775	17,575	16,079	14,921	13,680	12,970	13,700	12,300
Granted to nationals	6,174	5,388	4,277	4,260	4,452	4,165	3,942	3,959	3,647	3,794	3,482
Granted to U.S.	3,468	3,632	3,126	3,110	3,090	2,736	2,528	2,140	2,101	2,070	1,847
Granted to all foreigners	16,333	16,462	13,173	12,515	13,123	11,914	10,979	9,721	9,323	9,906	8,818
U.S. patents as percent of foreigners	21.2	22.1	23.7	24.9	23.5	23.0	23.0	22.0	22.5	20.9	20.9
Canada											
Total	24,417	25,836	25,806	28,981	29,193	29,242	29,295	21,246	21,287	20,544	21,750
Granted to nationals	1,222	1,263	1,263	1,461	1,395	1,587	1,551	1,218	1,368	1,208	1,301
Granted to U.S.	16,614	17,583	17,583	19,147	18,663	17,992	17,289	12,964	12,785	12,220	12,411
Granted to all foreigners	23,195	24,573	24,543	27,520	27,798	27,655	26,744	20,028	19,919	19,264	20,449
U.S. patents as percent of foreigners	71.6	71.6	71.6	69.6	67.1	65.1	64.6	64.7	64.2	63.4	60.7
Other EEC countries											
Total	25,505	24,133	24,627	26,263	26,124	24,322	24,752	25,280	23,341	22,276	NA
Granted to nationals	2,423	2,337	2,089	2,233	2,078	2,023	2,156	2,074	1,869	1,759	NA
Granted to U.S.	6,483	6,253	6,225	6,777	6,670	6,346	6,287	6,071	5,783	5,455	NA
Granted to all foreigners[3]	23,082	21,796	22,538	24,030	24,046	22,299	22,596	23,206	21,472	20,517	NA
U.S. patents as percent of foreigners	28.1	28.7	27.6	28.2	27.7	28.5	27.8	26.2	26.9	26.6	NA

[1] Includes patents granted to U.S. inventors by all the countries shown here (West Germany, Japan, the United Kingdom, Switzerland, Canada, and "other EEC countries"). Patents granted by France are not included due to the wide fluctuations in French patents granted to foreigners.

[2] Other European Economic Community (E.E.C.) countries included here are Belgium, Denmark, Ireland, Luxembourg, and the Netherlands. Comparable data for Italy are not available.

[3] Based on each country as a unit rather than the group of nations as a unit. For instance, patents granted to Denmark by the Netherlands are considered as non-resident or foreign patents here.

NA = not available.

SOURCE: World Intellectual Property Organization, *Industrial Property* Geneva: WIPO, December issues of 1967-76 and September 1977.

See figure 1-10.

Table 1-15. Relative change in productivity[1] in manufacturing industries of selected countries: 1960-77

[Index: 1967 = 100]

Year	United States	France	West Germany	Japan	United Kingdom	Canada
1960	78.9	68.7	67.8	52.6	76.8	75.1
1961	80.8	71.9	71.4	59.3	77.4	79.2
1962	84.6	75.2	75.8	61.9	79.3	83.3
1963	90.5	79.7	79.3	67.1	83.6	86.5
1964	95.2	83.7	85.2	75.9	89.7	90.3
1965	98.3	88.5	90.7	79.1	92.4	93.7
1966	99.8	94.7	93.9	87.1	95.7	96.9
1967	100.0	100.0	100.0	100.0	100.0	100.0
1968	103.7	111.4	106.9	112.6	107.1	106.8
1969	104.8	115.4	113.4	130.0	108.4	113.1
1970	104.4	121.2	116.1	146.5	108.6	114.7
1971	110.1	127.6	121.4	151.0	112.9	122.9
1972	115.7	135.1	128.7	162.3	121.2	128.5
1973	118.8	142.5	136.6	181.2	126.2	134.3
1974	112.6	146.5	145.0	181.7	127.6	136.6
1975	118.2	150.3	150.4	174.6	124.2	133.3
1976	123.2	164.0	162.8	188.7	128.4	139.4
1977 (prel.)	126.1	172.6	169.6	199.2	126.3	146.1

[1] Output per worker-hour.

SOURCES: Department of Labor, Bureau of Labor Statistics, Office of Productivity and Technology, "Output per Hour, Hourly Compensation, and Unit Labor Costs in Manufacturing, Eleven Countries, 1950-77," November 29, 1978, mimeograph.

See figure 1-11. Science Indicators—1978

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Table 1-16. Real Gross Domestic Product per employed civilian, for selected countries compared with the United States: 1960-77[1]

[Index, United States = 100]

Year	United States	France	West Germany	Japan	United Kingdom	Canada
1960	100	55.4	52.4	24.7	51.1	86.6
1961	100	57.0	53.1	27.2	49.8	85.8
1962	100	58.0	53.1	27.6	47.9	85.6
1963	100	59.0	53.2	29.6	48.5	86.2
1964	100	60.0	55.2	32.1	49.1	86.0
1965	100	60.8	56.2	32.2	48.2	85.6
1966	100	61.2	58.1	33.4	47.4	83.5
1967	100	63.4	57.3	36.8	49.0	83.4
1968	100	64.2	59.5	40.0	49.7	84.6
1969	100	67.6	63.2	43.9	50.4	86.2
1970	100	71.4	67.0	48.7	52.6	88.6
1971	100	72.9	67.5	50.8	53.9	90.6
1972	100	74.8	68.5	53.9	53.6	90.7
1973	100	76.4	70.2	56.5	54.8	90.8
1974	100	80.0	74.3	58.0	56.0	93.0
1975	100	81.2	74.7	59.5	55.4	91.9
1976	100	83.1	77.7	60.8	55.6	92.2
1977 (prel.)	100	84.7	79.1	62.2	55.1	91.6

[1] Output based on international price weights to enable comparable cross-country comparisons.

SOURCE: Department of Labor, Bureau of Labor Statistics, Office of Productivity and Technology, "Comparative Real Gross Domestic Product, Real GDP per Capita, and Real GDP per Employed Civilian, Seven Countries, 1950-77," June 1978, mimeograph.

See discussion following figure 1-11. Science Indicators—1978

Table 1-17. U.S. International transactions in royalties and fees: 1966-77

[Dollars in millions]

Year	Balance	Receipts	Payments
1966	$1,376	$1,516	$140
1967	1,581	1,747	166
1968	1,682	1,868	186
1969	1,797	2,019	222
1970	2,106	2,331	225
1971	2,304	2,545	241
1972	2,476	2,770	294
1973	2,840	3,225	385
1974	3,475	3,821	346
1975	3,827	4,300	473
1976	3,873	4,352	479
1977 (prel.)	4,278	4,725	447

SOURCE: Based on Appendix tables 1-18 and 1-19.

See figure 1-12. Science Indicators—1978

Table 1-18. U.S. receipts and payments of royalties and fees for direct investment abroad: 1966-77

[Dollars in millions]

	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977 (prel.)
Net receipts[1]												
Total	$1,163	$1,354	$1,431	$1,533	$1,758	$1,927	$2,115	$2,513	$3,070	$3,543	$3,530	$3,767
Developed Countries	854	982	1,027	1,101	1,289	1,429	1,609	1,949	2,388	2,770	2,793	3,029
Western Europe	496	579	594	651	755	848	971	1,180	1,428	1,765	1,702	1,850
Canada	246	266	285	287	336	355	377	416	541	566	631	670
Japan	43	55	59	66	80	96	114	170	211	223	260	300
Other developed countries[2]	69	83	88	97	118	131	147	183	209	216	200	208
Developing countries	279	352	377	393	428	452	453	519	630	722	686	695
International and unallocated	29	20	27	34	40	46	53	46	51	51	51	43
Net payments[3]												
Total	64	62	80	101	111	118	155	209	160	287	293	253
Canada	41	43	47	56	62	64	60	73	46	139	137	126
United Kingdom	12	11	21	25	19	11	15	20	17	26	8	22
Other European countries	10	8	9	16	23	39	78	113	157	132	157	134
Japan	1	1	3	4	4	1	1	1	-47	-26	-34	-38
Other countries	([4])	([4])	([4])	([4])	3	3	1	1	-13	-14	25	10

[1] Represents net receipts of payments by U.S. firms from their foreign affiliates for the use of intangible property such as patents, techniques, processes, formulas, designs, trademarks, copyrights, franchises, manufacturing-rights, management fees, etc.

[2] Other developed countries included here are Australia, New Zealand, and the Republic of South Africa.

[3] Payments measure net transactions between U.S. affiliates and their foreign patents. Affiliated payments are not further detailed because in many cases the amounts are so small their publication would disclose individual company data.

[4] Less than $0.5 million.

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

SOURCE: Department of Commerce, Bureau of Economic Analysis, *Revised Data Series on U.S. Direct Investment Abroad, 1966-74*, 1976; *Survey of Current Business*, June 1975, June 1976, and August 1978.

See figure 1-13.

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Table 1-19. U.S. receipts and payments of royalties and fees for unaffiliated[1] foreign residents: 1966-77

[Dollars in millions]

	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977 (prel.)
Net receipts												
Total	$353	$393	$437	$486	$573	$618	$655	$712	$751	$757	$822	$958
Developed countries	304	342	375	426	505	547	575	633	646	640	684	793
Western Europe	186	190	196	222	247	268	270	297	321	343	350	413
Canada	30	33	31	28	33	32	38	32	38	38	45	48
Japan	70	95	130	155	202	223	240	273	249	219	246	289
Other developed countries[2]	18	24	18	21	23	24	27	31	38	40	43	43
Developing countries	50	50	59	59	64	62	72	74	94	60	120	132
Eastern Europe	–	1	4	2	4	9	8	5	11	14	19	33
Net payments												
Total	76	104	106	120	114	123	139	176	186	186	186	194
Developed countries	72	100	102	116	107	119	134	166	176	178	182	188
Western Europe	67	93	94	107	99	110	121	146	156	160	160	163
Canada	2	3	4	4	4	5	6	6	7	9	9	9
Japan	3	4	4	4	4	4	6	13	12	9	13	15
Developing countries	4	3	4	5	7	4	5	9	8	4	6	6
Eastern Europe	(3)	(3)	(3)	(3)	(3)	(3)	1	1	2	2	1	(3)

[1] Represents receipts and payments between U.S. residents and residents or governments of foreign countries for the use of intangible property such as patents, copyrights, or manufacturing rights. Excludes fees and royalties related to foreign direct investments and film rentals.

[2] Other developed countries included here are Australia, New Zealand, and the Republic of South Africa.

[3] Less than $0.5 million.

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

SOURCE: Department of Commerce, Bureau of Economic Analysis tabulations, June, 1975 and *Survey of Current Business*, June 1976, and June 1978.

See figure 1-14.

Table 1-20. U.S. direct investment abroad in manufacturing for selected nations and industry groups: 1966-77

[Millions of U.S. dollars]

Country	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977 (prel.)
All Countries (T)	$20,740	$22,803	$25,160	$28,332	$31,049	$34,359	$38,325	$44,370	$51,172	$55,886	$61,061	$65,604
Chemical Products	3,840	4,541	5,068	5,539	5,865	6,519	7,253	8,415	10,172	11,107	12,183	13,374
Machinery	5,033	5,455	5,986	7,012	7,842	8,930	10,096	11,811	13,992	15,595	17,091	18,379
Developed Countries (T)	17,214	18,912	20,721	23,285	25,572	28,320	31,558	36,550	41,973	45,427	49,766	53,364
Chemical Products	2,857	3,396	3,803	4,164	4,419	4,959	5,500	6,488	7,821	8,471	9,295	10,135
Machinery	4,473	4,866	5,317	6,223	6,931	7,907	8,917	10,259	12,003	13,231	14,338	15,408
Canada (T)	6,697	7,059	7,535	8,404	8,971	9,504	10,491	11,755	13,450	14,691	15,965	16,658
Chemical Products	1,058	1,146	1,222	1,297	1,320	1,453	1,583	1,767	2,049	2,268	2,462	2,350
Machinery	1,345	1,424	1,508	1,743	1,773	1,891	2,111	2,325	2,682	3,042	3,246	3,420
All Western Europe (T)	8,906	9,867	10,940	12,372	13,819	15,828	17,529	20,777	23,990	26,013	28,788	31,390
Chemical Products	1,523	1,793	2,058	2,271	2,451	2,792	3,146	3,818	4,757	5,161	5,756	6,652
Machinery	2,681	2,930	3,226	3,829	4,383	5,097	5,727	6,743	7,971	8,774	9,550	10,237
France (T)	1,162	1,260	1,303	1,464	1,812	2,107	2,441	2,943	3,428	3,844	3,997	4,138
Chemical Products	164	215	226	266	299	330	390	453	543	592	688	700
Machinery	443	443	456	503	620	744	834	1,011	1,194	1,415	1,405	1,496
United Kingdom (T)	3,568	3,751	4,159	4,492	4,909	5,427	5,779	6,611	7,371	7,555	7,734	8,872
Chemical Products	591	608	632	644	702	819	870	1,042	1,221	1,262	1,327	1,679
Machinery	1,049	1,146	1,197	1,412	1,590	1,744	1,853	2,008	2,293	2,405	2,500	2,749
Germany (T)	1,748	1,956	2,149	2,681	2,675	3,107	3,637	4,442	4,814	5,328	6,706	6,993
Chemical Products	179	200	239	259	295	373	425	578	691	770	915	1,000
Machinery	526	583	692	906	976	1,172	1,388	1,683	1,949	2,101	2,436	2,628
Japan (T)	366	442	527	645	768	978	1,185	1,399	1,520	1,557	1,691	1,889
Chemical Products	87	103	131	161	180	209	244	301	327	360	374	399
Machinery	222	266	(D)	(D)	(D)	511	633	732	775	787	862	995
Developing Countries (T)	3,525	3,891	4,439	5,047	5,477	6,038	6,767	7,820	9,200	10,459	11,395	12,239
Chemical Products	983	1,145	1,264	1,375	1,446	1,561	1,753	1,927	2,351	2,636	2,888	3,239
Machinery	560	589	669	789	910	1,023	1,178	1,552	1,989	2,364	2,752	2,971

(T) = Total manufacturing.
(D) = These data are withheld by the Commerce Department to avoid disclosure of data for individual companies.

SOURCE: U.S. Department of Commerce, Bureau of Economic Analysis, *Selected Data on U.S. Direct Investment Abroad, 1966-76*, 1977; and Ralph Kozlow, John Rutter and Patricia Walker, "U.S. Direct Investment Abroad in 1977," *Survey of Current Business*, vol. 58 (August 1978), pp. 16-38.

See discussion preceding table 1-15.

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Table 1-21. U.S. trade balance[1] in R&D-intensive and non-R&D-intensive manufactured product groups: 1960-77.

[Dollars in millions]

Year	R&D-intensive			Non-R&D-intensive		
	Balance	Export	Import	Balance	Export	Import
1960	$ 5,891	$ 7,597	$ 1,706	-$179	$ 4,962	$ 5,141
1961	6,237	8,018	1,781	-12	4,730	4,742
1962	6,720	8,715	1,995	-691	4,940	5,631
1963	6,958	8,975	2,017	-765	5,284	6,049
1964	7,970	10,267	2,297	-678	6,121	6,799
1965	8,148	11,078	2,930	-2,027	6,281	8,308
1966	7,996	12,174	4,178	-3,325	6,913	10,238
1967	8,817	13,407	4,590	-3,729	7,437	11,166
1968	9,775	15,312	5,537	-6,581	8,506	15,087
1969	10,471	16,955	6,484	-6,698	9,830	16,528
1970	11,722	19,274	7,552	-8,285	10,069	18,354
1971	11,727	20,228	8,501	-11,698	10,215	21,913
1972	11,012	22,003	10,991	-15,039	11,737	26,776
1973	15,101	29,088	13,987	-15,370	15,643	31,013
1974	23,873	41,111	17,238	-15,573	22,412	37,985
1975	29,344	46,439	17,095	-9,474	24,511	33,985
1976	28,964	50,830	21,866	-16,499	26,411	42,910
1977	27,627	53,169	25,542	-24,378	27,284	51,662

[1] Exports less imports.

SOURCE: Department of Commerce, Domestic and International Business Administration, *Overseas Business Reports* August 1967, April 1972, April 1977 and June 1978.

See figure 1-15.

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Table 1-22. U.S. trade balance[1] in selected R&D-intensive manufactured product-groups: 1960-77

[Dollars in millions]

Product groups	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
Chemicals[2]																		
Balance	$955	$1,051	$1,104	$1,294	$1,662	$1,634	$1,718	$1,844	$2,158	$2,165	$2,376	$2,224	$2,118	$3,286	$4,801	$4,995	$5,187	$5,395
Export	1,776	1,789	1,876	2,009	2,364	2,403	2,675	2,802	3,287	3,383	3,826	3,836	4,133	5,749	8,819	8,691	9,959	10,827
Import	821	738	772	715	702	769	957	958	1,129	1,228	1,450	1,612	2,015	2,463	4,018	3,696	4,772	5,432
Nonelectrical machinery[3]																		
Balance	2,948	3,288	3,547	3,574	3,989	4,115	4,101	4,218	4,280	4,838	5,583	5,268	5,325	6,904	10,826	14,574	14,814	13,635
Export	3,386	3,743	4,087	4,209	4,860	5,275	5,778	6,181	6,560	7,460	8,686	8,772	9,864	12,556	17,298	21,633	22,835	23,140
Import	438	455	540	635	871	1,160	1,677	1,963	2,280	2,622	3,103	3,504	4,539	5,652	6,472	7,059	8,021	9,505
Electrical machinery[4]																		
Balance	804	891	[illegible]46	1,074	1,222	1,020	890	962	792	729	728	512	321	533	1,680	2,671	1,854	1,853
Export	1,090	1,225	1,[illegible]61	1,493	1,665	1,660	1,900	2,098	2,284	2,677	2,999	3,067	3,698	5,032	7,019	7,582	9,278	10,285
Import	286	334	415	419	443	640	1,010	1,136	1,492	1,948	2,271	2,555	3,377	4,499	5,339	4,911	7,424	8,432
Aircraft																		
Balance	970	766	857	726	791	990	824	1,271	2,015	2,140	2,382	3,049	2,580	3,556	5,258	5,617	5,670	5,265
Export	1,024	903	980	817	874	1,130	1,097	1,519	2,309	2,423	2,656	3,387	2,995	4,119	5,766	6,136	6,104	5,866
Import	54	137	123	91	83	140	273	248	294	283	274	338	415	563	508	519	434	601
Professional and scientific instruments																		
Balance	214	241	266	290	306	389	463	522	530	609	653	674	668	822	1,308	1,487	1,439	1,479
Export	321	358	411	447	504	610	724	807	872	1,012	1,107	1,166	1,313	1,632	2,209	2,397	2,654	3,051
Import	107	117	145	157	198	221	261	285	342	403	454	492	645	810	901	910	1,215	1,572

[1] Exports less imports.
[2] Includes drugs and other allied products.
[3] Includes computers.
[4] Includes communication equipment.

SOURCE: Department of Commerce, Domestic and International Business Administration, *Overseas Business Reports,* August 1967, April 1972, April 1977 and June 1978.

See figure 1-16.

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Table 1-23. U.S. trade balance[1] with selected nations for R&D-intensive manufactured products: 1966-77

[Dollars in millions]

Country	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
Developing nations[2]												
Balance	$3,441	$3,677	$4,430	$4,455	$4,928	$5,087	$5,277	$6,642	$10,656	$14,727	$16,052	$16,013
Export	3,682	3,923	4,822	5,002	5,679	5,996	6,765	8,966	14,024	17,701	20,104	20,993
Import	241	246	392	547	751	909	1,488	2,324	3,368	2,974	4,052	4,980
Western Europe[3]												
Balance	1,890	2,283	2,566	2,986	3,942	3,599	3,089	4,125	5,983	6,700	7,060	6,918
Export	3,865	4,359	5,020	5,655	6,927	6,861	7,345	9,596	12,622	13,540	14,648	15,712
Import	1,975	2,076	2,454	2,669	2,985	3,262	4,256	5,471	6,639	6,840	7,588	8,794
Canada												
Balance	1,800	1,760	1,719	1,914	1,684	1,865	2,333	3,001	4,242	4,833	4,732	4,530
Export	2,838	2,983	3,142	3,478	3,513	3,914	4,678	5,741	7,419	8,136	8,831	9,182
Import	1,038	1,223	1,423	1,564	1,829	2,049	2,345	2,740	3,177	3,303	4,099	4,652
Japan												
Balance	-133	-115	-200	-324	-224	-516	-971	-848	-550	-1,021	-2,754	-3,460
Export	661	772	930	1,180	1,536	1,520	1,639	2,218	3,007	2,389	2,601	2,792
Import	794	887	1,180	1,504	1,760	2,036	2,610	3,066	3,557	3,410	5,355	6,252
West Germany												
Balance	(4)	(4)	(4)	81	287	190	-56	-205	-198	64	58	-73
Exports	(4)	(4)	(4)	912	1,277	1,295	1,340	1,579	1,931	2,143	2,346	2,674
Imports	(4)	(4)	(4)	881	990	1,105	1,396	1,784	2,129	2,079	2,288	2,747

[1] Exports less imports.
[2] Includes the Republic of South Africa in 1966 and 1967.
[3] Includes West Germany.
[4] Included in the totals for Western Europe but not separately available.

SOURCE: Department of Commerce Domestic and International Business Administration, *Overseas Business Reports*, May 1972, June 1974, October 1976, and October 1978.

See figure 1-17.

Table 1-24. Examples of possible areas of increased scientific cooperation with Western Europe

Biology

- Genetic engineering
- Seed protein development
- Molecular biology
- Biomass utilization
- Enzyme biology
- Biochemical transformations/technology
- Nitrogen fixation
- Tissue and protoplast culture
- Tropical biology

Behavioral and neural sciences

- Neuroscience
- Cognitive development
- Linguistics (phonetics)
- Social psychology
- Visual sciences

Computer sciences

- Software methodology
- Shared data banks
- Computer-aided design
- Fault tolerant computers
- Large-scale systems
- Control-system design
- Theoretical computer science (semantics, algorithms)

Chemistry

- Inorganic and organometallic catalysis
- Electrochemical synthesis
- Fast reaction kinetics
- Oscillating reactions/dissipative structure
- Excited-state reactions
- Rarefied gas dynamics
- Neutron scattering
- Quantum chemistry and molecular dynamics
- Solid state chemistry
- Colloid chemistry

Earth and ocean sciences

- Genesis of energy and mineral deposits
- Polar geology, geomorphology and glaciology
- Permafrost research
- Marine geology
- Marine geophysics
- Geochemical analysis
- Rock magnetism
- Coastal geologic processes

Engineering

- Combustion
- Thermionics
- Soil mechanics
- MHD
- Heat and mass transfer
- Optical communication
- Coal processing and communication
- Fluidization
- Particulate processing
- Biochemical engineering

Materials sciences

- High voltage electron microscopy
- Raman spectroscopy
- Resonance raman spectroscopy
- Muon decay in solids
- Statistical mechanics
- Electron structure
- Defects in solids
- Ultra low temperature physics
- Corrosion
- Condensed matter
- Synchroton radiation applications

Mathematics

- Algebraic and arithmetic geometry
- Nonlinear differential equations
- Bifurcation theory
- Mathematical organization theory
- Minimal surfaces
- Axiomatic set theory
- Stochastic processes
- Category theory
- Statistical inference

Physics

- Atomic and molecular physics
  - Plasma physics
  - Quantum electronics
  - Molecular and colliding beams
- Condensed matter physics
  - Neutron scattering
  - Solid state physics
  - Superconductivity
- Nuclear physics
  - Accelerator development
- Elementary particle physics
  - Gravitational wave detectors
- Theoretical physics
  - Gravitational physics
  - Mathematical physics
  - Atomic structure

Science education

- Developmental psychology
- Learning theory
- Educational television
- Use of computers with children
- Environmental education
- Curriculum modes and materials

Social sciences

- International economics
- Mathematical economics
- Political economy
- Social psychology
- Socio-economic systems
- Family change
- Technological innovation
- Location analysis
- Sociology of law

NOTE: These examples were generated by a survey of NSF program officers. These areas of scientific activity are those in which Western European efforts are thought to be at a level of excellence comparable to that in the United States, or in which achievements were linked to the availability of unusual instrumentation or facilities.

SOURCE: National Science Foundation Advisory Council, "Expanded Scientific Cooperation with Western Europe," Mimeo, October 26, 1978.

See discussion in the introduction of the "International Interaction and Cooperation" section.

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Table 1-25. Distribution of undergraduate and graduate foreign students in science and technology curriculums at U.S. universities and colleges, by field and region: 1975

Field	Total	Asia	Africa	Latin America	Europe	Oceania	North America
				Percent			
All fields	100	100	100	100	100	100	100
Scientific & technical	57	61	56	54	50	48	38
Engineering	36	29	12	20	13	7	21
Life sciences	18	11	20	13	10	16	10
Social sciences	15	8	12	8	11	18	9
Physical sciences	12	8	6	5	8	4	7
Mathematical and computer sciences	6	3	3	4	5	3	3
Psychology	3	1	1	2	2	—	1
Technical training[1]	2	1	2	2	([2])	—	1
Non S/T fields	43	39	44	46	50	52	62
				Number			
All fields	178,830	96,860	25,290	29,820	14,400	2,740	9,720
Scientific & technical	101,980	59,500	14,130	16,1[illegible]	7,170	1,310	3,700
Engineering	37,080	28,270	3,020	6,070	1,920	180	640
Life sciences	17,930	10,990	5,110	3,790	1,470	440	1,240
Social sciences	15,710	7,450	3,030	2,310	1,650	490	780
Physical sciences	12,310	7,590	1,620	1,540	1,080	120	360
Mathematical and computer sciences	5,860	2,920	710	1,250	680	80	220
Psychology	2,660	1,040	260	720	300	—	340
Technical training[1]	2,300	1,240	380	490	70	—	120
Non S/T fields	76,850	37,360	11,160	13,650	7,280	1,430	6,020

[1] Includes business and commerce, mechanical and engineering, and natural science technical training leading to associate degrees and other awards below the baccalaureate.

[2] Less than 0.5 percent.

SOURCE: Calculated from data from Institute of International Education, *Open Doors: 1975/76-1976/77*, 1978, pp.106-108.

See table 1-6 in text.

Science Indicators—1978

Table 1-26. Doctoral degrees awarded to foreign students as a percent of all doctoral degrees from U.S universities by field: 1960-74

Field	1960-74 period	1960-64	1965-69	1970-74
All fields	14.4	12.7	13.9	15.3
All science and engineering fields	18.7	16.1	17.6	20.5
Mathematicians	17.9	16.2	15.3	20.4
Physicists	18.1	14.5	15.6	21.9
Chemists	15.3	12.6	13.9	18.2
Earth scientists	18.7	16.0	18.5	20.3
Engineers	28.1	21.6	23.8	34.1
Agricultural scientists	33.1	26.5	32.5	36.6
Medical scientists	21.5	19.7	22.3	21.6
Bioscientists	15.9	16.7	16.4	15.2
Psychologists	5.2	4.9	4.9	5.4
Social scientists	18.4	18.1	19.0	18.2
Nonscience total	7.4	6.4	7.3	7.8

SOURCE: *A Century of Doctorates* (Washington: National Research Council, 1978). p. 47

See figure 1-18.

Science Indicators—1978

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Table 1-27. Index of international cooperative research[1] by field: 1973-77

Field[2]	1973	1974	1975	1976	1977
	Internationally co-authored articles as a percent of all institutionally co-authored articles				
All fields	12.7	13.2	13.9	14.7	15.0
Clinical medicine	6.6	6.9	6.8	7.8	7.5
Biomedicine	18.7	14.2	15.2	15.7	16.3
Biology	15.5	13.6	15.4	17.0	17.0
Chemistry	16.3	17.2	17.7	18.1	20.7
Physics	22.7	23.7	25.4	25.9	27.5
Earth and space sciences	23.1	22.5	24.6	27.7	27.5
Engineering and technology	13.2	14.0	15.5	14.0	16.2
Psychology	10.6	10.8	10.7	8.4	12.5
Mathematics	34.3	39.5	39.8	38.6	37.9
	Internationally co-authored articles				
All fields	8,571	9,292	9,896	10,732	11,527
Clinical medicine	1,881	2,013	1,989	2,314	2,440
Biomedicine	1,454	1,581	1,775	1,862	2,032
Biology	723	655	779	853	915
Chemistry	1,088	1,241	1,286	1,384	1,546
Physics	1,570	1,757	1,933	2,142	2,320
Earth and space sciences	647	658	698	830	849
Engineering and technology	584	650	720	626	721
Psychology	151	178	158	171	188
Mathematics	473	558	557	548	515
	All institutionally co-authored articles				
All fields	67,528	70,174	71,051	73,251	76,787
Clinical medicine	28,617	28,974	29,078	29,564	32,643
Biomedicine	10,648	11,117	11,683	11,845	12,436
Biology	4,660	4,829	5,073	5,024	5,405
Chemistry	6,694	7,224	7,264	7,632	7,485
Physics	6,897	7,410	7,601	8,271	8,433
Earth and space sciences	2,798	2,920	2,832	2,994	3,085
Engineering and technology	4,412	4,642	4,647	4,470	4,437
Psychology	1,422	1,645	1,473	2,031	1,504
Mathematics	1,379	1,413	1,401	1,420	1,359

[1] Obtained by dividing the number of articles which were written by scientists and engineers from more than one country by the total number of articles jointly written by S/E's from different organizations. This index is based on the articles, notes, and reviews in over 2,100 of the influential journals carried on the 1973 *Science Citation Index* Corporate Tapes of the Institute for Scientific Information.

[2] See Appendix table 1-10 for the subfields included in these fields.

SOURCE: Computer Horizons, Inc., unpublished data.

See figure 1-19.

Table 1-28. Index of international cooperative research[1] for selected countries: 1973-77

Country[2]	1973	1974	1975	1976	1977
	Internationally co-authored articles as a percent of all institutionally co-authored articles				
United States	13.8	14.1	14.8	15.5	15.8
Japan	16.4	16.4	16.2	15.2	16.0
U.S.S.R.	9.6	10.8	13.3	14.2	17.3
France	26.7	26.9	29.8	31.3	32.7
Canada	37.7	38.9	37.8	38.8	39.0
United Kingdom	35.4	37.0	37.6	39.5	40.7
West Germany	35.6	37.4	38.2	40.7	41.3
	Internationally co-authored articles				
United States	4,920	5,182	5,378	5,815	6,131
Japan	474	495	547	558	638
U.S.S.R.	288	318	381	432	526
France	1,135	1,215	1,464	1,597	1,796
Canada	1,377	1,458	1,484	1,608	1,677
United Kingdom	2,065	2,260	2,385	2,611	2,664
West Germany	1,289	1,534	1,573	1,751	1,930
	All institutionally co-authored articles				
United States	35,581	36,727	36,346	37,501	38,916
Japan	2,888	3,023	3,375	3,667	3,994
U.S.S.R.	3,011	2,928	2,861	3,033	3,036
France	4,249	4,525	4,915	5,096	5,485
Canada	3,6[illegible]0	3,749	3,925	4,145	4,299
United Kingdom	5,827	6,106	6,350	6,614	6,853
West Germany	3,618	4,104	4,118	4,307	4,669

[1] Obtained by dividing the number of articles which were written by scientists and engineers from more than one country by the total number of articles jointly written by S/E's from different organizations. This index is based on the articles, notes and reviews in over 2,100 of the influential journals carried on the 1973 *Science Citation Index* Corporate Tapes of the Institute for Scientific Information.

[2] When an article is authored by scientists and engineers from more than one country, that article is prorated across the countries involved. For example, if a given article has several authors from France and the United States, it is split ½ to France and ½ to the United States, regardless of the number of actual authors from these countries.

SOURCE: Computer Horizons, Inc., unpublished data.

See figure 1-20.

Table 1-29. Distribution of scientific and technical articles[1] in U.S. and foreign journals by field: 1973-77

Field[2]	1973	1974	1975	1976	1977
	U.S. articles[3] in foreign journals[4]				
All fields	19,941	19,871	19,504	20,191	20,152
Clinical medicine	4,695	4,850	5,000	4,854	4,975
Biomedicine	4,124	4,092	4,098	4,544	4,306
Biology	1,660	1,711	1,999	2,180	2,049
Chemistry	2,346	2,342	2,107	1,970	2,018
Physics	2,661	2,702	2,513	2,516	2,742
Earth and space sciences	1,200	1,131	996	1,109	1,126
Engineering and technology	1,382	1,338	1,195	1,255	1,302
Psychology	784	695	591	728	779
Mathematics	1,089	1,010	1,005	1,035	855
	Foreign articles in U.S. journals				
All fields	29,270	29,761	31,242	33,355	33,953
Clinical medicine	6,794	6,867	6,882	7,560	7,923
Biomedicine	4,148	4,340	5,144	5,154	5,377
Biology	2,013	1,889	1,865	1,803	1,971
Chemistry	5,484	5,700	6,270	7,062	6,583
Physics	4,118	4,384	4,434	5,048	5,143
Earth and space sciences	1,284	1,204	1,108	1,170	1,146
Engineering and technology	3,723	3,611	3,748	3,618	3,848
Psychology	845	859	817	853	895
Mathematics	861	907	974	1,087	1,067
	Balance[5]				
All fields	9,329	9,890	11,738	13,164	13,801
Clinical medicine	2,099	2,017	1,882	2,706	2,948
Biomedicine	24	248	1,046	610	1,071
Biology	353	178	-134	-377	-78
Chemistry	3,138	3,358	4,163	5,092	4,565
Physics	1,457	1,682	1,921	2,532	2,401
Earth and space sciences	84	73	112	61	20
Engineering and technology	2,341	2,273	2,553	2,363	2,546
Psychology	61	164	226	125	116
Mathematics	-228	-103	-31	52	212

[1] Based on the articles, notes, and reviews in over 2,100 of the influential journals carried on the 1973 *Science Citation Index* Corporate Tapes of the Institute for Scientific Information.

[2] See Appendix table 1-10 for the subfields included in these fields.

[3] When an article is authored by scientists and engineers from more than one country, that article is prorated across the countries involved. For example, if a given article has several authors from France and the United States, it is split ½ to France and ½ to the United States, regardless of the number of actual authors from these countries.

[4] The country of a journal is determined by where it is published.

[5] Obtained by subtracting the number of U.S. articles in foreign journals from the number of foreign articles in U.S. journals.

SOURCE: Computer Horizons, Inc., unpublished data.

See table 1-8 in text.

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Table 1-30. Participation in international scientific congresses: 1960-77

Year	Number of congresses	Total participants	U.S. participants	Non-U.S. participants
1960-1962	23	33,082	9,033	24,049
1963-1965	28	37,984	10,012	27,952
1966-1968	42	59,748	12,297	47,451
1969-1971	38	55,711	12,956	42,755
1972-1974	73	73,819	18,630	55,189
1975-1977	52	59,658	12,767	46,891
Total	256	319,982	75,695	244,287

SOURCE: National Academy of Sciences, unpublished data.

See figure 1-21. Science Indicators—1978

Table 2-1. National R&D expenditures: 1960-79

[Dollars in billions]

Year	Current dollars	Constant 1972 dollars[1]	GNP implicit price deflator[2]
1960	$13.5	$19.7	0.6867
1961	14.3	20.7	.6928
1962	15.4	21.8	.7055
1963	17.1	23.8	.7159
1964	18.9	25.9	.7271
1965	20.0	27.0	.7432
1966	21.8	28.5	.7676
1967	23.1	29.3	.7902
1968	24.6	29.8	.8257
1969	25.6	29.6	.8672
1970	25.9	28.4	.9136
1971	26.6	27.7	.9602
1972	28.4	28.4	1.0000
1973	30.6	28.9	1.0580
1974	32.7	28.2	1.1602
1975	32.2	27.7	1.2715
1976	38.8	29.0	1.3376
1977 (prelim)	42.9	30.3	1.4161
1978 (est)	47.3	31.1	1.5190
1979 (est)	51.6	31.8	1.6250

[1]GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

[2]Deflators for 1978 and 1979 assume an inflation rate of 7.3 and 7.0 percent, respectively. It is likely that actual inflation rates will be substantially higher; therefore, the constant dollar estimates presented throughout this report may be too high.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-1978-79* (NSF 78-313), p. 36.

See figure 2-1. Science Indicators—1978

ERIC

Table 2-2. National R&D expenditures as a percent of GNP by source: 1960-79

[Dollars in billions]

Year	Current dollars: GNP	Current dollars: All R&D by source: Total	Current dollars: All R&D by source: Federal	Current dollars: All R&D by source: Other	Current dollars: Basic & applied research	Constant 1972 dollars[1]: GNP	Constant 1972 dollars[1]: All R&D by source: Total	Constant 1972 dollars[1]: All R&D by source: Federal	Constant 1972 dollars[1]: All R&D by source: Other	Constant 1972 dollars[1]: Basic & applied research
1960	$ 506.0	$13.5	$ 8.7	$ 4.8	$ 4.2	$ 736.9	$19.7	$12.7	$ 7.0	$ 6.1
1961	523.3	14.3	9.2	5.1	4.5	755.3	20.7	13.4	7.3	6.4
1962	563.8	15.4	[illegible]	5.5	5.4	799.1	21.8	14.0	7.8	7.6
1963	594.7	17.1	11.2	5.9	5.7	830.7	23.8	15.7	8.2	8.0
1964	635.7	18.9	12.5	6.3	6.4	874.3	25.9	17.2	8.7	8.8
1965	688.1	20.0	13.0	7.0	6.9	925.9	27.0	17.5	9.5	9.3
1966	753.0	21.8	14.0	7.9	7.4	981.0	28.5	18.2	10.3	9.7
1967	796.3	23.1	14.4	8.8	7.8	1,007.7	29.3	18.2	11.1	9.9
1968	868.5	24.6	14.9	9.7	8.4	1,051.8	29.8	18.1	11.7	10.2
1969	935.5	25.6	14.9	10.7	8.8	1,078.8	29.6	17.2	12.4	10.1
1970	982.4	25.9	14.7	11.2	9.2	1,075.3	28.4	16.1	12.3	10.1
1971	1,063.4	26.6	14.9	11.7	9.4	1,107.5	27.7	15.5	12.2	9.8
1972	1,171.1	28.4	15.8	12.6	9.8	1,171.1	28.4	15.8	12.7	9.8
1973	1,306.6	30.6	16.3	14.3	10.6	1,235.0	29.8	15.4	13.5	10.0
1974	1,412.9	32.7	16.8	15.9	11.5	1,217.8	28.2	14.4	13.8	9.9
1975	1,528.8	35.2	18.2	17.0	12.5	1,202.1	27.7	14.3	13.4	9.8
1976	1,700.1	38.8	19.6	19.2	14.0	1,271.0	29.0	14.7	14.3	10.4
1977 (prelim.)	1,887.2	42.9	21.6	21.3	15.3	1,332.7	30.3	15.2	15.0	10.8
1978 (est.)	2,100.0	47.3	23.8	23.5	16.8	1,382.5	31.1	15.7	15.5	11.0
1979 (est.)	2,325.0	51.6	25.7	25.9	18.5	1,430.8	31.8	15.8	15.9	11.4

As a percent of GNP

Year	All R&D by source: Total	All R&D by source: Federal	All R&D by source: Other	Basic & applied research
1960	2.67	1.72	0.95	0.83
1961	2.73	1.7[illegible]	.97	0.85
1962	2.73	[illegible]	98	0.95
1963	2.88	1.88	99	0.96
1964	2.97	1.97	.99	1.01
1965	2.91	1.89	1.02	1.00
1966	2.90	1.86	1.05	0.99
1967	2.90	1.81	1.11	0.9[illegible]
1968	2.83	1.72	1.12	0.97
1969	2.74	1.59	1.14	0.94
1970	2.64	1.50	1.14	0.94
1971	2.50	1.40	1.10	0.88
1972	2.43	1.35	1.08	0.84
1973	2.34	1.25	1.09	0.81
1974	2.31	1.19	1.13	0.81
1975	2.30	1.19	1.11	0.82
1976	2.28	1.15	1.13	0.82
1977 (prelim.)	2.27	1.14	1.13	0.81
1978 (est.)	2.25	1.13	1.12	0.80
1979 (est.)	2.21	1.11	1.11	0.80

[1]GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NOTE: Percents are calculated from unrounded figures. Detail may not add to total because of rounding.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-1978-79* (NSF 78-313) and Department of Commerce, Bureau of Economic Analysis, *Survey of Current Business*, and "Commerce News."

See figures 2-2 and 2-3

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Table 2-3. National expenditures for R&D by source: 1960-79

[Dollars in millions]

Year	Total	Federal Government	Industry	Universities and colleges[1]	Other nonprofit institutions
			Current dollars		
1960	$18,523	$ 8,738	$ 4,516	$ 149	$120
1961	14,316	9,250	4,757	165	144
1962	15,394	9,911	5,123	185	175
1963	17,059	11,204	5,456	207	192
1964	18,854	12,536	5,888	235	195
1965	20,044	13,012	6,548	267	217
1966	21,846	13,969	7,328	303	246
1967	23,146	14,395	8,142	345	264
1968	24,604	14,926	9,005	391	282
1969	25,631	14,895	10,010	420	306
1970	25,905	14,668	10,439	461	337
1971	26,595	14,892	10,813	529	361
1972	28,413	15,755	11,698	575	385
1973	30,615	16,309	13,278	615	413
1974	32,734	16,754	14,854	677	449
1975	35,200	18,152	15,787	750	511
1976	38,816	19,628	17,804	821	563
1977 (prelim)	42,902	21,649	19,739	893	621
1978 (est)	47,295	23,815	21,780	1,000	700
1979 ([illegible])	51,630	25,715	24,060	1,110	755
			Constant 1972 dollars[2]		
1960	$19,693	$12,725	$ 6,576	$ 217	$175
1961	20,664	13,351	6,866	238	209
1962	21,820	14,048	7,262	262	248
1963	23,829	15,651	7,621	289	268
1964	25,930	17,241	8,098	323	268
1965	26,970	17,508	8,811	359	292
1966	28,460	18,198	9,547	395	320
1967	29,291	18,217	10,303	437	334
1968	29,798	18,077	10,906	474	341
1969	29,556	17,176	11,543	484	353
1970	28,355	16,055	11,426	505	369
1971	27,697	15,509	11,261	551	376
1972	28,413	15,755	11,698	575	385
1973	28,937	15,415	12,550	581	391
1974	28,214	14,440	12,893	584	387
1975	27,684	14,276	12,416	590	402
1976	29,019	14,674	13,310	614	421
1977 (prelim)	30,296	15,288	13,939	631	439
1978 (est)	31,136	15,679	14,338	658	461
1979 (est)	31,772	15,824	14,800	683	465

[1]Includes State and local sources which have accounted for almost one-half of these expenditures since 1970.

[2]GNP implicit deflators used to convert current dollars to constant 1972 dollars.

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

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-1978-79* (NSF 78-313), p.36.

See figure 2-4.

Science Indicators — 1978

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Table 2-4. National expenditures for R&D by performer: 1960-79

[Dollars in millions]

Year	Total	Federal Government	Industry	Universities and colleges[1]	FFRDC's[2]	Other nonprofit institutions
			Current dollars			
1960	$13,523	$1,726	$10,509	$ 646	$ 360	$ 282
1961	14,316	1,874	10,908	763	410	361
1962	15,394	2,098	11,464	904	470	458
1963	17,059	2,279	12,630	1,081	530	539
1964	18,854	2,838	13,512	1,275	629	600
1965	20,044	3,093	14,185	1,474	629	663
1966	21,846	3,220	15,548	1,715	630	733
1967	23,146	3,396	16,385	1,921	673	771
1968	24,604	3,493	17,429	2,149	719	814
1969	25,631	3,503	18,308	2,226	725	870
1970	25,905	3,855	18,062	2,335	737	916
1971	26,595	4,156	18,311	2,500	716	912
1972	28,413	4,482	19,539	2,676	764	952
1973	30,615	4,619	21,233	2,940	817	1,006
1974	32,734	4,815	22,867	3,023	865	1,164
1975	35,200	5,397	24,164	3,409	987	1,243
1976	38,816	5,710	26,906	3,730	1,147	1,323
1977 (prelim)	42,902	6,142	29,895	4,064	1,384	1,417
1978 (est)	47,295	6,565	33,250	4,585	1,375	1,520
1979 (est)	51,630	6,940	36,750	4,965	1,425	1,550
			Constant 1972 dollars[3]			
1960	$19,693	$2,513	$15,304	$ 941	$ 524	$ 411
1961	20,664	2,705	15,745	1,101	592	521
1962	21,820	2,974	16,249	1,281	666	649
1963	23,829	3,183	17,642	1,510	740	753
1964	25,930	3,903	18,583	1,754	865	825
1965	26,970	4,162	19,086	1,983	846	892
1966	28,460	4,195	20,255	2,234	821	955
1967	29,291	4,298	20,735	2,431	852	976
1968	29,798	4,230	21,108	2,603	871	986
1969	29,556	4,039	21,112	2,566	836	1,003
1970	28,355	4,220	19,770	2,556	807	1,003
1971	27,697	4,328	19,070	2,604	746	950
1972	28,413	4,482	19,539	2,676	764	952
1973	28,937	4,366	20,069	2,779	772	951
1974	28,214	4,150	19,710	2,606	746	1,003
1975	27,684	4,245	19,004	2,681	776	978
1976	29,019	4,269	20,115	2,789	858	989
1977 (prelim)	30,296	4,337	21,111	2,870	977	1,001
1978 (est)	31,136	4,322	21,889	3,018	905	1,001
1979 (est)	31,772	4,271	22,615	3,055	877	954

[1] Includes State and local sources.
[2] Federally Funded Research and Development Centers administered by universities.
[3] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-1978-79* (NSF 78-313), p. 37.

See figure 2-5.

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Table 2-5. Scientists and engineers[1] employed in R&D by sector: 1961-77

[In thousands]

Year	Total	Federal Government	Industry	Universities and colleges	FFRDC's[2]	Other nonprofit institutions
1961	425.7	51.1	312.0	42.4	9.1	11.1
1965	494.5	61.8	348.4	53.4	11.1	19.9
1968	550.4	68.1	381.9	66.0	11.2	23.2
1969	556.6	69.9	385.6	68.3	11.6	21.2
1970	546.5	69.8	375.5	68.5	11.5	21.2
1971	526.4	66.5	358.4	68.4	11.5	21.6
1972	518.5	65.2	353.3	66.5	11.7	21.8
1973	517.5	62.3	357.4	63.5	12.0	22.3
1974	525.4	65.0	359.5	65.5	12.1	23.3
1975	534.8	64.5	362.6	70.2	12.7	24.8
1976	549.9	65.3	372.4	72.4	13.4	26.4
1977 (est)	571.1	64.5	390.1	75.0	14.0	27.5
1978 (est)	595.0	65.0	410.0	77.5	14.5	28.0
1979 (est)	610.0	65.5	421.0	80.0	15.0	28.5

[1]Full-time-equivalent basis, excluding those employed in State and local agencies, and calculated as the yearly average for the industry sector.

[2]Federally Funded Research and Development Centers administered by universities.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-1978-79* (NSF 78-313), p. 45, and unpublished data.

See figure 2-6.

Science Indicators—1978

Table 2-6. Expenditures for research and for development: 1960-79

[Dollars in millions]

Year	Research total: Current dollars	Research total: Constant 1972 dollars[1]	Development total: Current dollars	Development total: Constant 1972 dollars[1]
1960	$ 4,217	$ 6,141	$ 9,306	$13,552
1961	4,466	6,446	9,850	14,218
1962	5,389	7,639	10,005	14,181
1963	5,707	7,972	11,352	15,857
1964	6,417	8,825	12,437	17,105
1965	6,894	9,276	13,150	17,694
1966	7,415	9,660	14,431	18,8[illegible]
1967	7,842	9,924	15,304	19,3[illegible]
1968	8,436	10,217	16,168	19,581
1969	8,767	10,109	16,864	19,447
1970	9,226	10,098	16,679	18,256
1971	9,420	9,810	17,175	17,887
1972	9,800	9,800	18,613	18,613
1973	10,554	9,976	20,061	18,961
1974	11,488	9,900	21,246	18,312
1975	12,474	9,811	22,726	17,873
1976	13,966	10,441	24,850	18,578
1977 (prelim)	15,320	10,819	27,582	19,477
1978 (est)	16,770	11,041	30,525	20,095
1979 (est)	18,450	11,354	33,180	20,418

[1]GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-1978-79* (NSF 78-313), calculated from pp. 30-35.

See figure 2-7.

Science Indicators—1978

Table 2-7. Total research expenditures by source: 1960-79

[Dollars in millions]

Year	Total	Federal Government	Industry	Universities and colleges	Nonprofit institutions
			Current dollars		
1960	$ 4,217	$2,403	$1,568	$138	$108
1961	4,466	2,628	1,556	154	128
1962	5,389	3,198	1,864	172	155
1963	5,707	3,436	1,908	193	170
1964	6,417	3,994	2,027	221	175
1965	6,894	4,333	2,115	252	194
1966	7,415	4,561	2,351	285	218
1967	7,842	4,901	2,381	325	235
1968	8,436	5,155	2,660	373	248
1969	8,767	5,236	2,860	403	268
1970	9,226	5,527	2,954	448	297
1971	9,420	5,548	3,039	515	318
1972	9,800	5,725	3,177	555	343
1973	10,554	6,114	3,494	582	364
1974	11,488	6,485	3,975	635	393
1975	12,474	7,114	4,207	703	450
1976	13,966	7,947	4,752	771	496
1977 (prelim)	15,320	8,687	5,254	834	545
1978 (est)	16,770	9,475	5,745	940	610
1979 (est)	18,450	NA	NA	NA	NA
			Constant 1972 dollars[1]		
1960	$ 6,141	$3,499	$2,284	$201	$157
1961	6,446	3,792	2,246	223	185
1962	7,639	4,533	2,643	244	219
1963	7,972	4,799	2,665	270	238
1964	8,825	5,492	2,788	304	241
1965	9,276	5,830	2,846	339	261
1966	9,660	5,942	3,063	371	284
1967	9,924	6,202	3,014	411	297
1968	10,217	6,243	3,222	451	301
1969	10,109	6,038	3,297	465	309
1970	10,098	6,050	3,233	490	325
1971	9,810	5,778	3,165	536	331
1972	9,800	5,725	3,177	555	343
1973	9,976	5,779	3,303	550	344
1974	9,900	5,589	3,426	547	338
1975	9,811	5,595	3,309	553	354
1976	10,441	5,941	3,552	577	371
1977 (prelim)	10,819	6,134	3,710	589	385
1978 (est)	11,041	6,237	3,782	619	402
1979 (est)	11,354	NA	NA	NA	NA

[1]GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NA = Not available.

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

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-1978-79* (NSF 78-313), calculated from pp. 38 and 40.

See figure 2-8.

Science Indicators—1978

Table 2-8. Percent change in the number of science and technology articles[1] by U.S. authors by field: 1973-1977

Field[2]	Number 1973	Number 1977	Percent change
All fields	109,328	102,433	-6
Clinical medicine	32,565	33,425	3
Biomedicine	16,120	16,186	(3)
Biology	11,151	9,904	-11
Chemistry	10,566	8,976	-15
Physics	11,710	10,987	-6
Earth and space sciences	5,591	4,810	-14
Engineering and technology	11,954	10,078	-16
Psychology	5,540	4,949	-11
Mathematics	4,126	3,112	-25

[1]Based on articles, notes and reviews in over 2,100 of the influential journals carried on the 1973 *Science Citation Index* Corporate tapes of the Institute for Scientific Information.

[2]See Appendix table 1-10 for the subfields included in these fields.

[3]Less than 0.5 percent.

SOURCE: Computer Horizons Inc., unpublished data.

See figure 2-9.

Science Indicators—1978

Table 2-9. Distribution of scientific and technical articles[1] written by U.S. scientists and engineers by field and research sector: 1973 and 1977.

Field[2]	Year	Total (Number)	Universities and colleges (Number)	Federal Gov't (Number)	Industry[3] (Number)	Nonprofit institutions[3] (Number)	FFRDC's[4] (Number)	All others (Number)	Total (Percent)	Universities and colleges (Percent)	Federal Gov't (Percent)	Industry[3] (Percent)	Nonprofit institutions[3] (Percent)	FFRDC's[4] (Percent)	All others (Percent)
All fields	1973	109,328	72,358	11,667	11,008	7,300	3,282	3,713	100	66	11	10	7	3	3
	1977	102,433	69,319	10,150	9,285	6,854	3,202	3,623	100	68	10	9	7	3	3
Clinical medicine	1973	32,565	20,781	3,801	1,310	4,749	186	1,738	100	64	12	4	15	1	4
	1977	33,425	22,120	3,766	1,121	4,629	162	1,627	100	66	11	3	14	1	5
Biomedicine	1973	16,120	12,320	1,530	806	1,123	327	314	100	76	9	3	7	2	3
	1977	16,186	12,628	1,489	442	1,060	257	310	100	78	9	3	7	2	1
Biology	1973	11,151	7,733	2,188	384	377	53	416	100	69	20	3	3	([5])	5
	1977	9,904	7,169	1,610	322	302	53	448	100	72	16	3	3	([5])	6
Chemistry	1973	10,566	7,235	792	1,847	202	361	129	100	68	7	17	2	3	3
	1977	8,976	6,276	630	1,415	187	346	122	100	70	7	16	2	4	1
Physics	1973	11,710	7,238	1,032	1,706	[illegible]	1,308	276	100	62	9	15	1	11	2
	1977	10,987	6,772	854	1,672	143	1,318	228	100	62	8	15	1	12	2
Earth and space science	1973	5,591	3,769	883	281	170	383	105	100	67	16	5	3	7	2
	1977	4,810	3,347	631	269	137	309	59	100	70	13	6	3	6	2
Engineering and technology	1973	11,954	4,716	1,080	4,789	294	623	452	100	39	9	40	2	5	5
	1977	10,078	3,870	908	3,888	213	715	384	100	38	9	39	2	7	5
Psychology	1973	5,540	4,783	252	75	169	7	254	100	86	5	1	3	([5])	5
	1977	4,949	4,295	181	75	125	9	264	100	87	4	1	3	([5])	5
Mathematics	1973	4,126	3,782	109	109	66	32	28	100	92	3	3	2	[illegible]	—
	1977	3,112	2,842	81	81	[illegible]	33	17	100	91	3	3	2	[illegible]	—

[1] Based on articles, notes and reviews in over 2,100 of the influential journals carried on the 1973 *Science Citation Index* Corporate tapes of the Institute for Scientific Information.

[2] See Appendix table 1-10 for the subfields included in these fields.

[3] Excluding Federally Funded Research and Development Centers (FFRDC) administered by these sectors.

[4] FFRDC's administered by universities.

[5] Less than 0.5 percent.

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

SOURCE: Computer Horizons, Inc., unpublished data.

See discussion following figure 2-8.

Table 2-10. Index[1] of cooperative research based on scientific and technical articles[2] by field and selected research-performing sectors: 1973 and 1977.

Fields	Universities and colleges		Federal Government		Industry[3]		Nonprofit[3] institutions		FFRDC's[4]		State and local governments	
	1973	1977	1973	1977	1973	1977	1973	1977	1973	1977	1973	1977
All fields	35	39	43	51	22	26	57	60	38	43	62	64
Clinical medicine	52	55	59	68	36	40	63	66	36	51	72	74
Biomedicine	34	32	45	49	31	39	55	55	40	45	54	56
Biology	26	30	32	39	27	38	37	39	40	45	42	47
Chemistry	19	21	22	27	15	16	33	40	43	46	30	39
Physics	31	35	26	34	20	23	38	44	42	48	(5)	(5)
Earth and space sciences	32	35	37	41	39	39	45	43	40	46	(5)	(5)
Engineering and technology	29	30	28	29	18	21	24	26	24	25	22	29
Psychology	21	25	48	58	42	41	46	49	(5)	(5)	52	56
Mathematics	16	19	24	35	31	45	41	47	(5)	(5)	(5)	(5)

[1] Based on articles, notes and reviews in over 2,100 of the influential journals carried on the 1973 *Science Citation Index* Corporate Tapes of the Institute for Scientific Information.

[2] Consisting of the percentage of all articles which were written by scientists and engineers in a given organization with S/E's from another organization; e.g., if S/E's from one university co-author an article with S/E's from another university or corporation, it is assumed here that there was some degree of cooperative research performed.

[3] Excluding the Federally Funded Research and Development Centers administered by this sector.

[4] FFRDC's administered by universities.

[5] Because the total number of articles was less than 50, no index percentages are calculated.

SOURCE: Computer Horizons, Inc., unpublished data.

See figure 2-10.

Table 2-11. National R&D expenditures by character of work: 1960-79

[Dollars in millions]

Year	Current dollars: Basic research	Current dollars: Applied research	Current dollars: Development	Constant 1972 dollars[1]: Basic research	Constant 1972 dollars[1]: Applied research	Constant 1972 dollars[1]: Development
1960	$1,197	$ 3,020	$ 9,306	$1,743	$4,398	$13,552
1961	1,401	3,065	9,850	2,022	4,424	14,218
1962	1,724	3,665	10,005	2,444	5,195	14,181
1963	1,965	3,742	11,352	2,7[illegible]5	5,227	15,857
1964	2,289	4,128	12,437	3,148	5,677	17,105
1965	2,555	4,339	13,150	3,438	5,838	17,694
1966	2,814	4,601	14,431	3,666	5,994	18,800
1967	3,039	4,803	15,304	3,846	6,078	19,367
1968	3,274	5,162	16,168	3,965	6,252	19,581
1969	3,425	5,342	16,864	3,949	6,160	19,447
1970	3,513	5,713	16,679	3,845	6,263	18,256
1971	3,577	5,843	17,175	3,725	6,085	17,887
1972	3,748	6,052	18,613	3,748	6,052	18,613
1973	3,877	6,677	20,061	3,665	6,311	18,961
1974	4,144	7,344	21,246	3,571	6,329	18,312
1975	4,527	7,947	22,726	3,561	6,250	17,873
1976	4,881	9,085	24,850	3,649	6,792	18,578
1977 (prelim)	5,440	9,880	27,582	3,842	6,977	19,477
1978 (est)	6,045	10,725	30,525	3,980	7,061	20,095
1979 (est)	6,700	11,750	33,180	4,123	7,231	20,418

[1]GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NOTE: The following definitions apply to the character of work categories presented above.

Basic research. For three of the sectors—Federal Government, universities and colleges, and other nonprofit institutions — the definition of basic research is directed toward increases of knowledge in science with "... a fuller knowledge or understanding of the subject under study, rather than a practical application thereof." To take account of an individual industrial company's commercial goals, the definition for the industry sector is modified to indicate that basic research projects represent "...original investigations for the advancement of scientific knowledge...which do not have specific commercial objectives, although they may be in fields of present or potential interest to the reporting company."

Applied Research. The following is the core definition in the NSF questionnaire sent to the universities and colleges: "Applied research is directed toward practical application of knowledge." Here again, the definition for the industry survey takes account of the characteristics of industrial organizations it covers "...research projects which represent investigations directed to discovery of new scientific knowledge and which have specific commercial objectives with respect to either products or processes."

Development. The NSF survey, concept of development may be summarized as "... the systematic use of the knowledge or understanding gained from research directed toward the production of useful materials, devices, systems, or methods, including design and development of prototypes and processes."

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-1978-79* (NSF 78-313), pp. 39, 41, and 43.

See figure 2-11.

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Table 2-12. Basic research expenditures by source: 1960-79

[Dollars in millions]

Year	Total	Federal Government	Industry	Universities and colleges	Other nonprofit institutions
			Current dollars		
1960	$1,197	$ 715	$342	$ 72	$ 68
1961	1,401	874	361	85	81
1962	1,724	1,131	394	102	97
1963	1,965	1,311	425	121	108
1964	2,289	1,597	434	144	114
1965	2,555	1,809	461	164	121
1966	2,814	1,979	510	196	129
1967	3,039	2,184	492	223	140
1968	3,274	2,314	535	276	149
1969	3,425	2,425	540	298	162
1970	3,513	2,453	528	350	182
1971	3,577	2,434	547	400	196
1972	3,748	2,553	563	414	218
1973	3,877	2,640	605	408	224
1974	4,144	2,826	649	432	237
1975	4,527	3,087	688	479	273
1976	4,881	3,355	760	481	285
1977 (prelim)	5,440	3,756	840	527	317
1978 (est)	6,045	4,190	895	600	360
1979 (est)	6,700	NA	NA	NA	NA
			Constant 1972 dollars[1]		
1960	$1,743	$1,041	$498	$105	$ 99
1961	2,022	1,261	521	123	117
1962	2,444	1,603	559	145	[illegible]
1963	2,745	1,831	594	169	151
1964	3,148	2,196	597	198	157
1965	3,438	2,434	620	221	163
1966	3,666	2,578	665	255	168
1967	3,846	2,764	623	282	177
1968	3,965	2,802	648	334	181
1969	3,949	2,796	622	344	187
1970	3,845	2,685	578	383	199
1971	3,725	2,535	570	416	204
1972	3,748	2,553	563	414	218
1973	3,665	2,495	572	386	212
1974	3,571	2,436	559	372	204
1975	3,561	2,428	541	377	215
1976	3,649	2,508	568	360	213
1977 (prelim)	3,842	2,652	593	372	224
1978 (est)	3,980	2,758	589	395	237
1979 (est)	4,123	NA	NA	NA	NA

[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NA = Not available.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-1978-79* (NSF 78-313), p. 38.

See figure 2-12.

Science Indicators—1978

Table 2-13. Applied research expenditures by source: 1960-79

[Dollars in millions]

Year	Total	Federal Government	Industry	Universities and colleges	Other nonprofit institutions
			Current dollars		
1960	$ 3,020	$1,688	$1,226	$ 66	$ 40
1961	3,065	1,754	1,195	69	47
1962	3,665	2,067	1,470	70	58
1963	3,742	2,125	1,483	72	62
1964	4,128	2,397	1,593	77	61
1965	4,339	2,524	1,654	88	73
1966	4,601	2,582	1,841	89	89
1967	4,803	2,717	1,889	102	95
1968	5,162	2,841	2,125	97	99
1969	5,342	2,811	2,320	105	106
1970	5,713	3,074	2,426	98	115
1971	5,843	3,114	2,492	115	122
1972	6,052	3,172	2,614	141	125
1973	6,677	3,474	2,889	174	140
1974	7,344	3,659	3,326	203	156
1975	7,947	4,027	3,519	224	177
1976	9,085	4,592	3,992	290	211
1977 (prelim.)	9,880	4,931	4,444	307	228
1978 (est.)	10,725	5,285	4,850	340	250
1979 (est.)	11,750	NA	NA	NA	NA
			Constant 1972 dollars[1]		
1960	$ 4,398	$2,458	$1,786	$ 96	$ 58
1961	4,424	2,531	1,725	100	68
1962	5,195	2,930	2,084	99	82
1963	5,227	2,968	2,071	101	87
1964	5,677	3,296	2,191	106	84
1965	5,838	3,396	2,226	118	98
1966	5,994	3,364	2,398	116	116
1967	6,078	3,438	2,391	129	120
1968	6,252	3,441	2,574	117	120
1969	6,160	3,242	2,675	121	122
1970	6,253	3,365	2,655	107	126
1971	6,085	3,243	2,595	120	127
1972	6,052	3,172	2,614	141	125
1973	6,[illegible]11	3,284	2,731	164	132
1974	6,329	3,153	2,867	175	134
1975	6,250	3,167	2,768	176	139
1976	6,792	3,433	2,984	217	158
1977 (prelim.)	6,977	3,482	3,117	217	161
1978 (est.)	7,061	3,479	3,193	224	165
1979 (est.)	7,231	NA	NA	NA	NA

[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NA = Not available.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-1978-79* (NSF 78-313), p. 40.

See figure 2-12.

Science Indicators—1978

Table 2-14. Development expenditures by source: 1960-79

(Dollars in millions)

Year	Total	Federal Government	Industry	Universities and colleges	Other nonprofit institutions
			Current dollars		
1960	$ 9,306	$ 6,335	$ 2,948	$11	$12
1961	9,850	6,622	3,201	11	16
1962	10,005	6,713	3,259	13	20
1963	11,352	7,768	3,548	14	22
1964	12,437	8,542	3,861	14	20
1965	13,150	8,679	4,433	15	23
1966	14,431	9,408	4,977	18	28
1967	15,304	9,494	5,761	20	29
1968	16,168	9,772	6,345	17	34
1969	16,864	9,659	7,150	17	38
1970	16,679	9,141	7,485	13	40
1971	17,175	9,344	7,774	14	43
1972	18,613	10,030	8,521	20	42
1973	20,061	10,195	9,784	33	49
1974	21,246	10,269	10,879	42	56
1975	22,726	11,038	11,580	47	61
1976	24,850	11,681	13,052	50	67
1977 (prelim.)	27,582	12,962	14,485	59	76
1978 (est.)	30,525	14,340	16,035	60	90
1979 (est.)	33,180	NA	NA	NA	NA
			Constant 1972 dollars[1]		
1960	$13,552	$ 9,226	$ 4,293	$16	$17
1961	14,218	9,558	4,621	16	23
1962	14,181	9,515	4,619	18	29
1963	15,857	10,850	4,956	20	31
1964	17,105	11,748	5,310	19	28
1965	17,694	11,678	5,965	20	31
1966	18,800	12,256	6,484	23	37
1967	19,367	12,015	7,290	25	37
1968	19,581	11,835	7,684	21	41
1969	19,447	11,138	8,245	20	44
1970	18,256	10,005	8,193	14	44
1971	17,887	9,731	8,096	15	45
1972	18,613	10,030	8,521	20	42
1973	18,961	9,636	9,248	31	46
1974	18,312	8,851	9,377	36	48
1975	17,873	8,681	9,107	37	48
1976	18,578	8,733	9,758	37	50
1977 (prelim.)	19,477	9,153	10,229	42	54
1978 (est.)	20,095	9,440	10,556	39	59
1979 (est.)	20,418	NA	NA	NA	NA

[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NA = Not available.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-1978-79* (NSF 78-313), p. 42.

See figure 2-12.

Table 2-15. Federal obligations for R&D by major function: 1960-1979

Year	Dollars in billions				As percent of total obligations		
	Total	Defense	Space	Civilian	Defense	Space	Civilian
1960	$7.6	$6.1	$0.4	$1.1	80	5	14
1961	9.1	7.0	.8	1.3	77	9	14
1962	10.3	7.2	1.4	1.6	70	14	16
1963	12.5	7.8	2.9	1.9	62	23	15
1964	14.2	7.8	4.3	2.1	55	30	15
1965	14.6	7.3	5.0	2.3	50	34	16
1966	15.3	7.5	5.1	2.7	49	33	18
1967	16.5	8.6	4.6	3.3	52	28	20
1968	15.9	8.3	4.2	3.5	52	26	22
1969	15.6	8.4	3.7	3.6	54	24	23
1970	15.3	8.0	3.5	3.8	52	23	25
1971	15.5	8.1	2.9	4.5	52	19	29
1972	16.5	8.9	2.7	4.9	54	16	30
1973	16.8	9.0	2.6	5.2	54	15	31
1974	17.4	9.0	2.5	5.9	52	14	34
1975	19.0	9.7	2.5	6.8	51	13	36
1976	20.7	10.4	2.9	7.4	50	14	36
1977	23.9	11.9	3.1	9.0	50	13	38
1978	26.2	12.6	3.1	10.5	48	12	40
1979 (est.)	29.4	14.1	3.6	11.7	48	12	40

Source: *Special Analyses: Budget of the United States Government, Fiscal Year 1980*, p. 324.

NOTE: Detail may not add to totals due to rounding. Estimates given for 1979 may change significantly as the result of Congressional action on agency budget requests.

See figure 2-13. Science Indicators—1978

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Table 2-16. Federal obligations for R&D by function: 1969-79

[Dollars in millions]

	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978 (est)	1979 (est)
Total	$15,641	$15,340	$15,545	$16,498	$16,800	$17,415	$18,988	$20,724	$23,929	$26,419	$27,972
National Defense	8,356	7,981	8,110	8,902	9,002	9,016	9,679	10,430	11,864	12,786	13,833
Space	3,732	3,510	2,893	2,714	2,601	2,478	2,511	2,863	3,066	3,141	3,383
All civilian R&D	3,554	3,852	4,542	4,881	5,197	5,920	6,798	7,430	9,000	10,491	10,756
Health	1,127	1,126	1,338	1,589	1,624	2,096	2,177	2,366	2,604	2,911	3,034
Energy development and conversion	435	425	422	475	535	665	1,186	1,439	2,301	2,862	2,827
Science and technology base[1]	436	449	463	543	550	641	713	785	901	988	1,061
Environment	285	322	434	503	620	659	795	847	954	1,066	1,082
Transportation and communications	458	590	779	615	630	703	641	636	705	829	837
Natural resources	199	234	321	351	338	332	398	433	500	608	644
Food and fiber	225	241	247	291	297	292	350	388	459	532	543
Education	155	147	186	191	214	173	149	142	120	137	146
Income security and social services	97	106	128	125	157	134	149	133	159	182	207
Area and community development, housing, and public services	49	91	89	87	97	96	102	104	107	139	129
Economic growth and productivity	56	80	93	57	67	66	62	77	86	90	101
Crime prevention and control	5	9	10	25	35	36	46	36	32	73	48
International cooperation and development	27	32	32	29	33	27	30	44	72	74	97

[1] Basic research obligations which can be associated with the agencies' missions are not included here but are distributed across the appropriate functions.

NOTE: Detail may not add to totals because of rounding. Function categories are not the same as those of Appendix table 1-5, e.g., "Advancement of knowledge" does not equal "Science and technology base." Estimates given for 1979 may change significantly as a result of Congressional action on agency budgetary requests.

SOURCE: National Science Foundation, *An Analysis of Federal R&D Funding by Function, 1969-79* (NSF 78-320) p. 6.

See figure 2-14.

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Table 2-17. Federal expenditures for R&D plant: 1960-79

[Dollars in millions]

Year	Current dollars	Constant 1972 dollars[1]
1960	$ 443.8	$ 631.7
1961	539.1	778.1
1962	779.1	1,104.3
1963	673.6	940.9
1964	948.1	1,303.9
1965	1,077.4	1,449.7
1966	1,047.8	1,365.0
1967	786.1	994.8
1968	715.9	867.0
1969	652.2	752.1
1970	578.9	633.6
1971	612.7	638.1
1972	564.4	564.4
1973	638.0	603.0
1974	704.2	607.0
1975	829.9	652.7
1976	800.6	598.6
1977 (est.)	800.2	565.1
1978 (est.)	1,388.3	914.0
1979 (est.)	1,403.8	863.9

[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

SOURCE: National Science Foundation, *Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years 1977, 1978, & 1979*, Vol. XXVII, Detailed Statistical Tables (NSF 78-312), p. 101, and earlier volumes.

See figure 2-15.

Table 2-18. Federal obligations for R&D plant by performer: 1962-77

[Dollars in millions]

Year	Total	Federal Government	Industry	Universities and colleges	FFRDC's[1]	Nonprofit institutions
			Current dollars			
1962	$ 779.1	NA	NA	NA	NA	NA
1963	1,168.3	NA	NA	NA	NA	NA
1964	1,098.5	NA	NA	NA	NA	NA
1965	1,131.6	$ 913.0	NA	$141.6	$ 50.2	NA
1966	853.3	629.0	NA	162.9	31.1	NA
1967	620.1	239.0	NA	111.7	138.8	NA
1968	603.8	294.2	$ 81.1	98.1	101.7	$20.9
1969	669.0	260.4	141.7	61.9	176.6	25.8
1970	524.4	166.0	102.3	56.1	169.0	28.8
1971	611.2	200.0	167.4	49.2	178.7	5.8
1972	602.1	246.6	142.4	45.3	130.4	30.0
1973	774.3	323.8	221.8	42.6	162.3	18.8
1974	766.3	308.7	294.1	25.0	118.4	8.3
1975	820.7	346.8	291.9	35.9	131.8	14.1
1976	836.7	316.8	279.6	35.2	189.6	15.6
1977	1,367.2	711.9	319.2	33.7	277.8	12.8
			Constant 1972 dollars[2]			
1962	$1,104.3	NA	NA	NA	NA	NA
1963	1,631.9	NA	NA	NA	NA	NA
1964	1,510.8	NA	NA	NA	NA	NA
1965	1,522.6	$1,228.5	NA	$190.5	$ 67.5	NA
1966	1,148.2	819.4	NA	212.2	40.5	NA
1967	784.7	302.5	NA	141.4	175.7	NA
1968	731.3	356.3	$ 98.9	118.8	123.2	$25.3
1969	771.4	300.3	163.4	71.4	203.6	29.8
1970	574.[illegible]	181.7	112.0	61.4	185.0	31.5
1971	636.5	208.3	174.3	51.2	186.1	6.0
1972	602.1	246.6	142.4	45.3	130.4	30.0
1973	731.9	306.0	209.6	40.3	153.4	17.8
1974	658.3	265.2	252.6	21.5	101.7	7.1
1975	645.0	272.5	229.4	28.2	193.6	11.1
1976	625.0	236.6	208.8	26.3	141.5	11.6
1977	967.6	503.8	225.9	23.8	196.6	9.1

[1] Federally Funded Research and Development Centers administered by universities.
[2] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NA = not available.

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

SOURCE: National Science Foundation, *Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years, 1977, 1978 & 1979*, Vol. XXVII, Detailed Statistical Tables (NSF 77-312), p. 102, and earlier volumes.

See figure 2-16.

Table 3-1. Basic research expenditures: 1960-1979

[Dollars in millions]

Year	Current dollars	Constant 1972 dollars[1]	GNP implicit price deflator[2]
1960	$1,197	$1,743	0.6867
1961	1,401	2,022	.6928
1962	1,724	2,444	.7055
1963	1,965	2,745	.7159
1964	2,289	3,148	.7271
1965	2,555	3,438	.7432
1966	2,814	3,666	.7676
1967	3,039	3,846	.7902
1968	3,274	3,965	.8257
1969	3,425	3,949	.8672
1970	3,513	3,845	.9136
1971	3,577	3,725	.9602
1972	3,748	3,748	1.0000
1973	3,877	3,665	1.0580
1974	4,144	3,571	1.1602
1975	4,527	3,561	1.2715
1976	4,881	3,649	1.3376
1977 (prelim.)	5,440	3,842	1.4161
1978 (est.)	6,045	3,980	1.5190
1979 (est.)	6,700	4,123	1.6250

[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

[2] Deflators for 1978 and 1979 assume an inflation rate of 7.3 and 7.0 percent, respectively. It is likely that actual inflation rates will be substantially higher; therefore, the constant dollar estimates presented throughout this report may be too high.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-1978-79* (NSF 78-313), p. 38.

See figure 3-1.

Table 3-2. Basic research expenditures by source[1]: 1960-79

[Dollars in millions]

Year	Total	Federal Government	Industry	Universities and colleges[2]	Other nonprofit institutions
			Current dollars		
1960	$1,197	$ 715	$342	$ 72	$ 68
1961	1,401	874	361	85	81
1962	1,724	1,131	394	102	97
1963	1,965	1,311	425	121	108
1964	2,289	1,597	434	144	114
1965	2,555	1,809	461	164	121
1966	2,814	1,979	510	196	129
1967	3,039	2,184	492	223	140
1968	3,274	2,314	535	276	149
1969	3,425	2,425	540	298	162
1970	3,513	2,453	528	350	182
1971	3,577	2,434	547	400	196
1972	3,748	2,553	563	414	218
1973	3,877	2,640	605	408	224
1974	4,144	2,826	649	432	237
1975	4,527	3,087	688	479	273
1976	4,881	3,355	760	481	285
1977 (prelim.)	5,440	3,756	840	527	317
1978 (est.)	6,045	4,190	895	600	360
1979 (est.)	6,700	NA	NA	NA	NA
			Constant 1972 dollars[3]		
1960	$1,743	$1,041	$498	$105	$ 99
1961	2,022	1,261	521	123	117
1962	2,444	1,603	559	145	137
1963	2,745	1,831	594	169	151
1964	3,148	2,196	597	198	157
1965	3,438	2,434	620	221	163
1966	3,666	2,578	665	255	168
1967	3,846	2,764	623	282	177
1968	3,965	2,802	648	334	181
1969	3,949	2,796	622	344	187
1970	3,845	2,685	578	383	199
1971	3,725	2,535	570	416	204
1972	3,748	2,553	563	414	218
1973	3,665	2,495	572	386	212
1974	3,571	2,436	559	372	204
1975	3,561	2,428	541	377	215
1976	3,649	2,508	568	360	213
1977 (prelim.)	3,842	2,652	593	372	224
1978 (est.)	3,980	2,758	589	395	237
1979 (est.)	4,123	NA	NA	NA	NA

[1] Over 50 percent of the total basic research expenditures are accounted for by universities and colleges. Because data on individual non-Federal sources of basic research expenditures are not collected by survey but are estimated by NSF, the expenditures in the last three columns of this table are only approximations.

[2] Includes State and local government sources.

[3] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NA = Not Available.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-1978-79*, (NSF 78-313) p. 38.

See figure 3-2.

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Table 3-3. Basic research expenditures by performer: 1960-78

[Dollars in millions]

Year	Total	Federal Government laboratories	Industry[1]	Universities and colleges	FFRDC's[2]	Other nonprofit institutions[1]
			Current dollars			
1960	$1,197	$160	$376	$ 433	$ 97	$131
1961	1,401	206	395	536	115	149
1962	1,724	251	488	659	136	190
1963	1,965	255	522	814	159	215
1964	2,289	314	549	1,003	191	232
1965	2,555	364	592	1,138	208	253
1966	2,814	385	624	1,303	227	275
1967	3,039	418	629	1,457	250	285
1968	3,274	410	642	1,649	276	297
1969	3,425	516	618	1,711	275	305
1970	3,513	541	602	1,796	269	305
1971	3,577	491	590	1,914	260	322
1972	3,748	538	593	2,022	250	345
1973	3,877	537	631	2,055	297	357
1974	4,144	611	699	2,153	285	396
1975	4,527	682	719	2,410	309	407
1976	4,881	719	817	2,547	359	439
1977 (prelim.)	5,440	866	906	2,787	402	479
1978 (est.)	6,045	975	975	3,165	410	520
			Constant 1972 dollars[3]			
1960	$1,743	$233	$548	$ 631	$141	$191
1961	2,022	297	570	774	166	215
1962	2,444	356	692	934	193	269
1963	2,745	356	729	1,137	222	300
1964	3,148	432	755	1,379	263	319
1965	3,438	490	797	1,531	280	340
1966	3,666	502	813	1,697	296	358
1967	3,846	529	796	1,844	316	361
1968	3,965	497	778	1,997	334	360
1969	3,949	595	713	1,973	317	352
1970	3,845	592	659	1,966	294	334
1971	3,725	511	614	1,993	271	335
1972	3,748	538	593	2,022	250	345
1973	3,665	508	596	1,942	281	337
1974	3,571	527	602	1,856	246	341
1975	3,561	536	565	1,895	243	320
1976	3,649	538	611	1,904	268	328
1977 (prelim.)	3,842	612	640	1,968	284	338
1978 (est.)	3,980	642	642	2,084	270	342

[1] Includes the associated Federally Funded Research and Development Centers.
[2] Federally Funded Research and Development Centers administered by universities.
[3] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-1978-79*, (NSF 78-313), p. 39.

See figure 3-3.

Table 3-4. Distribution of scientific and technical articles[1] by U.S. scientists and engineers by field and level of research: 1973 and 1977.

Field and level of research	1973	1977	Percent change
Clinical medicine			
Basic research	12,596	13,088	4
Applied research	19,967	20,334	2
Biomedicine			
Basic research	15,481	15,538	(2)
Applied research	640	648	1
Biology			
Basic research	7,485	6,862	-8
Applied research	3,667	3,042	-17
Chemistry			
Basic research	9,861	8,418	-15
Applied research	705	558	-21
Physics			
Basic research	11,293	10,500	-7
Applied research	417	487	17
Earth and space sciences			
Basic research	5,067	4,203	-17
Applied research	524	607	16
Engineering and technology			
Basic research	879	919	5
Applied research	11,074	9,158	-16
Psychology			
Basic research	2,332	1,893	-19
Applied research	3,207	3,057	-5
Mathematics			
Basic research	3,650	2,728	-25
Applied research	476	384	-19

[1] Based on the articles, notes, and reviews in over 2,100 of the influential journals of the 1973 *Science Citation Index* Corporate Tapes of the Institute for Scientific Information.

[2] Less than 0.5 percent.

SOURCE: Computer Horizons, Inc., unpublished data.

See figure 3-4.

Table 3-5. Distribution of scientific and technical articles[1] by U.S. scientists and engineers by field and level of research: 1973 and 1977.

Field and level of research	Year	Total	Universities and colleges	Federal Gov't	Industry	Nonprofit institutions	All other
		Number					
Clinical medicine							
Basic research	1973	12,596	8,450	1,426	896	1,257	567
	1977	13,088	9,088	1,518	756	1,233	493
Applied research	1973	19,967	12,331	2,375	414	3,492	1,355
	1977	20,334	13,033	2,248	364	3,396	1,293
Biomedicine							
Basic research	1973	15,481	11,869	1,471	490	1,050	601
	1977	15,538	12,176	1,427	424	989	522
Applied research	1973	640	451	59	16	73	41
	1977	648	451	62	18	72	45
Biology							
Basic research	1973	7,485	5,474	1,281	142	298	290
	1977	6,862	5,218	918	150	266	310
Applied research	1973	3,667	2,259	907	243	80	178
	1977	3,042	1,951	692	172	36	491
Chemistry							
Basic research	1973	9,861	7,046	598	1,573	185	459
	1977	8,418	6,143	501	1,162	168	444
Applied research	1973	705	189	194	275	17	30
	1977	558	132	129	254	18	25
Physics							
Basic research	1973	11,293	7,079	982	1,527	140	1,565
	1977	10,500	6,574	772	1,506	136	1,512
Applied research	1973	417	159	49	179	9	21
	1977	487	198	82	166	6	35
Earth and space sciences							
Basic research	1973	5,067	3,500	795	181	153	438
	1977	4,203	3,047	542	143	116	355
Applied research	1973	524	270	88	100	19	49
	1977	607	300	89	126	21	71
Engineering and technology							
Basic research	1973	879	318	91	197	16	257
	1977	919	287	102	218	12	300
Applied research	1973	11,074	4,397	990	4,592	178	917
	1977	9,158	3,583	806	3,670	201	898
Psychology							
Basic research	1973	2,332	2,061	106	27	65	73
	1977	1,893	1,719	64	14	47	49
Applied research	1973	3,207	2,722	145	46	105	189
	1977	3,057	2,576	118	61	79	223
Mathematics							
Basic research	1973	3,650	3,405	82	65	63	35
	1977	2,728	2,523	68	58	53	26
Applied research	1973	476	377	27	44	3	25
	1977	384	319	13	23	5	24

(continued)

Table 3-5. (Continued)

Field and level of research	Year	Total	Universities and colleges	Federal Gov't	Industry	Nonprofit institutions	All other
				Percent			
Clinical medicine							
Basic research	1973	100	67	11	7	10	5
	1977	100	69	12	6	9	1
Applied research	1973	100	62	12	2	17	7
	1977	100	64	11	2	17	6
Biomedicine							
Basic research	1973	100	77	10	3	7	3
	1977	100	78	9	3	6	4
Applied research	1973	100	70	9	3	11	7
	1977	100	70	10	3	11	6
Biology							
Basic research	1973	100	73	17	2	4	4
	1977	100	76	13	2	4	5
Applied research	1973	100	62	25	7	2	4
	1977	100	64	23	6	1	6
Chemistry							
Basic research	1973	100	71	6	16	2	5
	1977	100	73	6	14	2	5
Applied research	1973	100	27	28	39	2	4
	1977	100	24	23	46	3	4
Physics							
Basic research	1973	100	63	9	14	1	13
	1977	100	63	7	14	1	15
Applied research	1973	100	38	12	43	2	5
	1977	100	41	17	34	1	7
Earth and space sciences							
Basic research	1973	100	69	16	4	3	8
	1977	100	72	13	3	3	9
Applied research	1973	100	52	17	19	3	9
	1977	100	49	15	21	3	12
Engineering and technology							
Basic research	1973	100	36	10	22	2	30
	1977	100	31	11	24	1	33
Applied research	1973	100	40	9	41	2	8
	1977	100	39	9	40	2	10
Psychology							
Basic research	1973	100	88	5	1	3	3
	1977	100	91	3	1	2	3
Applied research	1973	100	85	5	1	3	6
	1977	100	84	4	2	3	7
Mathematics							
Basic research	1973	100	93	2	2	2	1
	1977	100	92	2	2	2	2
Applied research	1973	100	79	6	9	1	5
	1977	100	83	3	6	1	7

[1] Based on the articles, notes, and reviews in over 2,100 of the influential journals of the 1973 *Science Citation Index* Corporate tapes of the Institute for Scientific Information.

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E: Computer Horizons, Inc., unpublished data.

Table 3-6. Index of cooperative research[1] based on scientific and technical articles, by field, level of research, and selected research-performing sectors: 1973 and 1977

Field and level of research	Universities and colleges		Federal Government		Industry[2]		Nonprofit institutions		FFRDC's[3]		State and local governments	
	1973	1977	1973	1977	1973	1977	1973	1977	1973	1977	1973	1977
Clinical medicine												
Basic research	47	50	58	62	27	34	61	61	33	47	63	66
Applied research	55	58	60	72	51	51	64	68	47	62	75	76
Biomedical												
Basic research	34	37	46	49	31	39	55	55	40	45	53	55
Applied research	40	48	36	34	[4]	[4]	51	51	[4]	[4]	[4]	[4]
Biology												
Basic research	25	28	34	40	29	44	38	40	37	43	37	47
Applied research	29	33	28	37	26	33	[4]	32	[4]	56	48	47
Chemistry												
Basic research	19	21	25	30	16	17	34	42	43	47	33	42
Applied research	21	23	11	11	10	9	[4]	[4]	[4]	[4]	[4]	[4]
Physics												
Basic research	31	35	27	35	20	23	39	45	42	48	[4]	[4]
Applied research	31	29	20	29	16	18	[4]	[4]	[4]	[4]	[4]	[4]
Earth and space sciences												
Basic research	32	35	38	42	45	45	47	45	41	48	[4]	[4]
Applied research	31	30	23	33	29	32	[4]	[4]	[4]	[4]	[4]	[4]
Engineering and technology												
Basic research	35	33	33	26	[4]	19	39	[4]	16	20	[4]	[4]
Applied research	28	30	27	29	17	21	23	26	29	28	21	28
Psychology												
Basic research	19	23	48	65	[4]	[4]	42	55	[4]	[4]	54	[4]
Applied research	23	26	48	54	40	41	48	44	[4]	[4]	51	51
Mathematics												
Basic research	16	18	26	32	33	48	42	45	[4]	[4]	[4]	[4]
Applied research	20	22	[4]	45	28	[4]	[4]	[4]	[4]	[4]	[4]	[4]

[1] Consisting of the percentage of all articles which were written by scientists and engineers in a given organization with S/E's from another organization; e.g., if S/E's from one university co-author an article with S/E's from another university or a corporation, it is assumed here that there was some degree of cooperative research performed.

[2] Excluding the Federally Funded Research and Development Centers administered by this sector.

[3] FFRDC's administered by universities.

[4] Because the total number of articles was less than 50, no index percentages are calculated.

NOTE: For this study, over 2,100 influential journals of the *1973 Science Citation Index* Corporate tapes of the Institute for Scientific Information for 1973 were assigned to two categories, the "more basic" and the "more applied" research. From field to field, this assignment may represent somewhat different concepts of "basic research," although for each field the same concept applies for both 1973 and 1977. For further information, see Francis Narin, *Evaluative Bibliometrics: The Use of Publication and Citation Analysis in the Evaluation of Scientific Activity* (Cherry Hill, N.J.: Computer Horizons, Inc., 1976), pp. 198-199.

SOURCE: Computer Horizons, Inc., unpublished data.

See table 3-1 in text.

Table 3-7. Examples of journals classified as "more basic" and "more applied" for Appendix tables 3-4, 3-5 and 3-6.

Field	The more basic	The more applied
Clinical medicine	Journal of Clinical Investigation Journal of Neurophysiology	Journal of the American Medical Association New England Journal of Medicine
Biomedicine	Advances in Human Genetics Journal of Biological Chemistry	Journal of Biosocial Science Journal of Medical Genetics
Biology	Journal of Economic Entomology Journal of Experimental Zoology	Journal of the Institute of Brewing Agronomy Journal
Chemistry	Journal of the American Chemical Society Analytical Chemistry	Journal of the American Leather Chemists Assoc. Industrial Engineering Chemistry Process Design and Development
Physics	Reviews of Modern Physics Physical Review	Photogrammetric Engineering and Remote Sensing IEEE Transactions on Sonics and Ultrasonics
Earth and space sciences	Journal of Geophysical Research Journal of the Atmospheric Sciences	Solar Energy AAPG Bulletin (American Association of Petroleum Geologists)
Engineering and technology	IEEE Transactions on Nuclear Science Journal of Chemical and Engineering Data	Journal of the Iron and Steel Institute AICHE Journal (American Institute of Chemical Engineers)
Psychology	Psychological Bulletin Journal of Experimental Psychology	Journal of Personality and Social Psychology Perceptual and Motor Skills
Mathematics	Journal of the American Statistical Association Transactions of the American Mathematical Society	Quarterly Journal of Applied Mathematics SIAM Journal on Numerical Analysis

SOURCE: Computer Horizons, Inc., unpublished.

Science Indicators—1978

Table 3-8. Federal obligations for basic research by agency: 1963-79

[Dollars in millions]

Year	All agencies	USDA	DOD	HEW	DOE[1]	NASA	NSF	All other agencies
				Current dollars				
1963	$1,152	$ 56	$231	$236	$219	$210	$141	$ 59
1964	NA	68	241	274	238	NA	155	67
1965	NA	90	263	308	258	NA	171	76
1966	NA	94	262	326	281	NA	223	94
1967	1,728	100	284	372	302	328	239	103
1968	1,721	100	263	397	282	321	252	106
1969	1,779	107	276	371	285	380	248	112
1970	1,762	116	247	388	287	358	245	121
1971	1,779	118	262	397	277	327	273	125
1972	1,974	137	270	461	268	332	368	138
1973	2,001	143	258	458	275	360	392	125
1974	2,076	146	244	561	270	306	415	134
1975	2,279	154	236	592	313	309	486	189
1976	2,425	171	248	652	346	293	524	191
1977	2,894	204	295	757	389	414	625	210
1978 (est.)	3,292	251	330	866	433	468	688	256
1979 (est.)	3,637	267	371	982	468	520	755	274
				Constant 1972 dollars[2]				
1963	$1,609	$ 78	$323	$330	$306	$293	$197	$ 82
1964	NA	94	331	377	327	NA	213	92
1965	NA	121	354	408	347	NA	230	102
1966	NA	122	341	425	366	NA	291	122
1967	2,187	127	359	471	382	415	302	130
1968	2,084	121	319	481	342	389	305	128
1969	2,051	123	318	428	329	438	286	129
1970	1,929	127	270	425	314	392	268	132
1971	1,853	123	273	413	288	341	284	130
1972	1,974	137	270	461	268	332	368	138
1973	1,891	135	244	433	260	331	371	118
1974	1,789	126	210	484	233	264	358	115
1975	1,792	121	186	465	246	243	382	149
1976	1,811	128	185	487	258	219	391	143
1977	2,048	144	209	536	275	293	442	149
1978 (est.)	2,187	167	219	575	288	311	457	170
1979 (est.)	2,273	167	232	614	292	325	472	171

[1] Data for 1963-73 represent obligations by the Atomic Energy Commission; 1974-76 represent obligations by the Energy Research and Development Administration; 1977-79 represent obligations by the Department of Energy.
[2] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NOTE: Details may not add to totals because of rounding.

NA = Not available

SOURCE: National Science Foundation, *Federal Funds for Research and Development, Fiscal Years 1977, 1978, and 1979*, Vol. XXVII (NSF 78-312), p. 164 and earlier volumes.

See figure 3-5.

Table 3-9. Federal obligations for basic research as a percent of each agency's R&D obligations by agency: 1963-79

Year	All agencies	USDA	DOD	HEW	DOE[1]	NASA	NSF	All other agencies
				Basic research as a percent of all R&D obligations				
1963	9	33	3	36	20	7	92	20
1964	NA	36	3	35	19	NA	91	22
1965	NA	40	4	35	21	NA	91	22
1966	NA	40	4	32	23	NA	91	17
1967	10	40	4	32	24	7	91	15
1968	11	39	3	32	21	7	89	17
1969	11	41	4	29	20	10	91	15
1970	11	41	3	32	21	9	85	12
1971	11	39	3	27	21	10	81	9
1972	12	39	3	26	21	11	81	12
1973	12	39	3	25	20	11	82	10
1974	12	39	3	24	18	10	75	10
1975	12	37	3	25	15	10	82	13
1976	12	37	3	26	14	9	86	12
1977	12	37	3	27	11	11	90	12
1978 (est.)	12	40	3	28	10	12	91	13
1979 (est.)	13	42	3	30	11	12	91	13
				Federal obligations for basic research (Current dollars in millions)				
1963	$1,152	$ 56	$231	$236	$219	$210	$141	$ 59
1964	NA	68	241	274	238	NA	155	67
1965	NA	90	263	303	258	NA	171	76
1966	NA	94	262	326	281	NA	223	94
1967	1,728	100	284	372	302	328	239	103
1968	1,721	100	263	397	282	321	252	106
1969	1,779	107	276	371	285	380	248	112
1970	1,762	116	247	388	287	358	245	121
1971	1,779	118	262	397	277	327	273	125
1972	1,974	137	270	461	268	332	368	138
1973	2,001	143	258	458	275	350	392	125
1974	2,076	146	244	561	270	306	415	134
1975	2,279	154	236	592	313	309	486	189
1976	2,425	171	248	652	346	293	524	191
1977	2,894	204	295	757	389	414	625	210
1978 (est.)	3,292	251	330	866	433	468	688	256
1979 (est.)	3,637	267	371	982	468	520	755	274
				Federal obligations for all R&D (Current dollars in millions)				
1963	$12,495	$168	$ 7,286	$ 656	$1,078	$2,857	$154	$ 295
1964	14,225	189	7,262	777	1,236	4,287	170	304
1965	14,614	225	6,797	869	1,241	4,952	187	343
1966	15,320	235	7,024	1,014	1,212	5,050	244	541
1967	16,529	253	8,049	1,147	1,257	4,867	262	694
1968	15,921	254	7,709	1,252	1,369	4,429	284	625
1969	15,641	260	7,696	1,297	1,406	3,963	274	744
1970	15,340	281	7,360	1,221	1,346	3,800	289	1,043
1971	15,545	305	7,509	1,476	1,303	3,258	337	1,357
1972	16,498	350	8,318	1,751	1,298	3,157	455	1,169
1973	16,800	366	8,404	1,838	1,363	3,061	480	1,288
1974	17,415	379	8,420	2,290	1,489	3,002	556	1,278
1975	18,988	420	9,012	2,363	2,047	3,064	595	1,486
1976	20,724	462	9,655	2,546	2,464	3,447	609	1,541
1977	23,929	547	10,963	2,787	3,536	3,703	697	1,695
1978 (est.)	26,420	632	11,825	3,132	4,196	3,876	754	2,005
1979 (est.)	27,972	636	12,838	3,271	4,175	4,192	829	2,031

[1] Data for years 1963-73 are from Atomic Energy Commission; 1974-76 are from Energy Research and Development Administration; 1977-79 are from Department of Energy.

NOTE: Details may not add to totals because of rounding.

NA – Not available.

SOURCES: National Science Foundation, *Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years, 1977, 1978, and 1979*, Vol. XXVII, Detailed Statistical Tables, Appendix C, (NSF 78-312), and earlier volumes, and unpublished data.

See figure 3-6.

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Table 3-10. Federal obligations for basic research by field of science: 1963-79

[Dollars in millions]

Field	1963	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978 (est.)	1979 (est.)
All fields	$1,152	$1,728	$1,721	$1,779	$1,762	$1,779	$1,974	$2,001	$2,076	$2,279	$2,425	$2,894	$3,292	$3,637
Life sciences	372	573	579	539	554	574	668	669	737	797	878	1,021	1,167	1,299
Biological	200	346	375	403	407	429	515	556	566	633	708	795	913	1,010
Clinical medical[1]	172	227	205	136	143	100	128	98	138	141	147	198	222	254
Other life sciences	(2)	(2)	(2)	(2)	4	45	25	16	33	23	24	28	31	35
Environmental sciences[3]	164	209	199	235	256	280	291	299	320	339	355	456	512	587
Physical sciences	404	605	599	662	589	582	625	618	640	702	722	874	978	1,068
Chemistry	84	123	119	131	135	126	146	151	155	168	175	223	243	267
Physics	228	348	352	350	320	328	345	338	346	365	383	448	492	518
Astronomy	74	107	110	174	129	122	125	119	132	161	159	193	232	268
Other physical sciences	20	27	18	7	5	7	8	10	7	8	5	10	11	15
Psychology	35	60	55	53	56	44	54	46	49	60	44	54	64	74
Mathematics and computer sciences	40	65	67	56	58	51	63	57	49	59	70	79	89	101
Engineering	110	156	156	151	180	169	185	204	190	234	240	303	346	374
Social sciences	25	57	61	71	64	70	80	78	73	73	85	95	117	128
Other sciences	2	4	4	11	4	9	9	28	16	15	33	12	20	25

[1] See Appendix table 3-7 for definitions of what is included in each of the fields presented above.
[2] Less than $0.5 million.
[3] Includes atmospheric sciences, geological sciences, oceanography and other environmental sciences (see also Appendix table 3-11).

SOURCE: National Science Foundation, *Federal Funds for Research and Development, Fiscal Years 1977, 1978, and 1979*, Vol. XXVII (NSF 78-312), p. 51-66.

See figures 3-7 and 3-8.

Table 3-11. Fields and subfields of Federal obligations for basic research shown in Figures 3-7, 3-8 and Appendix tables 3-10 and 3-13.

Field of science	Illustrative subfields
Life sciences	Biological sciences: those which, apart from the clinical medical and other medical sciences as defined below, deal with the origin, development, structure, function, and interaction of living things.
	Clinical medical sciences: those concerned with the study of the pathogenesis, diagnosis, or therapy of a particular disease or abnormal condition in living human subjects under controlled conditions.
	Other medical sciences: those concerned with studies of the causes, effects, prevention, or control of abnormal conditions in man or in his environment as they relate to health, except for the clinical aspects as defined above.
	Other life sciences: multidisciplinary projects within the broad field and for single-discipline projects for which a separate field has not been assigned.
Environmental sciences	Atmospheric sciences: aeronomy; solar; weather modification; extraterrestrial atmospheres; meteorology.
	Geological sciences: engineering geophysics; general geology, geodesy and gravity; geomagnetism, hydrology; inorganic geochemistry; isotopic geochemistry; organic geochemistry; laboratory geophysics; paleomagnetism; paleontology; physical geography and cartography; seismology; soil sciences.
	Oceanography: biological oceanography; chemical oceanography; physical oceanography; marine geophysics.
	Other environmental sciences: multidisciplinary projects within the broad field and for single-discipline projects for which a separate field has not been assigned.
Mathematics and computer sciences	Mathematics: algebra; analysis; applied mathematics; foundations and logic; geometry; numerical analysis; statistics; topology.
	Computer sciences: programming languages; computer and information sciences (general); design, development, and application of computer capabilities to data storage and manipulation; information sciences and systems; systems analysis.
	Other mathematical and computer sciences: multidisciplinary projects within the broad field and for single-discipline projects for which a separate field has not been assigned.
Engineering	Aeronautical: aerodynamics.
	Astronautical: aerospace; space technology.
	Chemical: petroleum; petroleum refining; process.
	Civil: architectural; hydraulic; hydrological; marine; sanitary and environmental; structural; transportation.
	Electrical: communication; electronic; power.
	Mechanical: engineering mechanics.
	Metallurgy and materials: ceramic; mining; textile; welding.
	Other engineering: multidisciplinary projects within the broad field and for single-discipline projects for which a separate field has not been assigned.

(continued)

Table 3-11. (Continued)

Social sciences	Anthropology: archaeology; cultural and personality; social and ethnology; applied anthropology.
	Economics: econometrics and economic statistics; history of economic thought; international economics; industrial, labor and agricultural economics; macroeconomics; microeconomics; public finance and fiscal policy; theory; economic systems and development.
	Political science: area or regional studies; comparative government; history of political ideas; international relations and law; national political and legal systems; political theory; public administration.
	Sociology: comparative and historical; complex organization; culture and social structure; demography; group interactions; social problems and social welfare; sociological theory.
	Other social sciences: linguistics; research in education; research in history; socioeconomic geography; research in law, e.g., attempts to assess impact on society of legal systems and practices.
Psychology	Biological aspects: experimental psychology; animal behavior; clinical psychology; comparative psychology; ethology.
	Social aspects: social psychology; educational, personnel, vocational psychology and testing; industrial and engineering psychology; development and personality.
	Other psychological sciences: multidisciplinary projects within the broad field and for single-discipline projects for which a separate field has not been assigned.
Physical sciences	Astronomy: laboratory astrophysics; optical astronomy; radio astronomy; theoretical astrophysics; X-ray, Gamma-ray, neutrino astronomy.
	Chemistry: inorganic; organo-metallic; organic; physical.
	Physics: acoustics; atomic and molecular; condensed matter; elementary particles; nuclear structure; optics; plasma.
	Other physical sciences: multidisciplinary projects within the broad field and for single-discipline projects for which a separate field has not been assigned.
Other sciences	Multidisciplinary and interdisciplinary projects that cannot be classified within one of the broad fields of science above.

SOURCE: National Science Foundation, *Annual Survey of Federal Funds for Research and Development, and Other Scientific Activities, Fiscal Years 1977, 1978, and 1979,* Vol. XXVII (NSF Form 818), pp. 6-8.

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Table 3-12. Basic research expenditures in universities and colleges by source[1]: 1960-78.

[Dollars in millions]

Year	Total	Federal Government	Industry	All other sources
		Current dollars		
1960	$ 433	$ 299	$24	$110
1961	536	382	25	129
1962	659	481	25	153
1963	814	610	25	179
1964	1,003	767	25	211
1965	1,138	879	26	233
1966	1,303	1,009	27	267
1967	1,457	1,124	31	302
1968	1,649	1,251	36	362
1969	1,711	1,279	39	393
1970	1,796	1,296	40	460
1971	1,914	1,349	46	519
1972	2,022	1,421	53	548
1973	2,055	1,456	57	542
1974	2,153	1,522	61	570
1975	2,410	1,694	72	644
1976	2,547	1,827	72	648
1977 (prelim)	2,787	1,992	82	713
1978 (est)	3,165	2,265	85	815
		Constant 1972 dollars[2]		
1960	$ 631	$ 435	$35	$160
1961	774	551	36	186
1962	934	682	35	217
1963	1,137	852	35	250
1964	1,379	1,055	34	290
1965	1,531	1,183	35	314
1966	1,697	1,314	35	348
1967	1,844	1,422	39	382
1968	1,997	1,515	44	438
1969	1,973	1,475	45	453
1970	1,966	1,419	44	504
1971	1,993	1,405	48	541
1972	2,022	1,421	53	548
1973	1,942	1,376	54	512
1974	1,856	1,312	53	491
1975	1,895	1,332	57	506
1976	1,904	1,366	54	484
1977 (prelim)	1,968	1,407	58	503
1978 (est)	2,084	1,491	56	537

[1] Over 50 percent of the total basic research expenditures are accounted for by universities and colleges. Because data on individual non-Federal sources of basic research expenditures are not collected by survey, but are estimated by the National Science Foundation, the allocation of expenditures among the last two columns may be only rough approximations.

[2] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-1978-79* (NSF 78-313), p. 31.

See figure 3-9. Science Indicators—1978

Table 3-13. Federal obligations for basic research in universities and colleges by field of science for selected agencies [1]: 1973-77.

[Dollars in millions]

Field	1973	1974	1975	1976	1977	Average annual percent change 1973-75	1975-77	1973-77
Life sciences	$366.3	$430.7	$451.5	$504.6	$566.5	11.0	12.0	11.5
Psychology	29.0	29.6	29.3	28.8	32.6	0.5	5.5	3.0
Physical sciences	177.3	177.1	201.6	211.0	241.1	6.6	9.4	7.8
Environmental sciences	80.5	89.2	102.6	106.7	144.1	12.9	18.5	15.7
Mathematics and computer sciences	40.9	36.3	41.6	45.7	54.9	0.9	14.9	7.6
Engineering	75.5	76.6	94.4	101.4	123.5	11.8	14.4	13.1
Social sciences	45.7	41.8	40.1	44.4	51.9	-6.4	13.8	3.2

[1] The agencies included here are the Department of Agriculture, Department of Defense, Department of Health, Education, and Welfare, Department of Energy and its predecessor agencies, and the National Science Foundation. The National Aeronautics and Space Administration is not included because data for all years are unavailable. The five agencies included represented approximately 93 percent of all agencies' obligations in 1977.

SOURCE: National Science Foundation, *Federal Funds for Research, Development and Other Scientific Activities, Fiscal Years 1977, 1978, and 1979*, Vol. XXVII, Detailed Statistical Tables, Appendix C. (NSF 78-312) p. III and earlier volumes, and unpublished data.

See figure 3-10. Science Indicators—1978

Table 3-14. Basic research expenditures in industry by source: 1960-78

[Dollars in millions]

Year	Total: Current dollars	Total: Constant 1972 dollars [1]	Industry: Current dollars	Industry: Constant 1972 dollars [1]	Federal Government: Current dollars	Federal Government: Constant 1972 dollars [1]
1960	$376	$548	$297	$433	$ 79	$115
1961	395	570	314	453	81	117
1962	488	692	345	489	143	203
1963	522	729	375	524	147	205
1964	549	755	384	528	165	227
1965	592	797	406	546	186	250
1966	624	813	451	588	173	225
1967	629	796	427	540	202	256
1968	642	778	462	560	180	218
1969	618	713	458	528	160	185
1970	602	659	444	486	158	173
1971	590	614	456	475	134	140
1972	593	593	463	455	130	130
1973	631	596	499	472	132	125
1974	699	602	536	462	163	140
1975	719	565	562	442	157	123
1976	817	611	632	472	185	138
1977 (prelim)	906	640	700	494	206	145
1978 (est)	975	642	750	494	225	148

[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

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

SOURCE: National Science Foundation, *National Patterns of R & D Resources, 1953-1978-79* (NSF 78-313), p. 31.

See figure 3-11. Science Indicators—1978

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Table 4-1. Expenditures for industrial R&D by source of funds: 1960-79

[Dollars in millions]

Year	Current dollars			Constant 1972 dollars[1]		
	Total	Company[2]	Federal Government	Total	Company[2]	Federal Government
1960	$10,509	$ 4,428	$ 6,081	$15,304	$ 6,448	$ 8,855
1961	10,908	4,668	6,240	15,745	6,738	9,007
1962	11,464	5,029	6,435	16,249	7,128	9,121
1963	12,630	5,360	7,270	17,642	7,487	10,155
1964	13,512	5,792	7,720	18,583	7,966	10,618
1965	14,185	6,445	7,740	19,086	8,672	10,414
1966	15,548	7,216	8,332	20,255	9,401	10,855
1967	16,385	8,020	8,365	20,735	10,149	10,586
1968	17,429	8,869	8,560	21,108	10,741	10,367
1969	18,308	9,857	8,451	21,112	11,366	9,745
1970	18,062	10,283	7,779	19,770	11,255	8,515
1971	18,311	10,645	7,666	19,070	11,086	7,984
1972	19,539	11,522	8,017	19,539	11,522	8,017
1973	21,233	13,088	8,145	20,069	12,370	7,698
1974	22,867	14,647	8,220	19,710	12,625	7,085
1975	24,164	15,559	8,605	19,004	12,237	6,768
1976	26,906	17,561	9,345	20,115	13,129	6,986
1977 (prelim.) ...	29,895	19,476	10,419	21,111	13,753	7,358
1978 (est.)	33,250	21,500	11,750	21,889	14,145	7,785
1979 (est.)	36,750	23,750	13,000	22,615	14,615	8,000

[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.
[2] Includes all sources other than the Federal Government.

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

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953–1978-79* (NSF 78-313), pp. 28-29.

See figure 4-1.

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Table 4-2. R&D expenditures by industry: 1960-77

Industry	1960	1962	1964	1966	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
	Current dollars in millions													
Total	$10,509	$11,464	$13,512	$15,548	$17,429	$18,308	$18,062	$18,311	$19,539	$21,233	$22,867	$24,164	$26,938	$29,907
Food and kindred products	104	121	144	164	184	199	225	231	246	253	278	312	329	368
Textiles and apparel	38	28	32	51	58	60	58	59	61	64	69	70	82	81
Lumber, wood products, and furniture	10	10	12	12	20	18	52	53	64	71	84	88	107	127
Paper and allied products	56	65	77	117	144	188	178	187	169	194	237	249	313	340
Chemicals and allied products	980	1,175	1,284	1,407	1,589	1,660	1,773	1,832	1,932	2,116	2,450	2,727	3,017	3,267
Industrial chemicals	666	738	865	918	965	974	980	942	941	999	1,127	1,200	1,323	1,480
Drugs and medicines	162	195	234	308	398	444	485	549	607	698	807	981	1,091	1,153
Other chemicals	152	242	185	181	226	242	308	341	384	419	518	546	602	654
Petroleum refining and extraction	296	310	393	371	437	467	515	505	468	498	622	693	767	913
Rubber products	121	141	158	168	223	261	276	289	377	426	469	467	502	586
Stone, clay & glass products	88	96	109	117	142	159	187	164	[illegible]	199	217	233	263	293
Primary metals	177	171	195	232	251	257	275	272	277	307	358	443	506	526
Ferrous metals and products	102	97	116	139	135	136	149	144	146	163	181	215	256	259
Nonferrous metals and products	75	74	79	93	115	121	126	128	130	145	177	228	250	267
Fabricated metal products	145	146	148	154	183	182	207	242	253	291	313	324	358	389
Nonelectrical machinery	949	914	1,015	1,217	1,483	1,546	1,729	1,860	2,158	2,549	2,985	[illegible]	3,487	3,970
Office, computing, and accounting machines	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	1,456	1,733	2,103	2,220	2,402	2,758
Electrical equipment and communication	2,532	2,639	2,972	3,626	4,083	4,348	4,220	4,389	4,680	4,902	5,011	5,105	5,636	5,952
Radio and TV receiving equipment	(2)	(2)	(2)	47	55	57	70	64	48	49	51	50	52	58
Electronic components	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	330	406	489	549	691	751
Communication equipment and communication	1,324	1,591	1,872	2,249	2,520	2,671	2,604	2,739	2,583	2,613	2,424	2,385	2,511	2,798
Other electrical equipment	1,208	1,048	1,100	1,330	1,508	1,620	1,546	1,588	1,719	1,834	2,047	2,121	2,382	2,345
Motor vehicles and other transportation equipment	884	999	1,182	1,344	1,499	1,566	1,591	1,768	2,010	2,477	2,476	2,430	2,872	3,419
Motor vehicles and motor vehicle equipment	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	1,954	2,405	2,389	2,340	2,778	3,302
Other transportation equipment	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	56	72	87	90	94	117
Aircraft and missiles	3,514	4,042	5,078	5,526	5,765	5,682	5,219	4,881	4,950	5,052	5,278	5,713	6,339	7,078
Professional and scientific instruments	329	209	331	468	663	742	744	746	838	961	1,075	1,173	1,298	1,405
Scientific and mechanical measuring instruments	160	101	74	87	118	123	131	133	163	186	221	266	325	375
Optical, surgical, photographic, and other instruments	169	208	257	381	545	619	613	612	675	775	854	907	974	1,030
Other manufacturing industries	119	65	65	77	101	104	128	131	146	158	177	205	217	245
Nonmanufacturing industries	168	234	319	497	603	655	705	704	707	715	768	735	845	950

(continued)

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Table 4-2. (Continued)

Industry	1960	1962	1964	1966	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
	Constant 1972 dollars in millions [3]													
Total	$15.304	$16,249	$18.583	$20.255	$21.108	$21.119	$19.770	$19.070	$19.539	$20,069	$19.710	$19.000	$20.139	$21.119
Food and kindred products	151	172	198	214	223	229	246	241	246	239	240	245	246	260
Textiles and apparel	55	40	44	66	70	69	63	61	61	60	59	65	61	57
Lumber, wood products, and furniture	15	14	17	16	24	21	57	55	64	67	72	89	80	90
Paper and allied products	82	92	106	[illegible]	174	217	195	195	189	183	204	198	234	240
Chemicals and allied products	1.427	1.665	1.766	1.833	1.924	1.914	1,941	1.908	1,932	2,000	2,112	2.144	2,256	2,307
Industrial chemicals	970	1,048	1,190	1,196	1,169	1,123	1,073	981	941	944	971	944	989	1,031
Drugs and medicines	236	276	322	401	482	512	531	572	607	660	696	771	816	814
Other chemicals	221	343	254	236	274	270	337	355	384	396	445	429	450	482
Petroleum refining and extraction	431	439	541	483	529	539	584	526	468	471	536	545	573	645
Rubber products	176	200	217	219	270	301	302	301	377	403	404	387	375	414
Stone, clay, & glass products	128	136	150	152	172	183	183	171	183	188	187	183	197	207
Primary metals	258	242	268	302	304	298	301	283	277	290	309	348	378	371
Ferrous metals and products	149	137	160	181	163	157	163	150	146	154	156	169	191	183
Nonferrous metals and products	109	105	109	121	139	140	138	133	130	137	153	179	250	189
Fabricated metal products	211	207	204	201	222	210	227	252	253	275	270	265	268	275
Nonelectrical machinery	1.382	1.298	1.398	1.585	1,798	1.763	1,893	1,937	2.158	2,409	2.573	2,513	2,607	2,803
Office, computing, and accounting machines	([1])	([1])	([1])	([1])	([1])	([1])	([1])	([1])	1.456	1.636	1.813	1.746	1.796	1.948
Electrical equipment and communication	3.687	3,741	4.087	4.724	4.974	5,014	4,619	4.571	4.680	4.633	4.319	4.014	4.214	4.203
Radio and TV receiving equipment	([2])	([2])	([2])	61	67	66	77	67	46	46	44	39	39	41
Electronic components	([1])	([1])	([1])	([1])	([1])	([1])	([1])	([1])	330	384	421	432	517	530
Communication equipment and communication	1,928	2,255	2,575	2,930	3,052	3,080	2,850	2,853	2,583	2,470	2,089	1,875	1,877	1,976
Other electrical equipment	1.759	1.485	1.153	1.733	1.826	1.868	1.692	1.652	1.719	1.733	1.764	1,668	1,781	1,656
Motor vehicles and other transportation equipment	1,287	1.416	1.626	1.751	1.815	1.806	1,741	1,841	2,010	2,341	2.134	1.911	2,147	2.414
Motor vehicles and motor vehicle equipment	([1])	([1])	([1])	([1])	([1])	([1])	([1])	([1])	1.954	2,273	2,059	1.840	2,077	2.332
Other transportation equipment	([1])	([1])	([1])	([1])	([1])	([1])	([1])	([1])	56	68	75	71	70	83
Aircraft and missiles	5,117	5.729	6.984	7.199	6.982	6,783	5.713	5.083	4.950	4.775	4.549	4.492	4.739	4.998
Professional and scientific instruments	479	438	455	610	603	856	814	777	838	908	927	922	970	992
Scientific and mechanical measuring instruments	233	143	102	113	143	142	143	139	163	176	190	209	243	265
Optical, surgical, photographic, and other instruments	246	295	353	496	660	714	671	637	675	733	736	713	728	727
Other manufacturing industries	173	92	89	100	122	120	140	136	146	149	153	161	162	173
Nonmanufacturing industries	245	332	439	647	730	755	772	733	707	676	662	578	632	671

[1] Data not tabulated at this level prior to 1972.
[2] Included in the Other electrical equipment group
[3] GNP implicit price deflators used to convert current dollars to constant 1972 dollars

NOTE: Detail may not add to totals because of rounding

SOURCE —1960 and 1962 National Science Foundation, *Research and Development in Industry, 1971* (NSF 73-305), p 28, 1964-1975 National Science Foundation, *Research and Development in Industry, 1976* (NSF 78-314), p 12, 1976-77 National Science Foundation, preliminary data

See figure 4-2

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Table 4-3. Concentration of total R&D expenditures in the highest ranking companies, by industry: 1977

Industry	Percent of total R&D funds in industry		
	First 4 companies	First 8 companies	First 20 companies
Total	20	34	53
Food and kindred products	25	40	65
Textiles and apparel	30	45	66
Lumber, wood products, and furniture	67	76	85
Paper and allied products	64	75	89
Chemicals and allied products	32	45	69
Industrial chemicals	67	82	97
Drugs and medicines	35	59	93
Other chemicals	54	67	82
Petroleum refining and extraction	59	83	98
Rubber products	74	84	92
Stone, clay, and glass products	55	74	89
Primary metals	33	48	75
Ferrous metals and products	49	67	88
Nonferrous metals and products	45	65	90
Fabricated metal products	36	54	71
Nonelectrical machinery	61	72	82
Office, computing, and accounting machines	83	92	97
Electrical equipment and communication	57	71	85
Radio and TV receiving equipment	85	90	99
Electronic components	63	80	91
Communication equipment and communication	73	89	96
Other electrical equipment	83	88	94
Motor vehicles and motor vehicle equipment	94	97	99
Other transportation equipment	84	93	97
Aircraft and missiles	53	80	98
Professional and scientific instruments	55	73	82
Scientific and mechanical measuring instruments	54	63	77
Optical, surgical, photographic, and other instruments	71	85	93
Other manufacturing industries	37	54	77
Nonmanufacturing industries	37	56	77

SOURCE: National Science Foundation, preliminary data.

See figure 4-3.

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Table 4-4. Company[1] and Federal funding of industrial R&D, for selected industries: 1967 and 1977

[Dollars in millions]

Industry	Total 1967	Total 1977	Federal 1967	Federal 1977	Company[1] 1967	Company[1] 1977
			Current dollars			
Total	$16,385	$29,907	$8,365	$10,545	$8,020	$19,362
Chemicals and allied products	1,507	3,267	210	294	1,297	2,973
Industrial chemicals	966	1,460	181	278	785	1,182
Drugs, medicines, and other chemicals	541	1,807	29	16	512	1,771
Petroleum refining and extraction	371	913	16	74	355	839
Primary metals	242	526	8	25	234	501
Ferrous metals and products	135	259	1	5	134	254
Nonferrous metals and products	107	267	6	20	100	247
Fabricated metal products	163	389	13	45	151	344
Nonelectrical machinery	1,326	3,970	322	577	1,004	3,393
Electrical equipment and communication	3,867	5,952	2,296	2,696	1,571	3,256
Aircraft and missiles	5,669	7,078	4,531	5,496	1,138	1,582
Professional and scientific instruments	542	1,405	189	156	353	1,249
Scientific and mechanical measuring instruments	104	375	37	10	67	365
Optical, surgical, photographic, and other instruments	438	1,030	152	146	286	884
Other manufacturing industries	2,139	5,457	393	745	1,745	4,711
Nonmanufacturing industries	559	950	387	437	172	514
			Constant 1972 dollars[2]			
Total	$25,200	$21,119	$12,865	$7,447	$12,335	$13,673
Chemicals and allied products	2,318	2,307	323	208	1,995	2,099
Industrial chemicals	1,468	1,031	278	196	1,207	835
Drugs, medicines, and other chemicals	832	1,276	45	11	787	1,245
Petroleum refining and extraction	571	645	25	52	546	592
Primary metals	372	371	12	18	360	354
Ferrous metals and products	208	183	2	4	206	179
Nonferrous metals and products	165	189	9	14	154	174
Fabricated metal products	251	275	20	32	232	243
Nonelectrical machinery	2,039	2,803	495	407	1,544	2,396
Electrical equipment and communication	5,947	4,203	3,531	1,904	2,416	2,299
Aircraft and missiles	8,719	4,998	6,969	5,881	1,750	1,117
Professional and scientific instruments	834	992	291	110	543	882
Scientific and mechanical measuring instruments	160	265	57	7	103	216
Optical, surgical, photographic, and other instruments	674	727	234	103	440	624
Other manufacturing industries	3,290	3,854	604	526	1,544	3,327
Nonmanufacturing industries	860	671	595	309	265	363

[1] Includes all sources other than the Federal Government.

[2] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

SOURCE: National Science Foundation, *Research and Development in Industry, 1976* (NSF 76-314), pp. 12, 15, 18; and preliminary data.

See table 4-2 in text.

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Table 4-5. Mean absolute percentage errors of estimates of R&D expenditures in industry made by several organizations

Organization and type of expenditures estimated	Estimation period		
	Years estimated beyond available data		
	One year	Two years	Three years
National Science Foundation:			
Total R&D in all industry	2	4	NA
Industry-funded R&D[1] in all industry	4	7	NA
Federally funded R&D in all industry	3	5	NA
Battelle Memorial Institute:			
Total R&D in all industry	NA	NA	4
Industry-funded R&D[1] in all industry	NA	NA	8
Federally funded R&D in all industry	NA	NA	8
	Year surveyed		
	Prior year	Current year	Three years in future
McGraw-Hill Publications Company:			
Total R&D in all industry	3	5	11
Total R&D in individual industries	14	17	22

[1] Includes all sources other than the Federal Government.

NA = Not available.

NOTE: These percents result from comparing the various estimates with the actual R&D expenditures subsequently reported by the National Science Foundation. NSF data for some years have been revised since their use by these organizations.

SOURCES: NSF percent errors calculated from *National Patterns of R&D Resources: 1953-70*, National Science Foundation (NSF 69-30), 1969, pp. 26-27, and subsequent volumes.

McGraw-Hill percent errors calculated from "Research and Development in American Industry," McGraw-Hill Publications Company, May 6, 1966, and subsequent issues.

Battelle percent errors calculated from "Probable Levels of R&D Expenditure in 1969: Forecast and Analysis," Battelle Memorial Institute, December 1968, and subsequent issues.

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Table 4-6. Industrial R&D expenditures for basic research, applied research, and development: 1960-79

[Dollars in millions]

Year	Total	Basic research	Applied research	Development
		Current dollars		
1960	$10,509	$376	$2,029	$ 8,104
1961	10,908	395	1,977	8,536
1962	11,464	488	2,449	8,527
1963	12,630	522	2,457	9,651
1964	13,512	549	2,600	10,363
1965	14,185	592	2,658	10,935
1966	15,548	624	2,843	12,081
1967	16,385	629	2,915	12,841
1968	17,429	642	3,124	13,663
1969	18,308	618	3,287	14,403
1970	18,062	602	3,426	14,034
1971	18,311	590	3,413	14,308
1972	19,539	593	3,512	15,434
1973	21,233	631	3,822	16,780
1974	22,867	699	4,284	17,884
1975	24,164	719	4,576	18,869
1976	26,906	817	5,113	20,976
1977 (prelim.)	29,895	906	5,669	23,320
1978 (est.)	33,250	975	6,250	26,025
1979 (est.)	36,750	NA	NA	NA
		Constant 1972 dollars[1]		
1960	$15,304	$548	$2,955	$11,801
1961	15,745	570	2,854	12,321
1962	16,249	692	3,471	12,086
1963	17,642	729	3,432	13,481
1964	18,583	755	3,576	14,253
1965	19,086	797	3,576	14,713
1966	20,255	813	3,704	15,739
1967	20,735	796	3,689	16,250
1968	21,108	778	3,783	16,547
1969	21,112	713	3,790	16,609
1970	19,770	659	3,750	15,361
1971	19,070	614	3,554	14,901
1972	19,539	593	3,512	15,434
1973	20,069	596	3,612	15,860
1974	19,710	602	3,692	15,415
1975	19,004	565	3,599	14,840
1976	20,115	611	3,823	15,682
1977 (prelim.)	21,111	590	4,003	16,468
1978 (est.)	21,889	642	4,115	17,133
1979 (est.)	22,438	NA	NA	NA

[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NA = Not available.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953–1978-79* (NSF 78-313), pp. 28-35.

See figure 4-4.

Table 4-7. Expenditures for industrial basic research, applied research, and development, by source, 1960-78

[Dollars in millions]

Year	Basic research			Applied research			Development		
	Federal support	Company support[1]	Federal portion (Percent)	Federal support	Company support[1]	Federal portion (Percent)	Federal support	Company support[1]	Federal portion (Percent)
1960	$ 79	$297	21.0	$ 833	$1,196	41.1	$ 5,169	$ 2,935	63.8
1961	81	314	20.5	812	1,165	41.1	5,347	3,189	62.6
1962	143	345	29.3	1,011	1,438	41.3	5,281	3,246	61.9
1963	147	375	28.2	1,007	1,450	41.0	6,116	3,535	63.4
1964	165	384	30.1	1,040	1,560	40.0	6,515	3,848	62.9
1965	186	406	31.4	1,038	1,620	39.1	6,516	4,419	59.6
1966	173	451	27.7	1,039	1,804	36.5	7,120	4,961	58.9
1967	202	427	32.1	1,066	1,849	36.6	7,097	5,744	55.3
1968	180	462	28.0	1,043	2,081	33.4	7,337	6,326	53.7
1969	160	458	25.9	1,051	2,272	30.9	7,276	7,127	50.5
1970	158	444	26.2	1,049	2,377	30.6	6,572	7,462	46.8
1971	134	456	22.7	974	2,439	28.5	6,558	7,750	45.8
1972	130	463	21.9	952	2,560	27.1	6,935	8,499	44.9
1973	132	499	20.9	993	2,829	26.0	7,020	9,760	41.8
1974	163	536	23.3	1,025	3,259	23.9	7,032	10,852	39.3
1975	157	562	21.8	1,130	3,446	24.7	7,318	11,551	38.8
1976	185	632	22.6	1,205	3,908	23.6	7,955	13,021	37.9
1977 (prelim.)	206	700	22.7	1,345	4,324	23.7	8,868	14,452	38.0
1978 (est.)	225	750	23.1	1,550	4,750	24.6	10,025	16,000	38.5

[1] Includes all sources other than the Federal Government.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-1978-79* (NSF 78-313), pp. 30-35.

See figures 4-5 and 4-6.

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Table 4-8. Percent distribution of total, Federal, and company[1] industrial R&D expenditures into basic research, applied research, and development: 1960-78

Year	Total	Basic research	Applied research	Development
		Total expenditures		
1960	100.0	3.6	19.3	77.1
1961	100.0	3.6	18.1	78.3
1962	100.0	4.3	21.4	74.4
1963	100.0	4.1	19.5	76.4
1964	100.0	4.1	19.2	76.7
1965	100.0	4.2	18.7	77.1
1966	100.0	4.0	18.3	77.7
1967	100.0	3.8	17.8	78.4
1968	100.0	3.7	17.9	78.4
1969	100.0	3.4	18.0	78.7
1970	100.0	3.3	19.0	77.7
1971	100.0	3.2	18.6	78.1
1972	100.0	3.0	18.0	79.0
1973	100.0	3.0	18.0	79.0
1974	100.0	3.1	18.7	78.2
1975	100.0	3.0	18.9	78.1
1976	100.0	3.0	19.0	78.0
1977 (prelim.)	100.0	3.0	19.0	78.0
1978 (est.)	100.0	2.9	18.9	78.2
		Federal expenditures		
1960	100.0	1.3	13.7	85.0
1961	100.0	1.3	13.0	85.7
1962	100.0	2.2	15.7	82.1
1963	100.0	2.0	13.9	84.1
1964	100.0	2.1	13.5	84.4
1965	100.0	2.4	13.4	84.2
1966	100.0	2.1	12.5	85.5
1967	100.0	2.4	12.7	84.8
1968	100.0	2.1	12.2	85.7
1969	100.0	1.9	12.0	86.1
1970	100.0	2.0	13.5	84.5
1971	100.0	1.7	12.7	85.5
1972	100.0	1.6	11.9	86.5
1973	100.0	1.6	12.2	86.2
1974	100.0	2.0	12.5	85.5
1975	100.0	1.8	13.1	85.0
1976	100.0	2.0	12.9	85.1
1977 (prelim.)	100.0	2.0	12.9	85.1
1978 (est.)	100.0	1.9	13.1	85.0
		Company[1] expenditures		
1960	100.0	6.7	27.0	66.3
1961	100.0	6.7	25.0	68.3
1962	100.0	6.9	28.6	64.5
1963	100.0	7.0	27.1	66.0
1964	100.0	6.8	26.9	66.4
1965	100.0	6.3	25.1	68.6
1966	100.0	6.2	25.0	68.8
1967	100.0	5.3	23.1	71.6
1968	100.0	5.2	23.5	71.3
1969	100.0	4.6	23.0	72.3
1970	100.0	4.3	23.1	72.6
1971	100.0	4.3	22.9	72.8
1972	100.0	4.0	22.2	73.8
1973	100.0	3.8	21.8	74.6
1974	100.0	3.7	22.3	74.1
1975	100.0	3.6	22.1	74.2
1976	100.0	3.6	22.3	74.1
1977 (prelim.)	100.0	3.6	22.2	74.2
1978 (est.)	100.0	3.5	22.1	74.4

[1] Includes all sources other than the Federal Government

NOTE: Detail may not add to totals because of rounding

SOURCE: Computed from data in Appendix table 4-7.

See figure 4-6.

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Table 4-9. Sources of support of basic research, applied research, and development in selected industries: 1967 and 1977

[Dollars in millions]

Industry	Basic research			Applied research			Development		
	Company[1] funds	Federal funds	Federal portion (Percent)	Company[1] funds	Federal funds	Federal portion (Percent)	Company[1] funds	Federal funds	Federal portion (Percent)
1967									
Total	$453	$202	31	$1,915	$1,068	36	$5,664	$7,118	56
Food and kindred products	10	0	(3)	70	0	0	87	1	1
Lumber, wood products, and furniture	1	0	(3)	4	0	(3)	9	0	(3)
Chemicals and allied products	150	42	22	544	55	9	659	115	15
Industrial chemicals	(2)	(2)	(3)	(2)	(2)	(3)	(2)	(2)	(3)
Drugs, medicines, and other chemicals	(2)	(2)	(3)	(2)	(2)	(3)	(2)	(2)	(3)
Petroleum refining and extraction	31	1	3	190	4	2	210	33	14
Primary metals	13	0	(3)	84	5	6	140	3	2
Fabricated metal products	3	0	(3)	37	2	5	112	11	9
Nonelectrical machinery	27	3	10	132	67	34	926	323	26
Office, computing, and accounting machines	(2)	(2)	(3)	(2)	(2)	(3)	(2)	(2)	(3)
All other nonelectrical machinery	(2)	(2)	(3)	(2)	(2)	(3)	(2)	(2)	(3)
Electrical equipment and communication	92	32	26	254	237	48	1,221	1,970	62
Communication equipment and communication	77	25	25	160	181	53	664	1,136	63
All other electrical equipment	15	7	(3)	94	56	37	557	834	60
Aircraft and missiles	37	33	47	238	493	67	783	3,984	84
Professional equipment	(2)	(2)	(3)	(2)	(2)	(3)	(2)	(2)	(3)
Scientific and mechanical measuring instruments	(2)	0	(3)	(2)	(2)	(3)	(2)	(2)	(3)
Optical, surgical, photographic, and other instruments	(2)	(2)	(3)	(2)	(2)	(3)	(2)	(2)	(3)
Nonmanufacturing industries	9	44	83	59	158	73	74	196	73
1977									
Total	$696	$214	24	$4,275	$1,377	24	$14,391	$8,954	38
Food and kindred products	19	0	(3)	(2)	(2)	(3)	222	0	0
Lumber, wood products, and furniture	7	0	(3)	37	0	0	83	0	0
Chemicals and allied products	269	68	25	1,245	117	9	1,459	110	7
Industrial chemicals	83	59	42	500	112	18	595	107	15
Drugs, medicines, and other chemicals	186	9	5	745	5	1	864	3	0
Petroleum refining and extraction	(2)	(2)	(3)	(2)	(2)	(3)	454	38	8
Primary metals	(2)	(2)	(3)	(2)	(2)	(3)	276	21	7
Fabricated metal products	2	0	(3)	85	3	3	257	43	14
Nonelectrical machinery	56	3	5	15	140	10	3,032	434	13
Office, computing, and accounting machines	(2)	(2)	(3)	(2)	(2)	(3)	2,038	407	17
All other nonelectrical machinery	(2)	(2)	(3)	(2)	(2)	(3)	994	27	3
Electrical equipment and communication	157	25	14	683	337	33	2,416	2,334	49
Communication equipment and communication	131	17	1[illegible]	350	130	27	1,111	1,060	49
All other electrical equipment	26	8	24	333	207	38	1,305	1,274	49
Aircraft and missiles	31	25	45	338	423	56	1,214	5,048	81
Professional equipment	19	3	(3)	172	11	6	1,057	142	12
Scientific and mechanical measuring instruments	(2)	(2)	(3)	(2)	(2)	(3)	294	8	3
Optical, surgical, photographic, and other instruments	(2)	(2)	(3)	(2)	(2)	(3)	763	134	15
Nonmanufacturing industries	7	35	83	178	204	53	329	198	38

[1] Includes all sources other than the Federal Government.
[2] Not separately available but included in total.
[3] Percentage cannot be calculated with precision.

SOURCE: National Science Foundation, *Research and Development in Industry, 1967* (NSF 69-28), pp. 66 and 67, and preliminary data.

See table 4-3 in text.

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Table 4-10. Expenditures for basic research and net sales, by individual manufacturing industry: 1977

[Dollars in millions]

Industry	Basic research expenditures	Net sales	Basic research expenditures per $10,000 of net sales
Total	$869	$946,748	$ 9
Food and kindred products	19	95,282	2
Lumber, wood products and furniture	7	16,507	4
Paper and allied products	9	36,369	2
Chemicals and allied products	336	90,855	37
Industrial chemicals	142	41,141	35
Drugs and medicines	131	18,587	70
Other chemicals	63	31,127	20
Petroleum refining and extraction	48	137,938	3
Rubber products	9	23,970	4
Stone, clay, and glass products	41	24,253	17
Primary metals	15	68,407	2
Ferrous metals and products	5	44,773	1
Nonferrous metals and products	10	23,634	4
Fabricated metal products	2	32,298	1
Nonelectrical machinery	59	78,870	7
Office, computing, and accounting machines	43	23,476	18
Electrical equipment and communication	181	94,448	19
Electronic components	6	10,722	6
Communication equipment and communication	146	37,067	39
Radio and TV receiving equipment and all other electrical equipment	29	46,659	6
Motor vehicles and motor vehicle equipment	12	106,205	1
Aircraft and missiles	56	54,532	10
Professional and scientific instruments	22	23,365	9
Scientific and mechanical measuring instruments	10	6,764	15
Optical, surgical, photographic, and other instruments	12	16,601	7
All other manufacturing industries	53	63,449	8

SOURCE: National Science Foundation, preliminary data.

See table 4-4 in text.

Table 4-11. Expenditures for basic research in industry by field of science: 1967-77

[Dollars in millions]

Field	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
	Current dollars										
Total	$629	$642	$615	$602	$590	$593	$631	$699	$719	$817	$910
Physical sciences	308	317	324	297	281	277	276	319	320	359	405
Chemistry	162	191	213	195	180	183	193	229	228	253	285
Physics and astronomy	146	126	111	102	101	94	83	90	92	106	120
Mathematics	12	13	13	13	14	12	14	13	14	18	19
Environmental sciences	14	11	11	8	8	6	7	10	15	17	19
Atmospheric sciences	(2)	(2)	(2)	(2)	3	(2)	2	3	6	6	5
Geological sciences	(2)	(2)	(2)	(2)	3	4	3	5	5	7	7
Oceanography	(2)	(2)	(2)	(2)	2	(2)	1	1	3	4	7
Engineering[1]	172	181	170	170	159	183	185	178	181	204	233
Life sciences	69	76	74	86	94	82	102	119	122	134	156
Biological sciences	(2)	50	58	51	57	61	77	83	85	102	128
Clinical medical sciences	(2)	26	16	35	37	21	25	36	37	32	28
Other sciences	53	43	26	28	34	33	47	60	67	85	78
	Constant 1972 dollars[3]										
Total	$796	$778	$709	$659	$614	$593	$596	$602	$565	$611	$692
Physical sciences	390	384	374	325	293	277	261	275	252	268	286
Chemistry	205	231	246	213	187	183	182	197	179	189	201
Physics and astronomy	185	153	128	112	105	94	78	78	72	79	85
Mathematics	15	16	15	14	15	12	13	11	11	13	13
Environmental sciences	18	13	13	9	8	6	7	9	12	13	13
Atmospheric sciences	(2)	(2)	(2)	(2)	3	(2)	2	3	5	4	4
Geological sciences	(2)	(2)	(2)	(2)	3	4	3	4	4	5	5
Oceanography	(2)	(2)	(2)	(2)	2	(2)	1	1	2	3	5
Engineering[1]	218	219	196	186	166	183	175	153	142	153	165
Life sciences	87	92	85	94	98	82	96	103	96	100	110
Biological sciences	(2)	61	67	56	59	61	73	72	67	76	90
Clinical medical sciences	(2)	31	18	38	39	21	24	31	29	24	20
Other sciences	67	52	30	31	35	33	44	52	53	64	55

[1] Includes metallurgy.
[2] Not separately available but included in total.
[3] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

SOURCE: 1967-1975: National Science Foundation, *Research and Development in Industry, 1976* (NSF 78-314), p. 51; 1976-77: National Science Foundation, preliminary data.

See figure 4-7.

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Table 4-12. Distribution of industry's own funds for basic research to various performers: 1960-1978

[Dollars in millions]

	Expenditures						Percentages		
	Current dollars			Constant 1972 dollars[1]					
Year	Industry	Universities and colleges	Non-profits	Industry	Universities and colleges	Non-profits	Industry	Universities and colleges	Non-profits
1960	$297	$24	$21	$433	$35	$31	86.8	7.0	6.1
1961	314	25	22	453	36	32	87.0	6.9	6.1
1962	345	25	24	489	35	34	87.6	6.3	6.1
1963	375	25	25	524	35	35	88.2	5.9	5.9
1964	384	25	25	528	34	34	88.5	5.8	5.8
1965	406	26	29	546	35	39	88.1	5.6	6.3
1966	451	27	32	588	35	42	88.4	5.3	6.3
1967	427	31	34	540	39	43	86.8	6.3	6.9
1968	462	36	37	560	44	45	86.4	6.7	6.9
1969	458	39	43	528	45	50	84.8	7.2	8.0
1970	444	40	44	486	44	48	84.1	7.6	8.3
1971	456	46	45	475	48	47	83.4	8.4	8.2
1972	463	53	47	463	53	47	82.2	9.4	8.3
1973	499	57	49	472	54	46	82.5	9.4	8.1
1974	536	61	52	462	53	45	82.6	9.4	8.0
1975	562	72	54	442	54	40	81.7	10.5	7.8
1976	632	72	56	472	54	42	83.2	9.5	7.4
1977 (prelim.)	700	82	58	494	58	41	83.3	9.8	6.9
1978 (est.)	750	85	60	494	56	39	83.8	9.5	6.7

[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

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

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953–1978-79* (NSF 78-313), pp. 30-35.

See figure 4-8.

Table 4-13. Expenditures for applied research and development, by product field and source of funds: 1977

[Dollars in millions]

Product field	Total funding	Company funding[1]	Federal funding	Federal portion (Percent)
Total	$28,997	$18,666	$10,331	35.6
Ordnance, and accessories, not elsewhere classified	288	57	231	80.2
Guided missiles and spacecraft	3,035	304	2,731	90.0
Food and kindred products	350	(2)	(2)	(2)
Textile mill products	96	(2)	(2)	(2)
Chemicals, except drugs and medicines	2,024	1,984	40	2.0
Industrial inorganic and organic chemicals	620	603	17	2.7
Plastics materials and synthetic resins, rubber, and fibers	747	731	16	2.1
Agricultural chemicals	236	234	2	0.8
Other chemicals	422	417	5	1.2
Drugs and medicines	959	947	12	1.3
Petroleum refining and extraction	473	456	17	3.6
Rubber and miscellaneous plastics products	378	(2)	(2)	(2)
Stone, clay, and glass products	191	(2)	(2)	(2)
Primary metals	327	321	6	1.8
Ferrous metals and products	172	169	3	1.7
Nonferrous metals and products	155	152	3	1.9
Fabricated metal products	1,157	549	608	52.5
Nonelectrical machinery	3,572	3,338	234	6.6
Engines and turbines	531	480	51	9.6
Farm machinery and equipment	222	(2)	(2)	(2)
Construction, mining, and materials handling machinery	378	(2)	(2)	(2)
Metalworking machinery and equipment	126	(2)	(2)	(2)
Office, computing, and accounting machines	1,856	1,716	140	7.5
Other nonelectrical machinery	458	424	34	7.4
Electrical equipment, except communication	905	672	233	25.7
Electric transmission and distribution equipment	225	128	97	43.1
Electrical industrial apparatus	299	213	86	28.8
Other electrical equipment and supplies	381	331	50	13.1
Communication equipment and electronic components	5,038	2,587	2,451	48.7
Motor vehicles and other transportation equipment	2,611	2,415	196	7.5
Motor vehicles and equipment				
Other transportation equipment	201	90	111	55.2
Aircraft and parts	3,125	975	2,150	68.8
Professional and scientific instruments	1,260	986	274	21.7
Other product fields, not elsewhere classified	3,209	2,073	1,136	35.4

[1] Includes all sources other than the Federal Government.
[2] Not separately available but included in total.

SOURCE: National Science Foundation, preliminary data.

See figures 4-9 and 4-10.

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Table 4-14. Percent changes in constant dollar[1] applied research and development expenditures, by product field: 1971-77

Product field	Percent change
Total	11
Ordnance and accessories, not elsewhere classified	2
Guided missiles and spacecraft	−13
Food and kindred products	14
Textile mill products	10
Chemicals, except drugs and medicines	2
Industrial inorganic and organic chemicals	6
Plastics materials and synthetic resins, rubber, and fibers	−1
Agricultural chemicals	24
Other chemicals	3
Drugs and medicines	22
Petroleum refining and extraction	21
Rubber and miscellaneous plastics products	19
Stone, clay, and glass products	2
Primary metals	4
Ferrous metals and products	2
Nonferrous metals and products	10
Fabricated metal products	12
Nonelectrical machinery	36
Engines and turbines	46
Nonelectrical machinery (continued)	
Farm machinery and equipment	67
Construction, mining, and materials handling machinery	31
Metalworking machinery and equipment	2
Office, computing, and accounting machines	39
Other nonelectrical machinery	17
Electrical equipment, except communication	−11
Electrical transmission and distribution equipment	−16
Electrical industrial apparatus	8
Other electrical equipment and supplies	−19
Communication equipment and electronic components	17
Motor vehicles and other transportation equipment	32
Motor vehicles and equipment	33
Other transportation equipment	[illegible]
Aircraft and parts	−15
Professional and scientific instruments	31
Other product fields, not elsewhere classified	85

[1] GNP implicit price deflators use to convert current dollars to constant dollars.

SOURCE: Calculated from National Science Foundation, *Research and Development in Industry, 1976* (NSF 78-314), p. 54; and preliminary data.

See table 4-5 in text.

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Table 4-15. Industrial expenditures for energy R&D by primary technology and source of funds: 1973-78

[Dollars in millions]

Primary energy technology	1973	1974	1975	1976	1977	1978 (est.)
				Total		
All technologies	$1,004	$1,213	$1,374	$1,606	$1,930	$2,146
Fossil fuel	433	507	532	583	695	803
Oil	297	325	321	368	420	443
Coal	49	65	109	127	177	246
Mining	NA	4	9	10	9	9
Synthetic fuel	NA	21	50	74	116	118
Other	NA	39	50	43	52	59
Gas	51	74	66	68	78	84
Shale	7	13	14	15	15	23
Other fossil fuel	29	30	23	5	5	7
Nuclear	501	601	700	799	906	943
Fission	476	568	659	741	823	867
Fusion	25	34	41	58	83	76
Geothermal	1	2	6	13	24	26
Solar	2	7	19	43	65	70
Conservation and utilization	} 67	20	52	83	124	170
All other energy technologies		76	64	65	116	134
				Federal		
All technologies	$385	$482	$622	$754	$914	NA
Fossil fuel	10	13	42	79	129	NA
Oil	2	3	6	12	17	NA
Coal	7	9	32	47	87	NA
Mining	NA	} 3	} 16	3	4	NA
Synthetic fuel	NA			26	58	NA
Other	NA	6	16	18	25	NA
Gas				16	20	NA
Shale	} 1	} 1	} 4	} 4	} 5	NA
Other fossil fuel						NA
Nuclear	366	444	540	601	669	NA
Fission	349	421	503	547	592	NA
Fusion	18	23	37	54	77	NA
Geothermal	} 1	} 3	} 12	8	9	NA
Solar				26	43	NA
Conservation and utilization	} 8	8	10	17	32	NA
All other energy technologies		14	18	23	32	NA
				Company[1]		
All technologies	$619	$731	$752	$852	$1,016	NA
Fossil fuel	423	494	490	504	566	NA
Oil	295	322	315	358	403	NA
Coal	42	56	77	80	90	NA
Mining	NA	} 23	} 43	7	5	NA
Synthetic fuel	NA			48	58	NA
Other	NA	33	34	25	27	NA
Gas				52	58	NA
Shale	} 86	} 116	} 98	} 16	} 15	NA
Other fossil fuel						NA
Nuclear	135	157	160	198	237	NA
Fission	127	147	156	194	231	NA
Fusion	7	11	4	4	6	NA
Geothermal	} 2	} 6	} 14	5	15	NA
Solar				17	22	NA
Conservation and utilization	} 59	12	42	66	92	NA
All other energy technologies		62	46	62	84	NA

[1]Includes all sources other than the Federal Government

NA - Not available

SOURCES: — 1973: National Science Foundation, *Research and Development in Industry, 1974*, (NSF 76-322), p. 59.
— 1974: National Science Foundation, *Research and Development in Industry, 1975*, (NSF 77-324), p. 63.
— 1975: National Science Foundation, *Research and Development in Industry, 1976*, (NSF 78-314), p. 45.
— 1976, 1977, and 1978: National Science Foundation, preliminary data.

See figure 4-16.

Table 4-16. Industrial expenditures for pollution abatement R&D by type of pollution and source of funds: 1973-78

[Dollars in millions]

Year	Source	All types	Air pollution: All	Air pollution: Automotive emissions	Air pollution: Electric power plant emissions	Air pollution: All other	Water	Solid waste	Other types
1973	Total	$ 603	$461	NA	NA	NA	$ 76	$10	$ 56
	Federal	35	10	NA	NA	NA	4		21
	Company[1]	568	451	NA	NA	NA	82		35
1974	Total	657	508	$383	NA	NA	60	14	75
	Federal	51	17	NA	NA	NA	5		29
	Company[1]	606	491	NA	NA	NA	69		46
1975	Total	647	478	348	$28	$102	71	23	75
	Federal	41	14	7		7	4		23
	Company[1]	606	464	369		95	90		52
1976	Total	759	571	426	31	114	87	21	80
	Federal	51	26	10		16	7	1	17
	Company[1]	708	545	447		98	80	20	63
1977	Total	918	685	495	67	123	105	28	100
	Federal	57	23	10		13	7	7	20
	Company[1]	861	662	552		110	98	21	80
1978	Total (est.)	1,050	787	531	93	163	114	30	119

[1] Includes all sources other than the Federal Government.

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

NA = Not available

SOURCES: — 1973: National Science Foundation, *Research and Development in Industry, 1974,* (NSF 76-322), p. 60.
— 1974: National Science Foundation, *Research and Development in Industry, 1975,* (NSF 77-324), p. 65.
— 1975: National Science Foundation, *Research and Development in Industry, 1976,* (NSF 78-314), p. 47.
— 1976, 1977, and 1978: National Science Foundation, preliminary data.

See figure 4-17.

Table 4-17. U.S. patents granted, by nationality of inventor and date of grant: 1960-77

Year	All U.S. patents	To U.S. inventors	To foreign inventors
1960	47,170	39,472	7,698
1961	48,368	40,154	8,214
1962	55,691	45,579	10,112
1963	45,679	37,174	8,505
1964	47,375	38,411	8,964
1965	62,857	50,332	12,525
1966	68,408	54,636	13,772
1967	65,652	51,274	14,378
1968	59,103	45,783	13,320
1969	67,560	50,398	17,162
1970	64,432	47,077	17,355
1971	78,320	55,979	22,341
1972	74,813	51,519	23,294
1973	74,148	51,509	22,639
1974	76,281	50,648	25,633
1975	72,029	46,731	25,298
1976	70,223	44,281	25,942
1977	65,218	41,452	23,766

SOURCE: Office of Technology Assessment and Forecast, U.S. Patent and Trademark Office, *Special Report: A Profile of U.S. Patent Activity, 1963-1977*, p. iii.

See figure 4-18. Science Indicators—1978

Table 4-18. U.S. patents granted to U.S. inventors, by type of owner and date of grant: 1961-77

Year	All patents	Owners			
		U.S. corporations	U.S. Government	U.S. individuals[1]	Foreign[2]
1961	40,154	27,382	1,460	11,233	79
1962	45,579	31,377	1,276	12,817	109
1963	37,174	25,722	1,017	10,358	77
1964	38,411	26,808	1,174	10,336	93
1965	50,332	35,698	1,522	13,032	80
1966	54,636	39,893	1,512	13,050	181
1967	51,274	36,745	1,726	12,634	169
1968	45,783	33,351	1,458	10,768	206
1969	50,398	37,033	1,810	11,362	193
1970	47,077	34,903	1,761	10,157	256
1971	55,979	40,676	2,135	12,746	422
1972	51,519	36,873	1,762	12,578	306
1973	51,509	36,515	2,078	12,677	239
1974	50,648	35,655	1,729	12,978	286
1975	46,731	33,404	1,882	11,202	243
1976	44,281	32,119	1,807	10,119	236
1977	41,452	29,522	1,479	10,247	204

[1]Includes unassigned patents.

[2]Comprises patents assigned to foreign corporations, governments, and individuals.

SOURCE: Office of Technology Assessment and Forecast, U.S. Patent and Trademark Office, *Special Report: A Profile of U.S. Patent Activity 1963-77*, p. iii, and unpublished data.

See figure 4-19. Science Indicators—1978

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Table 4-19. Distribution of U.S. patents due to U.S. inventors, by product field and class of ownership, for patents granted in 1967 and 1977

Product field	Percent U.S. corporations		Percent U.S. Government		Percent U.S. individuals[1]	
	1967	1977	1967	1977	1967	1977
All product fields	72	71	3	4	25	25
Food and kindred products	75	79	5	5	19	17
Textile mill products	82	81	5	8	12	14
Chemicals and allied products	91	91	3	3	5	5
Chemicals, except drugs and medicines	91	92	3	3	5	5
Basic industrial inorganic and organic chemicals	91	93	3	3	5	3
Industrial inorganic chemicals	84	86	7	5	8	8
Industrial organic chemicals	92	94	3	3	4	3
Plastics materials and synthetic resins	94	93	1	2	4	4
Agricultural chemicals	88	92	3	2	8	6
All other chemicals	85	85	7	8	8	7
Soap, detergents, and cleaning preparations; perfumes, cosmetics, and other toilet preparations	89	91	4	2	7	6
Paints, varnishes, lacquers, enamels, and allied products	86	82	0	5	14	14
Miscellaneous chemical products	83	81	9	12	8	7
Drugs and medicines	90	91	1	2	7	6
Petroleum and natural gas extraction and petroleum refining	91	86	1	2	8	11
Rubber and miscellaneous plastics products	69	69	2	3	28	28
Stone, clay, glass, and concrete products	78	74	1	3	20	22
Primary metals	80	79	5	4	15	15
Primary ferrous products	78	77	4	5	17	17
Primary and secondary nonferrous products	82	84	7	4	11	10
Fabricated metal products	63	59	2	2	35	39
Machinery, except electrical	70	68	2	2	28	30
Engines and turbines	64	53	5	4	30	43
Farm and garden machinery and equipment	55	56	1	1	43	43
Construction, mining, and material handling machinery and equipment	62	63	1	1	37	35
Metal working machinery and equipment	70	67	1	1	29	32
Office computing and accounting machines	80	81	4	3	16	15
Other machinery, except electrical	71	71	2	2	27	27
Special industry machinery, except metal working machinery	74	75	1	1	24	23
General industrial machinery and equipment	70	69	2	2	28	29
Refrigeration and service industry machinery	65	62	1	1	34	36
Miscellaneous machinery, except electrical	66	70	2	3	32	27
Electrical and electronic machinery, equipment and supplies	78	77	6	6	15	16
Electrical equipment, except communication equipment	79	78	4	4	17	17
Electrical transmission and distribution equipment	81	79	6	7	13	14
Electrical industrial apparatus	84	86	4	3	11	11
Other electrical machinery, equipment and supplies	76	75	3	3	21	22
Household appliances	71	65	0	1	29	34
Electrical lighting and wiring equipment	76	78	4	2	20	20
Miscellaneous electrical machinery, equipment, and supplies	80	80	5	4	14	16
Communication equipment and electronic components	79	77	8	8	12	14
Radio and television receiving equipment, except communication types	79	80	8	8	13	11
Electronic components and accessories and communication equipment	79	77	9	8	12	14
Transportation equipment	58	54	7	7	35	39
Motor vehicles and other transportation equipment, except aircraft	58	54	7	7	35	39
Motor vehicles and motor vehicle equipment	61	58	1	2	38	40
Guided missiles and space vehicles and parts	67	64	19	18	13	19
Other transportation equipment	62	59	2	2	35	40
Ship and boat building and repairing	52	45	4	4	44	50
Railroad equipment	79	80	1	1	19	19
Motorcycles, bicycles, and parts	79	66	0	0	21	34
Miscellaneous transportation equipment	66	65	1	1	33	34
Ordnance, except missiles	46	37	29	36	25	26
Aircraft and parts	60	53	4	3	36	44
Professional and scientific instruments	68	67	5	5	27	27

[1]Includes unassigned patents.

SOURCE: Calculated from Office of Technology Assessment and Forecast, U.S. Patent and Trademark Office, *Special Report: Patenting in 55 Standard Industrial Classification Fields (1963-77), Considering Original Patents Only,* 1978. "All product fields" calculated from Appendix table 4-17.

See figure 4-20.

Table 4-20. Number of U.S. patents due to U.S. inventors, by product field, for patents granted in 1967 and 1977

Product field	1967	1977	Percent change, 1967-1977
All product fields	51,274	41,452	-19.2
Food and kindred products	451	535	18.6
Textile mill products	457	437	- 4.4
Chemicals and allied products	7,910	7,132	- 9.8
Chemicals, except drugs and medicines	7,843	7,001	-10.7
Basic industrial inorganic and organic chemicals	4,324	3,554	-17.8
Industrial inorganic chemicals	929	893	- 3.9
Industrial organic chemicals	3,751	2,953	-21.3
Plastics materials and synthetic resins	2,207	1,692	-23.3
Agricultural chemicals	687	1,227	78.6
All other chemicals	742	705	- 5.0
Soap, detergents, and cleaning preparations, perfumes, cosmetics, and other toilet preparations	282	280	- 0.7
Paints, varnishes, lacquers, enamels, and allied products	29	44	51.7
Miscellaneous chemical products	521	479	- 8.1
Drugs and medicines	762	1,249	63.9
Petroleum and natural gas extraction and petroleum refining	841	719	-14.5
Rubber and miscellaneous plastics products	2,801	2,451	-12.5
Stone, clay, glass, and concrete products	1,138	1,121	- 1.5
Primary metals	664	467	-29.7
Primary ferrous products	502	316	-37.1
Primary and secondary nonferrous products	399	295	-26.1
Fabricated metal products	7,369	5,825	-21.0
Machinery, except electrical	16,206	12,367	-23.7
Engines and turbines	1,117	1,305	16.8
Farm and garden machinery and equipment	1,630	1,279	-21.5
Construction, mining, and material handling machinery and equipment	3,116	2,196	-29.8
Metal working machinery and equipment	1,563	1,098	-29.7
Office computing and accounting machines	1,640	1,393	-15.1
Other machinery, except electrical	10,074	7,124	-29.3
Special industry machinery, except metal working machinery	4,007	2,799	-30.1
General industrial machinery and equipment	5,305	3,662	-31.0
Refrigeration and service industry machinery	1,373	903	-34.2
Miscellaneous machinery, except electrical	744	660	-11.3
Electrical and electronic machinery, equipment and supplies	10,688	8,601	-19.5
Electrical equipment, except communication equipment	6,229	4,351	-30.1
Electrical transmission and distribution equipment	2,189	1,437	-34.4
Electrical industrial apparatus	1,865	1,151	-38.3
Other electrical machinery, equipment and supplies	3,166	2,280	-28.0
Household appliances	1,087	658	-39.5
Electrical lighting and wiring equipment	804	582	-27.6
Miscellaneous electrical machinery, equipment, and supplies	1,280	1,034	-19.2
Communication equipment and electronic components	5,639	5,079	- 9.9
Radio and television receiving equipment, except communication types	847	839	- 0.9
Electronic components and accessories and communication equipment	5,546	5,020	- 9.5
Transportation equipment	3,153	3,071	- 2.6
Motor vehicles and other transportation equipment	2,946	2,900	- 1.6
Motor vehicles and motor vehicle equipment	1,584	1,769	11.7
Guided missiles and space vehicles and parts	401	274	-31.7
Other transportation equipment	1,000	811	-18.9
Ship and boat building and repairing	335	273	-18.5
Railroad equipment	510	379	-25.7
Motorcycles, bicycles, and parts	111	83	-25.2
Miscellaneous transportation equipment	534	462	-13.5
Ordnance, except missiles	333	339	1.8
Aircraft and parts	833	1,130	35.7
Professional and scientific instruments	4,719	5,015	6.3

SOURCE: Calculated from Office of Technology Assessment and Forecast, U.S. Patent and Trademark Office, *Special Report: Patenting in 55 Standard Industrial Classification Fields (1963-77), Considering Original Patents Only*, 1978. "All product fields" from Appendix table 4-17.

See figure 4-21.

Table 5-1. Average annual percent increases in science and engineering employment and in other economic and manpower variables: 1950-1976

	1950-63	1963-70	1970-76
Scientists and engineers[1]	6.6	3.2	1.5
Scientists[1]	7.0	4.8	4.1
Engineers	6.5	2.5	.4
Nonfarm workers[2]	1.8	3.2	1.9
GNP[3]	3.5	3.8	2.9

[1] Excludes psychologists, social scientists, and computer specialists, for whom comparable data are not available for these years.
[2] Nonfarm wage and salary workers.
[3] Gross National Product (in constant 1972 dollars).

SOURCES: Rates computed by the National Science Foundation from data in: *Employment of Scientists and Engineers, 1950-70,* Bulletin 1781, United States Department of Labor, 1973, p. 11; unpublished data from the United States Department of Labor; and the *Economic Report of the President, 1978,* pp. 258, 289.

See figure 5-1.

Science Indicators—1978

Table 5-2. Scientists and engineers by field, sex and employment status: 1974 and 1976

Field and sex	Total		In labor force: Total		Employed: Total		Employed: In S/E		Employed: Outside S/E		Unemployed but seeking employment		Outside labor force	
	1974	1976	1974	1976	1974	1976	1974	1976	1974	1976	1974	1976	1974	1978
All fields	2,481,800	2,705,800	2,288,000	2,451,700	2,248,200	2,377,100	NA	2,090,300	NA	268,800	39,800	74,600	193,800	254,100
Men	2,265,000	2,455,800	2,109,700	2,240,000	2,072,100	2,179,900	NA	1,914,400	NA	265,600	32,600	60,100	160,300	215,800
Women	216,800	250,000	183,300	211,700	178,100	197,200	NA	175,900	NA	21,300	7,200	14,500	33,500	38,800
Physical scientists	247,900	280,600	206,500	237,300	201,400	227,400	NA	189,400	NA	38,000	5,100	9,900	41,400	43,300
Men	227,200	254,100	189,900	215,800	185,500	207,500	NA	176,400	NA	31,100	4,400	8,400	37,300	38,300
Women	20,700	26,500	16,600	21,500	15,900	19,900	NA	13,100	NA	8,900	700	1,500	4,100	5,100
Mathematical scientists	101,000	110,200	84,500	92,200	82,800	88,300	NA	85,700	NA	2,600	1,700	3,900	16,500	18,000
Men	81,000	87,200	70,600	76,000	69,300	72,700	NA	70,300	NA	2,300	1,300	3,300	10,400	11,200
Women	20,000	22,900	13,900	16,200	13,500	15,600	NA	15,300	NA	300	400	500	6,100	6,800
Computer specialists	170,000	179,900	167,100	173,500	166,200	172,300	NA	167,200	NA	5,200	900	1,100	2,900	6,400
Men	135,400	143,500	135,400	139,500	134,900	138,700	NA	134,400	NA	4,300	500	800	([1])	4,000
Women	34,600	36,400	31,700	34,000	31,300	33,600	NA	32,700	NA	900	400	400	2,900	2,400
Environmental scientists[2]	79,000	85,700	71,500	77,400	69,100	74,800	NA	52,000	NA	22,900	2,400	2,600	7,500	8,300
Men	73,700	79,300	67,100	73,000	64,600	71,100	NA	49,900	NA	21,200	2,300	1,800	6,600	6,300
Women	5,200	6,400	4,400	4,400	4,300	3,700	NA	2,100	NA	1,600	100	700	900	2,000
Life scientists	266,000	314,100	243,400	286,300	238,600	277,500	NA	224,900	NA	52,600	4,800	8,800	22,600	27,800
Men	214,100	253,300	197,400	232,700	193,400	226,000	NA	176,400	NA	49,600	4,000	6,600	16,700	20,600
Women	51,900	60,800	46,000	53,700	45,200	51,400	NA	48,500	NA	2,900	800	2,200	5,900	7,200
Social scientists	217,000	237,200	192,400	211,400	187,900	198,300	NA	163,600	NA	34,700	4,500	13,100	24,600	25,600
Men	164,000	179,200	147,100	162,100	144,500	153,200	NA	124,900	NA	28,300	2,700	9,000	16,900	17,100
Women	53,000	58,000	45,300	49,300	43,400	45,200	NA	38,700	NA	6,400	1,800	4,200	7,700	8,600
Psychologists	109,300	122,900	94,000	105,700	89,600	97,800	NA	84,200	NA	13,500	4,400	8,000	15,300	17,200
Men	84,200	92,300	73,000	80,000	71,500	76,700	NA	64,600	NA	12,100	1,500	3,300	11,200	12,300
Women	25,100	30,700	21,000	25,700	18,100	21,100	NA	19,700	NA	1,400	2,900	4,700	4,100	4,900
Engineers	1,291,600	1,375,200	1,228,600	1,268,000	1,212,600	1,240,700	NA	1,123,400	NA	117,300	16,000	27,200	63,000	107,200
Men	1,284,900	1,366,900	1,224,200	1,261,000	1,208,300	1,234,000	NA	1,117,600	NA	116,500	15,900	26,900	60,700	105,900
Women	6,700	8,300	4,400	7,000	4,300	6,700	NA	5,800	NA	900	100	300	2,300	1,300

[1] Too few cases to estimate.
[2] Includes earth scientists, oceanographers, and atmospheric scientists.

NA - Not available

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

SOURCE: National Science Foundation, *Detailed Statistical Tables. U.S. Scientists and Engineers, 1976* (NSF 79-305), based on pp. 14, 46-49 and unpublished data.

See figures 5-2, 5-8 and 5-10.

Table 5-3. Employed scientists and engineers as an average percent of total nonproduction workers in selected industries: 1952-1975

Industry	Average percents for each period			
	1952-1956	1957-1961	1962-1966	1967-1975
Chemicals	23	24	25	23
Primary metals[1]	10	12	12	11
Fabricated metals	9	10	10	10
Nonelectrical machinery	12	14	16	14
Electrical equipment	23	26	27	24
Instruments	18	21	23	20

SOURCE: National Science Foundation, "Scientific and Technical Personnel in Private Industry," *Reviews of Data on Science Resources* (NSF 78-302), p. 4.

See figure 5-3. Science Indicators—1978

Table 5-4. Full-time-equivalent scientists and engineers employed in R&D by sector: 1954-1979

(In thousands)

Year	Total	Federal Government[1]	Industry[2]	Universities and colleges	FFRDC's[3]	Nonprofit organizations
1954	237.1	37.7	164.1	25.0	5.0	5.3
1958	354.1	46.0	256.1	36.5	8.1	7.4
1961	425.7	51.1	312.0	42.4	9.1	11.1
1965	494.5	61.8	348.4	53.4	11.1	19.9
1969	556.6	69.9	385.6	68.3	11.6	21.2
1970	546.5	69.8	375.5	68.5	11.5	21.2
1971	526.4	66.5	358.4	68.4	11.5	21.6
1972	518.5	65.2	353.3	66.5	11.7	21.8
1973	517.5	62.3	357.4	63.5	12.0	22.3
1974	525.4	65.0	359.5	65.5	12.1	23.3
1975	534.8	64.5	362.6	70.2	12.7	24.8
1976	549.9	65.3	372.4	72.4	13.4	26.4
1977 (est.)	571.1	64.5	390.1	75.0	14.0	27.5
1978 (est.)	595.0	65.0	410.0	77.5	14.5	28.0
1979 (est.)	610.0	65.5	421.0	80.0	15.0	28.5

[1] Includes both civilian and military service personnel and managers of R&D.
[2] Excludes social scientists.
[3] Federally Funded Research and Development Centers administered by universities.

SOURCES: National Science Foundation, *National Patterns of R&D Resources: Funds and Personnel in the United States, 1953-1978-79* (NSF 78-313), p. 45, and *National Patterns of R&D Resources: Funds and Personnel in the United States, 1953-1977* (NSF 77-310), p. 32.

See figure 5-4. Science Indicators—1978

Table 5-5. Employed doctoral scientists and engineers by primary work activity: 1973 and 1977

Primary work activity	1973 Number	1973 Percent	1977 Number	1977 Percent
Total	220,400	100	284,200	100
Research and development	97,700	44	124,200	44
Basic research	34,300	16	43,500	15
Applied research	28,700	13	36,400	13
Development	8,500	4	13,500	5
R&D management	26,200	12	30,700	11
Teaching	80,000	36	90,400	32
Management or administration[1]	19,900	9	29,700	10
Consulting	4,100	2	6,100	2
Sales/professional services	8,100	4	15,200	5
Other activities	7,000	3	12,800	5
Activity not reported	3,700	2	5,800	2

[1] Other than R&D management.

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

SOURCE: National Science Foundation, *Detailed Statistical Tables. Characteristics of Doctoral Scientists and Engineers in the United States, 1977* (NSF 79-306), pp. 4-5.

See figure 5-5 and table 5-1 in text. Science Indicators—1978

Table 5-6. Employed doctoral scientists and engineers by type of employer and Federal support status: 1973 and 1977

Employer type and support status	1973 Number	1973 Percent	1977 Number	1977 Percent
Total employed	220,400	100	284,200	100
Type of employer:				
Educational institutions	129,400	59	163,100	57
Business and industry	53,400	24	71,500	25
Federal Government[1]	20,200	9	23,600	8
Nonprofit organizations	8,000	4	10,200	4
Hospitals and clinics	4,500	2	8,600	3
Other employers	4,600	2	5,800	2
Employer type not reported	300	(2)	1,400	(2)
Federal support status:				
Receiving Federal support	103,400	47	119,600	42
No Federal support	108,300	49	152,700	54
Support status unknown	4,900	2	7,500	3
Support status not reported	3,800	1	4,500	2

[1] Includes the military services and the Commissioned Corps.
[2] Less than 0.5 percent

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

SOURCE: National Science Foundation, *Detailed Statistical Tables. Characteristics of Doctoral Scientists and Engineers in the United States, 1977* (NSF 79-306), pp. 5, 22 and "Work Activities of Doctoral Scientists and Engineers Show Substantial Change between 1973 and 1977," *Science Resources Studies Highlights*, National Science Foundation (NSF 78-316).

See figure 5-6. Science Indicators—1978

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Table 5-7. Number of experienced[1] scientists and engineers employed in nonscience or nonengineering jobs by field and reason for non-S/E employment: 1976

Field	Total in non-S/E	Prefer non-S/E	Promoted out	Better pay	Locational preference	Believe S/E job not avail.	Other reasons	Reason not reported
All S/E's in nonscience/nonengineering	34,961	7,959	10,276	2,650	2,016	3,507	6,198	2,355
Physical scientists	1,368	368	655	29	25	138	103	50
Mathematical scientists	1,358	205	287	80	276	53	431	26
Computer specialists	1,265	491	311	70	84	51	184	94
Environmental scientists[2]	371	142	49	25	([3])	10	119	26
Engineers	19,447	2,856	7,704	1,654	803	2,710	2,893	827
Life scientists	2,913	1,104	500	424	139	141	280	325
Psychologists	2,111	769	210	134	80	64	612	242
Social scientists	6,108	2,024	560	234	609	340	1,576	765

[1] Those who were in the labor force at the time of the 1970 Census of Population.
[2] Includes earth scientists, oceanographers, and atmospheric scientists.
[3] No cases reported.

SOURCE: National Science Foundation, unpublished data.

See table 5-2 in text. Science Indicators—1978

Table 5-8. Average annual unemployment rates: 1963-77

(In percent)

Year	Total labor force	Professional and technical workers	Scientists		Engineers	
			Total	Doctoral	Total	Doctoral
1963	5.7	1.8	NA	NA	1.2	NA
1964	5.2	1.7	NA	NA	1.5	NA
1965	4.5	1.5	NA	NA	1.1	NA
1966	3.8	1.3	.4	NA	.7	NA
1967	3.8	1.3	NA	NA	.6	NA
1968	3.6	1.2	.9	.5	.7	NA
1969	3.5	1.3	NA	NA	.8	NA
1970	4.9	2.0	1.6	.9	2.2	NA
1971	5.9	2.9	2.6	1.4	2.9	1.9
1972	5.6	2.4	NA	NA	2.0	NA
1973	4.9	2.2	NA	1.2	1.0	.8
1974	5.6	2.3	2.2	NA	1.3	NA
1975	8.5	3.2	NA	1.0	2.6	.7
1976	7.7	3.2	4.0	NA	2.0	NA
1977	7.0	3.0	NA	1.3	1.3	.6

SOURCES: Department of Labor, *Employment and Training Report of the President, 1978*, p. 215; Bureau of Labor Statistics, unpublished data; National Science Foundation, *American Science Manpower* (biennial series, 1964-1970) and unpublished data; National Science Foundation, *Characteristics of Doctoral Scientists and Engineers in the United States* (biennial series, 1973-1977); National Science Foundation, *Detailed Statistical Tables. U. S. Scientists and Engineers, 1976* (NSF 79-305); and National Science Foundation, *Unemployment Rates and Unemployment Characteristics for Scientists and Engineers, 1971* (NSF 72-307), p. 11.

See figure 5-8. Science Indicators—1978

Table 5-9. Unemployment rates for engineers as a percent of the rates for professional, technical and kindred workers: 1967-1977

Year	Unemployment rates (Percent)		Engineers' unemployment rate as a percent of PTK unemployment rate
	Engineers	PTK[1]	
1967	0.6	1.3	46
1968	0.7	1.2	58
1969	0.8	1.3	62
1970	2.2	2.0	110
1971	2.9	2.9	100
1972	2.0	2.4	83
1973	1.0	2.2	45
1974	1.3	2.3	57
1975	2.6	3.2	81
1976	2.0	3.2	62
1977	1.3	3.0	43

[1] Professional, technical and kindred workers.

SOURCES: Bureau of Labor Statistics and National Science Foundation, unpublished data; U.S. Department of Labor, *Employment and Training Report of the President, 1978*, p. 215.

See figure 5-9. Science Indicators—1978

Table 5-10. Number of doctoral scientists and engineers by field and employment status: 1977

Field	Total	Labor force: Total	Employed: Total	Employed: In S/E	Employed: Not in S/E	In post-doctoral appointments	Unemployed and seeking employment	Outside the labor force
All fields	303,300	287,500	274,500	251,600	22,900	9,800	3,300	15,700
Physical scientists	62,100	58,200	54,900	48,800	5,700	2,600	800	3,800
Chemists	40,600	37,800	35,800	31,800	3,900	1,600	500	2,900
Physicists and astronomers	21,400	20,400	19,100	17,000	2,100	1,000	300	1,000
Mathematical scientists	15,400	14,700	14,500	13,500	1,000	100	200	700
Mathematicians	13,700	13,000	12,800	11,800	900	100	200	600
Statisticians	1,700	1,700	1,700	1,700	(2)	(1)	(2)	(1)
Computer specialists	5,800	5,800	5,700	5,600	100	(2)	(1)	100
Environmental scientists	13,500	13,100	12,700	12,200	500	400	100	400
Earth scientists	10,200	9,800	9,500	9,100	400	200	100	400
Oceanographers	1,600	1,600	1,500	1,500	(2)	(2)	(2)	(1)
Atmospheric scientists	1,700	1,700	1,600	1,600	(2)	100	(1)	(1)
Engineers	46,500	45,300	44,600	42,100	2,600	400	300	1,200
Life scientists	78,300	72,900	66,700	62,900	3,800	5,200	1,000	5,400
Biological scientists	46,800	43,000	38,100	35,400	2,700	4,100	800	3,800
Agricultural scientists	15,000	14,400	14,100	13,500	600	200	100	700
Medical scientists	16,500	15,600	14,500	14,000	400	1,000	100	900
Psychologists	35,700	34,100	33,200	30,800	2,400	600	400	1,600
Social scientists	45,800	43,300	42,200	35,600	6,600	500	600	2,500
Economists	11,700	10,800	10,700	8,800	1,900	100	100	800
Sociologists and anthropologists	10,400	9,800	9,300	8,500	900	200	300	600
Other social scientists	23,800	22,800	22,200	18,300	3,900	300	300	1,100

[1] No cases reported.
[2] Less than 50.

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

SOURCE: National Science Foundation, *Detailed Statistical Tables. Characteristics of Doctoral Scientists and Engineers in the United States, 1977* (NSF 79-306), based on pp. 24-26.

See figure 5-10.

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Table 5-11. Transition of 1974 and 1975 S/E bachelor's and master's degree recipients from school to work: 1976

Status in 1976	Bachelor's degree recipients	Master's degree recipients
Total	614,900	108,500
Full-time graduate students	144,600	20,600
Employed	406,800	81,000
In S/E jobs	181,900	62,700
In non-S/E jobs	224,900	18,200
Not employed	63,500	6,900
Unemployed and seeking	37,800	3,800
Not in the labor force	25,700	3,100

SOURCES: National Science Foundation, "Employment Patterns of Recent Entrants into Science and Engineering," *Reviews of Data on Science Resources* (NSF 78-310), pp. 2, 10, 11; and unpublished data.

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

See figure 5-11. Science Indicators—1978

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Table 5-12. Selected employment characteristics of employed 1974 and 1975 bachelor's and master's degree recipients[1] in science and engineering, by field of study and sex: 1976

Field of study	Bachelor's degree						Master's degree					
	Total employed			Employed in S/E			Total employed			Employ[illegible]		
	Total	Men	Women	Total	Men	Women	Total	Men	Women	Total	M[illegible]	Women
All fields	406,800	283,600	123,200	181,900	145,700	36,200	81,000	66,300	14,700	62,700	53,[illegible]00	9,700
Physical sciences	17,300	14,300	3,100	10,200	8,400	1,900	6,300	5,100	1,100	4,000	3,200	800
Chemistry	9,500	7,500	2,100	6,400	4,900	1,500	3,000	2,300	700	2,400	1,800	600
Physics and astronomy	3,600	3,400	200	2,300	2,200	200	1,400	1,400	([2])	1,000	1,000	([2])
Other physical sciences	4,200	3,400	800	1,500	1,300	200	1,900	1,400	400	600	400	200
Environmental sciences[3]	4,600	3,800	700	2,700	2,300	400	1,400	1,100	300	1,200	1,000	200
Mathematics	29,400	18,000	11,400	13,500	8,700	4,800	5,700	4,200	1,400	3,200	2,300	800
Computer sciences	9,000	6,800	2,200	8,100	6,100	2,000	4,100	3,400	600	3,500	3,000	500
Engineering	83,200	81,400	1,800	69,400	67,800	1,600	27,500	26,700	800	25,600	24,900	700
Life sciences	80,500	57,000	23,400	40,000	28,600	11,300	13,300	9,800	3,500	10,100	7,600	2,500
Biology	55,500	34,300	21,200	26,100	16,200	9,900	9,600	6,600	3,000	7,200	4,900	2,300
Agricultural sciences	25,000	22,700	2,200	13,800	12,400	1,400	3,700	3,200	500	2,900	2,700	200
Social sciences	118,700	72,100	46,500	22,300	14,500	7,900	13,600	9,900	3,800	8,200	6,000	2,300
Economics	18,700	15,400	3,300	3,700	3,400	300	3,300	2,900	400	2,200	1,800	400
Sociology and anthropology	54,400	22,600	31,700	10,400	4,900	5,600	4,000	2,200	1,900	2,900	1,700	1,200
Other social sciences	45,600	34,100	11,500	8,200	6,200	2,000	6,300	4,800	1,500	3,100	2,500	700
Psychology	64,100	30,200	33,900	15,600	9,300	6,300	9,200	6,000	3,300	7,000	5,000	1,900

[1] Excludes those enrolled full-time in graduate school in 1976.
[2] Less than 50.
[3] Includes earth sciences, oceanography, and atmospheric sciences.

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

SOURCE: National Science Foundation, "Employment Patterns of Recent Entrants Into Science and Engineering," *Reviews of Data on Science Resources* (NSF 78-310), pp. 10-11.

Science Indicators—1978

See figure 5-12.

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Table 5-13. Salaries and earnings of R & D scientists and engineers, production workers, and male professional and technical workers: 1970-1976

Year	Median monthly salaries of R&D scientists and engineers: Dollars	Index (1970 = 100)	Average hourly earnings of production workers: Dollars	Index (1970 = 100)	Annual earnings of male professional and technical workers: Dollars	Index (1970 = 100)
1970	$1,437	100.0	$3.44	100.0	$12,255	100.0
1971	1,512	105.2	3.67	106.7	12,518	102.1
1972	1,571	109.3	3.92	114.0	13,542	110.5
1973	1,621	112.8	3.92	114.0	14,306	116.7
1974	1,729	120.3	4.22	122.7	14,873	121.4
1975	1,852	128.9	4.54	132.0	15,796	128.9
1976	1,963	136.6	4.87	141.6	16,939	138.2

NOTE: Earnings of professional and technical workers are for full-time, year-round employees. Earnings of production workers are for those on private (non-public) payrolls.

SOURCES: Indexes calculated by NSF based on data in Battelle Columbus Laboratories, *National Survey of Compensation Paid Scientists and Engineers Engaged in Research and Development Activities, 1974, 1975 and 1976*, Table 25, p. xxxiv; U. S. Department of Labor, *Employment and Training Report of the President, 1978*, p. 265; and U. S. Bureau of the Census, *Current Population Reports*, series P-60, Nos. 80, 85, 93, 101, and 107.

See figure 5-13.

Science Indicators—1978

Table 5-14. Percent change in average monthly salary offers to bachelor's degree candidates in selected fields: 1973-74 to 1976-77.

Curriculum	Average monthly salary offers: 1973-74	1976-77	Percent Change
Business	$ 803	$ 927	15
Humanities	691	810	17
Social Sciences	737	887[1]	20
Engineering			
Chemical	1,042	1,389	33
Civil	967	1,185	23
Electrical	986	1,245	26
Mechanical	1,001	1,286	28
Agricultural sciences	785	924	18
Biological sciences	720	882	22
Chemistry	884	1,102	25
Computer sciences	915	1,123	23
Mathematics	874	1,073	23

[1] Based on data in *CPC Salary Survey*.

SOURCES: *CPC Salary Survey, Final Report July 1976* and *July 1978* (Bethlehem, Pa.: College Placement Council), p. 3.

See figure 5-14.

Science Indicators—1978

Table 5-15. Trends in Graduate Record Examination verbal and quantitative test scores: 1970-71 to 1976-77

Prospective field of graduate study	Aptitude type	1970-71 Number	1970-71 Mean	1970-71 S.D.	1971-72 Number	1971-72 Mean	1971-72 S.D.	1972-73 Number	1972-73 Mean	1972-73 S.D.	1973-74 Number	1973-74 Mean	1973-74 S.D.	1974-75 Number	1974-75 Mean	1974-75 S.D.	1975-76 Number	1975-76 Mean	1975-76 S.D.	1976-77 Number	1976-77 Mean	1976-77 S.D.
Science fields																						
Physical sciences	V	499	512	136	323	500	134	474	519	130	454	502	126	526	508	133	11,402	500	129	9,630	514	119
	Q		650	106		643	109		648	105		648	113		630	110		623	116		634	110
Mathematical sciences	V	415	517	141	248	495	135	362	510	131	404	513	139	384	506	126	5,309	520	133	5,643	513	138
	Q		675	104		673	91		676	96		675	97		661	104		673	99		666	104
Engineering	V	665	444	132	372	446	122	544	465	132	573	449	133	594	440	127	6,716	471	132	9,695	482	133
	Q		656	98		651	97		665	93		663	100		649	103		654	105		657	100
Life sciences	V	1,036	491	122	716	491	122	1,069	504	117	1,202	508	121	1,347	509	118	25,546	506	115	24,216	506	118
	Q		556	120		553	122		570	116		569	117		568	118		557	121		558	119
Basic social sciences	V	2,085	533	117	1,570	527	118	2,176	522	120	2,153	525	119	2,165	521	120	27,962	534	118	29,018	526	121
	Q		530	116		526	120		521	125		521	127		518	126		526	123		518	126
Nonscience fields																						
Health professions	V	358	500	114	256	502	108	376	509	107	471	508	113	597	502	103	11,192	513	104	[illegible]	507	107
	Q		496	119		501	117		508	120		507	120		513	119		530	118		527	120
Education	V	2,993	472	110	2,120	463	112	2,988	452	113	2,953	449	113	2,745	454	113	22,911	464	114	[illegible]	454	113
	Q		462	120		457	119		450	119		442	120		445	120		459	120		449	119
Arts and humanities	V	2,686	546	118	1,659	534	117	2,571	537	120	2,574	541	125	2,405	542	121	35,257	537	122	33,848	543	110
	Q		494	118		492	116		493	122		494	121		490	120		494	126		502	112
Applied social sciences	V	983	492	113	694	482	111	1,036	464	121	1,160	493	121	1,270	488	118	40,061	471	118	30,369	477	120
	Q		480	121		475	123		475	126		477	122		464	123		461	125		465	126
Other nonsciences	V	880	496	124	580	490	124	961	501	125	917	498	124	901	496	125	11,246	507	123	12,229	498	126
	Q		498	123		500	119		502	121		495	126		498	126		509	127		510	129

NOTE: V = verbal, Q = quantitative, and S.D. = standard deviation.

SOURCES: Data for the years 1970-71 thru 1974-75 are from a one-in-fifteen sample study of examinees of those years. See Robert F. Boldt, *Trends in Aptitude of Graduate Students in Science* (Princeton, N.J.: Educational Testing Service, 1976), p. 20. Mean scores and standard deviations for 1975-76 and 1976-77 were calculated by NSF from unpublished tabulations furnished by the Educational Testing Service, based on the test results of a high proportion of all examinees of those years.

See figure 5-15.

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Table 5-16. Number of doctoral scientists and engineers by type of employer and age: 1977

Type of employer	Total	Age								
		Under 30	30-34	35-39	40-44	45-49	50-54	55-59	60-64	Over 64[1]
Total	303,300	8,900	55,500	68,800	46,300	38,700	32,000	23,800	14,800	14,600
Business and industry	71,500	1,800	13,600	18,200	11,400	9,000	7,300	5,600	3,100	1,500
Educational institutions	163,100	5,400	30,100	37,200	25,800	22,200	17,900	13,100	7,700	3,600
4-year colleges/universities	156,500	5,300	29,000	35,500	24,800	21,400	17,100	12,500	7,400	3,500
Other educational institutions	6,600	100	1,100	1,700	1,000	800	800	600	300	100
Hospitals and clinics	8,600	300	2,800	1,900	1,200	900	1,000	600	300	100
Nonprofit organizations	10,200	400	2,000	2,500	1,400	1,200	1,100	800	400	400
Government	29,000	600	5,300	6,600	5,100	4,100	3,400	2,100	1,200	600
Federal[2]	23,600	400	4,200	5,400	4,300	3,400	2,800	1,800	900	400
State	3,800	100	800	900	600	500	400	200	200	100
Other government	1,500	100	300	300	200	200	200	100	100	100
Other employers	600	(3)	100	200	100	100	(3)	(3)	(3)	(3)
Employer not reported	1,300	(3)	100	200	200	100	200	200	200	200
Not employed	19,000	400	1,900	2,000	1,100	1,000	1,000	1,300	1,900	8,300

[1] Includes 490 not reporting age.
[2] Includes the military services and the Commissioned Corps.
[3] Fewer than 50.

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

SOURCE: National Science Foundation, *Detailed Statistical Tables. Characteristics of Doctoral Scientists and Engineers in the United States, 1977* (NSF 79-306), p. 27.

See figure 5-16.

Science Indicators—1978

Table 5-17. Number of doctoral scientists and engineers by primary work activity and age: 1977

Primary work activity	Total	Age								
		Under 30	30-34	35-39	40-44	45-49	50-54	55-59	60-64	Over 64[1]
Total	303,300	8,900	55,500	68,800	46,300	38,700	32,000	23,800	14,800	14,600
Research and development	124,100	4,800	28,200	30,700	19,900	15,300	11,700	7,900	4,300	1,600
Basic research	43,500	2,800	12,700	10,300	6,300	4,500	3,300	1,900	1,300	500
Applied research	36,400	1,400	8,900	9,000	5,700	4,400	3,000	2,500	1,100	500
Development	13,500	400	3,300	4,200	2,200	1,400	1,000	600	400	100
Management of R&D	30,700	200	3,300	7,200	5,700	5,000	4,400	2,900	1,500	500
Management and administration	29,800	100	2,600	5,700	5,200	5,100	4,800	3,500	1,900	700
Teaching	90,400	2,400	15,200	21,500	14,400	12,700	10,100	7,500	4,500	2,000
Report writing	5,400	200	800	1,200	800	700	600	500	300	300
Consulting	6,100	100	1,000	1,400	900	600	600	600	500	500
Production and inspection	2,200	100	600	600	300	200	200	100	100	(2)
Sales/professional services	15,200	600	3,400	3,300	2,000	1,900	1,700	1,300	600	500
Other activities	5,200	100	900	1,100	800	600	700	400	400	200
Activity not reported	5,800	200	900	1,100	700	600	700	600	400	400
Not employed	19,000	400	1,900	2,000	1,100	1,000	1,000	1,300	1,900	8,300

[1] Includes 490 not reporting age.
[2] Fewer than 50.

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

SOURCE: National Science Foundation, *Detailed Statistical Tables. Characteristics of Doctoral Scientists and Engineers in the United States, 1977* (NSF 79-306), based on p. 33.

See figure 5-17.

Science Indicators—1978

Table 5-18. Primary work activity[1] of 1971-74 doctoral recipients in science and engineering

	Year of doctorate							
	1971		1972		1973		1974	
Primary work activity	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Total	17,200	100	16,900	100	16,400	100	17,300	100
Research and development	7,900	46	7,700	46	8,000	49	8,800	51
Basic research	3,700	22	3,600	22	3,800	23	4,100	24
Applied research	2,700	16	2,700	16	2,400	15	3,000	17
Development	1,000	6	900	5	1,000	6	1,100	6
Management of R&D	500	3	500	3	700	5	700	4
Teaching	6,200	36	5,900	35	5,600	34	5,400	31
Management and administration	600	4	600	4	700	4	600	3
Consulting	300	2	300	2	300	2	300	2
Sales/professional services	700	4	800	4	1,000	6	1,200	7
Other activities	600	3	500	3	600	3	700	4
Activity not reported	900	5	1,100	6	300	2	300	2

[1] Reflects employment in spring following year of doctorate.

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

SOURCE: National Science Foundation, unpublished data.

See figure 5-18.

Science Indicators—1978

Table 5-19. Employed scientists and engineers by field and sex: 1976-1977[1]

(In thousands)

	All S/E's (1976)			Doctoral S/E's (1977)		
Field	Total	Men	Women	Total	Men	Women
All fields	2,377.2	2,180.0	197.2	284.2	256.7	27.5
Physical scientists	227.4	207.5	19.9	57.4	54.5	2.9
Mathematical scientists	88.3	72.7	15.6	14.6	13.6	1.0
Computer specialists	172.3	138.7	33.6	5.8	5.6	.2
Environmental scientists[2]	74.8	71.1	3.7	13.0	12.6	.4
Engineers	1,240.7	1,234.0	6.7	45.0	44.7	.3
Life scientists	277.5	226.1	51.4	71.9	62.9	9.0
Psychologists	97.8	76.7	21.1	33.7	26.1	7.6
Social scientists	198.3	153.1	45.2	42.7	36.7	6.0

[1] Comparable data are not available for the same years for each group.
[2] Includes earth scientists, oceanographers, and atmospheric scientists.

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

SOURCE: National Science Foundation, *Detailed Statistical Tables. U. S. Scientists and Engineers: 1976* (NSF 79-305) based on p. 14; and National Science Foundation, *Detailed Statistical Tables. Characteristics of Doctoral Scientists and Engineers in the United States, 1977* (NSF 79-306) based on pp. 24-26.

See figure 5-19.

Science Indicators—1978

Table 5-20. Median annual salaries of full-time doctoral scientists and engineers[1] by field, sex, and race: 1977

Field	Total	Sex		Race				
		Men	Women	White	Black	American Indian	Asian	Not reported
All fields	$25,600	$26,000	$20,700	$25,700	$23,800	$23,900	$23,800	$25,700
Physical scientists	26,600	26,800	21,200	26,800	23,900	(2)	23,300	26,500
Chemists	26,600	27,000	20,900	26,900	24,200	(2)	23,200	26,000
Physicists/astronomers	26,500	26,600	23,100	26,700	(2)		23,300	27,300
Mathematical scientists	23,300	23,600	19,900	23,400	23,200	(2)	22,100	23,100
Mathematicians	23,100	23,400	19,900	23,200	22,800	(2)	22,500	23,100
Statisticians	25,100	25,400	19,800	25,500	(2)	(2)	(2)	(2)
Computer specialists	25,800	26,100	20,800	26,500	(2)	(2)	21,200	(2)
Environmental scientists	25,800	26,000	19,700	25,900	(2)	(2)	23,500	30,800
Earth scientists	25,900	26,000	20,000	25,900	(2)	(2)	23,500	29,100
Oceanographers	24,100	24,400	19,200	24,100	(2)	(2)		(2)
Atmospheric scientists	28,300	28,900	19,200	27,800	(2)	(2)	22,700	(2)
Engineers	28,600	28,700	22,900	29,300	28,600	(2)	25,000	27,800
Life scientists	24,700	25,100	21,000	24,800	24,800	22,500	22,600	24,600
Biological scientists	23,800	24,300	20,500	23,900	24,700	(2)	22,100	23,600
Agricultural scientists	24,800	24,900	20,200	25,000	(2)	(2)	20,600	25,300
Medical scientists	28,000	28,900	22,800	28,300	26,900	(2)	25,400	26,500
Psychologists	24,100	24,900	20,600	24,100	21,500	22,300	24,400	25,700
Social scientists	24,100	24,700	20,200	24,100	22,900	(2)	22,900	24,900
Economists	27,000	27,500	23,600	27,000	(2)	(2)	25,900	28,300
Sociologists/anthropol.	22,200	22,900	19,700	22,200	23,200	(2)	22,200	22,600
Other social scientists	23,200	23,900	19,800	23,300	22,700	(2)	21,100	24,500

[1] Excludes the military services and the Commissioned Corps.
[2] Fewer than 20 individuals in a sample reported salary; therefore, no national estimates could be made.

SOURCE: National Science Foundation. *Detailed Statistical Tables. Characteristics of Doctoral Scientists and Engineers in the United States, 1977* (NSF 79-306), p. 50.

See figure 5-20.

Table 5-21. Median annual salaries of full-time doctoral scientists and engineers[1] by age and sex: 1977

Age	Total	Men	Women
Total	$25,600	$26,000	$20,700
Under 30	18,500	18,700	17,400
30-34	20,400	20,600	18,400
35-39	23,600	24,000	20,000
40-44	26,500	26,800	21,700
45-49	29,200	29,700	23,100
50-54	30,900	31,400	24,700
55-59	31,600	32,200	24,200
60-64	31,400	31,900	25,000
Over 64	31,200	31,900	25,100

[1] Excludes the military services and the Commissioned Corps.

SOURCE: National Science Foundation, *Detailed Statistical Tables. Characteristics of Doctoral Scientists and Engineers in the United States, 1977* (NSF 79-306), p. 51, and unpublished data.

See figure 5-21. Science Indicators—1978

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Table 5-22. Bachelor's degrees granted to women as a percent of total bachelor's degrees by field: 1965-1976

Year	All S/E fields	Physical sciences[1]	Engineering	Mathematical sciences[2]	Life sciences	Social sciences[3]
			Women as percent of total			
1965	22.0	14.1	0.4	32.0	23.8	33.8
1966	22.8	13.6	.4	33.2	23.0	34.4
1967	23.4	13.5	.5	34.1	22.7	34.5
1968	25.2	13.8	.6	36.7	23.3	36.1
1969	25.8	13.7	.8	36.6	23.2	36.7
1970	26.1	13.8	.8	36.1	22.8	37.0
1971	26.9	14.0	.8	36.0	22.9	38.3
1972	27.6	15.1	1.1	35.9	23.7	38.6
1973	28.4	15.0	1.2	36.3	24.5	39.5
1974	30.1	16.6	1.6	36.6	26.1	41.2
1975	31.6	18.4	2.1	37.0	28.6	42.9
1976	32.7	19.2	3.7	35.3	30.8	44.2
			Number of women recipients			
1965	36,213	2,532	139	6,453	8,277	18,812
1966	39,482	2,333	146	6,702	8,464	21,837
1967	44,002	2,402	184	7,334	8,948	25,134
1968	53,463	2,674	211	8,841	10,091	31,646
1969	63,196	2,952	313	10,348	11,308	38,275
1970	68,878	2,969	338	10,516	11,875	43,180
1971	72,996	3,014	365	9,818	11,803	47,996
1972	77,671	3,148	501	9,784	12,694	51,544
1973	83,839	3,121	580	9,985	14,570	55,583
1974	91,793	3,536	706	9,719	17,836	59,996
1975	93,342	3,838	860	8,656	20,811	59,177
1976	95,597	4,139	1,443	7,678	23,789	58,548
			Total recipients			
1965	164,936	17,916	36,795	19,668	34,842	55,715
1966	173,471	17,186	35,815	20,182	36,864	63,424
1967	187,849	17,794	36,188	21,530	39,408	72,929
1968	212,174	19,442	37,614	24,084	43,260	87,774
1969	244,519	21,591	41,553	28,263	48,713	104,399
1970	264,122	21,551	44,772	29,109	52,129	116,561
1971	271,176	21,549	45,387	27,306	51,461	125,473
1972	281,228	20,887	46,003	27,250	53,484	133,604
1973	295,391	20,809	46,989	27,528	59,486	140,579
1974	305,062	21,287	43,530	26,570	68,226	145,449
1975	294,920	20,896	40,065	23,385	72,710	137,864
1976	292,174	21,559	39,114	21,749	77,301	132,451

[1] Includes environmental sciences (earth sciences, oceanography, and atmospheric sciences).
[2] Includes computer sciences.
[3] Includes psychology.

SOURCE: National Center for Education Statistics, *Earned Degrees Conferred*, annual series. Degrees have been classified on the basis of the NSF taxonomy.

See figure 5-22.

Table 5-23. Science and engineering doctoral degree[1] recipients by field and sex: 1965-1977

Year	All S/E fields	Physical sciences[2]	Engineering	Mathematical sciences[3]	Life sciences	Social sciences[4]
			All S/E doctoral degree recipients			
1965	10,477	2,865	2,073	685	2,539	2,315
1966	11,456	3,058	2,299	769	2,712	2,618
1967	12,982	3,502	2,603	830	2,967	3,080
1968	14,411	3,667	2,847	970	3,501	3,426
1969	15,949	3,910	3,249	1,064	3,796	3,930
1970	17,731	4,400	3,432	1,222	4,163	4,514
1971	18,880	4,494	3,495	1,236	4,533	5,122
1972	18,940	4,226	3,475	1,281	4,505	5,453
1973	18,948	4,016	3,338	1,222	4,574	5,798
1974	18,316	3,696	3,144	1,196	4,407	5,873
1975	18,352	3,611	2,959	1,149	4,540	6,093
1976	17,872	3,442	2,791	1,003	4,480	6,156
1977	17,373	3,410	2,641	959	4,266	6,097
			Women			
1965	744	127	7	50	263	297
1966	911	132	8	48	326	397
1967	1,086	161	9	48	401	467
1968	1,295	185	12	47	483	568
1969	1,472	205	10	56	537	664
1970	1,62[illegible]	243	15	77	538	753
1971	1,929	244	16	96	656	917
1972	2,101	269	21	96	680	1,035
1973	2,446	257	45	119	795	1,230
1974	2,590	260	34	115	784	1,397
1975	2,838	284	50	110	863	1,531
1976	2,986	296	53	113	870	1,654
1977	3,103	303	74	128	845	1,753
			Women as percent of total			
1965	7	4	(5)	7	10	13
1966	8	4	(5)	6	12	15
1967	8	5	(5)	6	14	15
1968	9	5	(5)	5	14	17
1969	9	5	(5)	5	14	17
1970	9	6	(5)	6	13	17
1971	10	5	(5)	8	14	18
1972	11	6	1	7	15	19
1973	13	6	1	10	17	21
1974	14	7	1	10	18	24
1975	15	8	2	10	19	25
1976	17	9	2	11	19	27
1977	18	9	3	13	20	29

[1] Excludes first-professional degrees such as M.D., D.D.S., D.V.M., and J.D.
[2] Includes environmental sciences (earth sciences, oceanography, and atmospheric sciences).
[3] Includes computer sciences.
[4] Includes psychology.
[5] Less than 0.5 percent.

SOURCE: National Academy of Sciences, *Doctorate Recipients from U. S. Universities*, annual series. Degrees are classified on the basis of the NSF taxonomy.

See figure 5-23.

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Table 5-24. Employed 1974 and 1975 S/E bachelor's degree recipients working in science and engineering by field of study and sex: 1976

Field of study	Total employed		Employed in S/E			
			Number		Percent	
	Men	Women	Men	Women	Men	Women
All fields	283,600	123,200	145,700	36,200	51	29
Physical sciences[1]	18,100	3,800	10,700	2,300	59	61
Mathematical sciences[2]	24,800	13,600	14,700	6,800	59	50
Life sciences	57,000	23,400	28,600	11,300	50	48
Social Sciences[3]	102,300	80,400	23,800	14,200	24	18
Engineers	81,400	1,800	67,800	1,600	83	89

[1] Includes environmental sciences (earth sciences, oceanography and atmospheric sciences).
[2] Includes computer sciences.
[3] Includes psychology.

SOURCE: National Science Foundation, "Employment Patterns of Recent Entrants into Science and Engineering," *Reviews of Data on Science Resources* (NSF 78-310), p. 10.

See figure 5-24.

Table 5-25. Number and percent of scientists and engineers by field and minority groups: 1976

Field	All scientists and engineers	Total minorities[1]		Blacks		Asians		Other minorities[1]	
		Number	Percent	Number	Percent	Number	Percent	Number	Percent
All fields	2,705,800	112,200	4.1	40,400	1.5	45,400	1.7	26,400	1.0
Engineers	1,375,200	47,900	3.5	12,600	.9	23,000	1.7	12,300	.9
Mathematical scientists	110,200	4,900	4.4	2,700	2.5	1,600	1.5	600	.5
Computer specialists	179,900	8,100	4.5	3,700	2.1	3,700	2.1	700	.4
Life scientists	314,100	12,000	3.8	3,600	1.1	4,100	1.3	4,300	1.4
Physical and environmental[2] scientists	366,300	15,400	4.2	4,500	1.2	6,300	1.7	4,600	1.2
Social scientists and psychologists	360,100	23,800	6.6	13,200	3.7	6,700	1.9	3,900	1.1

[1] Includes approximately 9,500 not responding to this question.
[2] Includes earth scientists, oceanographers, and atmospheric scientists.

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

SOURCE: National Science Foundation, *Detailed Statistical Tables. U.S. Scientists and Engineers: 1976* (NSF 79-305), p. 15.

See figure 5-25. Science Indicators—1978

Table 5-26. Distribution of employed scientists and engineers by field and selected minority groups: 1976

Field	All S/E's		Blacks		Asians	
	Total employed	Percent	Total employed	Percent	Total employed	Percent
All fields	2,377,100	100	33,000	100	41,400	100
Engineers	1,240,800	52	11,700	36	20,600	50
Mathematical scientists	88,300	4	2,000	6	1,100	3
Computer specialists	172,300	7	3,500	11	3,600	9
Life scientists	277,500	12	2,900	9	3,900	9
Physical scientists	227,400	10	3,300	10	5,400	13
Environmental scientists[1]	74,800	3	100	([2])	500	1
Psychologists	97,800	4	1,300	4	3,100	7
Social scientists	198,300	8	8,200	25	3,300	8

[1] Includes earth scientists, oceanographers, and atmospheric scientists.
[2] Less than 0.5 percent.

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

SOURCE: National Science Foundation, *Detailed Statistical Tables. U.S. Scientists and Engineers: 1976* (NSF 79-305), based on pp. 15-16.

See figure 5-26. Science Indicators—1978

Table 5-27. Number of scientists and engineers by highest earned degree and racial group: 1976

Highest earned degree	Total	White	Black	American Indian	Asian	Other[1]
Total	2,705,800	2,593,600	40,400	2,600	45,400	23,800
Doctorate	286,400	266,500	3,000	400	14,800	1,600
Master's	658,800	631,500	9,500	400	12,100	5,100
Bachelor's	1,688,800	1,625,100	27,300	1,500	18,100	16,700
Other[2]	71,800	70,500	600	300	400	200

[1] Includes approximately 9,500 not responding to this question.
[2] Includes professional medical, associate and other earned degrees.

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

SOURCE: National Science Foundation, *Detailed Statistical Tables. U.S. Scientists and Engineers: 1976* (NSF 79-305), p. 24.

See table 5-3 in text.

Table 5-26. Median annual salaries of full-time employed doctoral scientists and engineers[1] by field and primary work activity: 1977

Primary work activity	All fields	Physical scientists	Mathematical scientists	Computer specialists	Environmental scientists[2]	Engineers	Life scientists	Psychologists	Social scientists
All activities	$25,600	$26,600	$23,300	$25,800	$25,800	$28,600	$24,700	$24,100	$24,100
Management and administration	31,900	33,400	29,900	31,400	31,400	34,200	31,300	28,100	29,900
Of R&D	33,100	34,300	33,000	33,100	32,500	34,500	31,900	30,800	30,200
Of non-R&D	30,200	31,000	29,200	30,200	30,400	33,300	30,200	26,800	29,500
Of both	32,200	32,700	28,400	32,100	32,100	34,800	32,300	29,400	29,800
Research and Development	25,600	26,300	25,800	24,900	25,800	27,000	24,100	24,300	24,800
Basic research	24,600	25,300	24,800	26,900	25,900	27,700	23,800	23,000	24,200
Applied research	26,300	27,000	27,700	28,100	25,700	27,000	24,600	25,200	26,000
Development and design	26,100	26,700	25,500	24,200	25,700	27,000	23,500	23,600	20,600
Teaching	22,600	22,600	21,700	22,900	22,400	25,200	22,500	21,900	22,300
Report writing	25,100	25,200	28,600	(3)	24,700	27,900	23,700	25,400	25,600
Consulting	28,200	30,500	(3)	(3)	28,500	30,300	25,500	25,500	28,000
Production and inspection	22,900	22,900	(3)	(3)	(3)	24,200	22,200	(3)	(3)
Sales and professional services	24,700	27,500	(3)	(3)	(3)	28,700	25,700	23,800	26,000
Other activities	24,900	30,000	21,500	(3)	25,900	26,100	23,200	26,100	24,100

[1] Excludes the military services and the Commissioned Corps.
[2] Includes earth scientists, oceanographers, and atmospheric scientists.
[3] No median computed for groups with fewer than 20 individuals reporting salaries.

SOURCE: National Science Foundation, *Detailed Statistical Tables, Characteristics of Doctoral Scientists and Engineers in the United States, 1977* (NSF 79-306), p. 51.

Table 5-29. Median annual salaries of full-time employed doctoral scientists and engineers[1] by field and type of employer: 1977

Employer type	All fields	Physical scientists	Mathematical scientists	Computer specialists	Environmental scientists[2]	Engineers	Life scientists	Psychologists	Social scientists
Total	$25,600	$26,600	$23,300	$25,800	$25,800	$28,600	$24,700	$24,100	$24,100
Business and industry	29,900	29,900	27,400	26,000	28,600	30,000	28,700	33,300	30,200
Educational institutions	23,700	23,600	22,700	24,400	23,600	26,500	23,500	22,700	23,100
Universities and 4-year colleges	23,800	23,900	22,800	24,400	23,700	26,500	23,600	22,700	23,200
2-year colleges	20,900	20,800	17,800	(3)	(3)	23,800	20,600	20,300	22,400
Elementary and secondary schools:	22,400	18,100	(3)	(3)	(3)	(3)	19,300	23,900	20,700
Hospitals and clinics	23,600	26,500	(3)	(3)	(3)	(3)	25,300	23,200	(3)
Nonprofit organizations	26,800	25,900	28,600	(3)	27,600	30,100	24,500	24,400	26,800
Federal Government[1]	29,700	29,700	29,300	30,500	30,700	30,000	28,400	30,600	31,400
State government	21,600	20,200	(3)	(3)	21,000	21,700	21,100	22,900	22,100
Other government	22,100	(3)	(3)	(3)	(3)	(3)	22,700	23,600	19,800
Other employers	37,500	(3)	(3)	(3)	(3)	(3)	(3)	(3)	37,400

[1] Excludes the military services and the Commissioned Corps.
[2] Includes earth scientists, oceanographers, and atmospheric scientists.
[3] No median computed for groups with fewer than 20 individuals reporting salaries.

SOURCE: National Science Foundation, *Detailed Statistical Tables. Characteristics of Doctoral Scientists and Engineers in the United States, 1977* (NSF 79-306), p. 52.

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Table 5-30. Median annual salaries of full-time employed women doctoral scientists and engineers[1] by field and type of employer: 1977

Employer type	All fields	Physical scientists	Mathematical scientists	Computer specialists	Environmental scientists[2]	Engineers	Life scientists	Psychologists	Social scientists
Total	$20,700	$21,200	$19,900	$20,800	$19,700	$22,900	$21,000	$20,600	$20,200
Business and industry	24,400	23,800	(3)	23,000	22,400	23,400	23,600	25,600	26,200
Educational institutions	20,000	19,500	19,500	19,700	18,700	21,400	20,500	19,700	19,800
Universities and 4-year colleges	20,000	19,600	19,800	19,700	18,600	21,400	20,600	19,300	19,800
2-year colleges	19,700	20,000	(3)	(3)	(3)	(3)	20,100	19,300	19,700
Elementary and secondary schools	21,000	(3)	(3)	(3)	(3)	(3)	(3)	22,200	(3)
Hospitals and clinics	21,000	(3)	(3)	(3)	(3)	(3)	21,600	21,000	(3)
Nonprofit organizations	21,100	21,500	(3)	(3)	(3)	(3)	20,100	21,600	21,000
Federal Government	26,600	26,200	(3)	(3)	(3)	(3)	26,200	26,100	28,600
State government	19,500	(3)	(3)	(3)	(3)	(3)	21,600	19,900	17,500
Other government	21,700	(3)	(3)	(3)	(3)	(3)	19,800	23,200	(3)

[1] Excludes the military services and the Commissioned Corps.
[2] Includes earth scientists, oceanographers, and atmospheric scientists.
[3] No median salary computed for groups with fewer than 20 individuals reporting salaries.

SOURCE: National Science Foundation. *Detailed Statistical Tables. Characteristics of Doctoral Scientists and Engineers in the United States, 1977* (NSF 79-306), p. 64.

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Table 5-31. Median annual salaries of full-time employed women doctoral scientists and engineers[1] by field and primary work activity: 1977

Primary work activity	All fields	Physical scientists	Mathematical scientists	Computer specialists	Environmental scientists[2]	Engineers	Life scientists	Psychologists	Social scientists
All activities	$20,700	$21,200	$19,900	$20,800	$19,700	$22,900	$21,000	$20,600	$20,200
Management and administration	25,100	25,700	24,800	(3)	21,700	(3)	25,500	24,400	24,400
of R&D	26,300	27,100	(3)	(3)	(3)	(3)	27,900	26,700	22,900
Of non-R&D	24,100	26,200	(3)	(3)	(3)	(3)	24,100	23,600	24,700
Of both	25,500	(3)	(3)	(3)	(3)	(3)	26,800	(3)	25,200
Research and development	21,000	22,600	22,000	22,500	21,100	23,000	20,700	19,900	20,700
Basic research	20,600	21,500	19,500	(3)	20,000	(3)	20,600	18,800	20,700
Applied research	22,200	23,600	(3)	(3)	23,200	23,200	21,100	21,100	21,500
Development and design	20,500	22,200	(3)	21,500	(3)	(3)	(3)	(3)	(3)
Teaching	19,500	18,800	19,100	19,400	18,800	21,000	20,300	19,000	19,500
Report writing	20,600	(3)	(3)	(3)	(3)	(3)	21,000	20,700	18,000
Consulting	22,300	(3)	(3)	(3)	(3)	(3)	22,300	22,200	(3)
Production and inspection	19,700	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)
Sales and professional services	21,200	(3)	(3)	(3)	(3)	(3)	23,100	21,300	(3)
Other activities	20,500	20,700	(3)	(3)	(3)	(3)	20,700	(3)	17,400

[1] Excludes the military services and the Commissioned Corps.
[2] Includes earth scientists, oceanographers, and atmospheric scientists.
[3] No median salary computed for groups with fewer than 20 individuals reporting salaries.

SOURCE: National Science Foundation, *Detailed Statistical Tables: Characteristics of Doctoral Scientists and Engineers in the United States, 1977* (NSF 79-306), p. 64.

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Table 5-32. Distribution of employed scientists and engineers by field and minority group: 1976

Field	All scientists and engineers	Minority scientists and engineers: All minorities[1]	Blacks	Asians	Other minorities[1]
		Number			
All fields	2,377,100	98,200	33,000	41,400	23,800
Engineers	1,240,800	44,100	11,700	20,600	11,800
Mathematical scientists	88,300	3,300	2,000	1,100	200
Computer specialists	172,400	7,900	3,500	3,600	800
Life scientists	277,500	10,500	2,900	3,900	3,700
Physical scientists	227,400	12,200	3,300	5,400	3,500
Environmental scientists[2]	74,800	1,100	100	500	500
Psychologists	97,700	5,400	1,300	3,100	1,000
Social scientists	198,300	14,000	8,200	3,300	2,500
		Percent			
All fields	100	4.1	1.4	1.7	1.0
Engineers	100	3.6	.9	1.7	1.0
Mathematical scientists	100	3.8	2.3	1.2	.2
Computer specialists	100	4.6	2.0	2.1	.5
Life scientists	100	3.8	1.0	1.4	1.3
Physical scientists	100	5.4	1.5	2.4	1.5
Environmental scientists[2]	100	1.5	.1	.7	.7
Psychologists	100	5.5	1.3	3.2	1.0
Social scientists	100	7.1	4.1	1.7	1.3

[1] Includes an estimated 8,500 not reporting race.
[2] Includes earth scientists, oceanographers, and atmospheric scientists.

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

SOURCE: National Science Foundation, *Detailed Statistical Tables. U. S. Scientists and Engineers: 1976* (NSF 79-305), based on pp. 15-16

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Appendix II

Methodology of Doctorate Supply/Utilization Projections

DESCRIPTION OF THE METHODOLOGY FOR PROJECTING DOCTORAL SCIENTIST AND ENGINEER SUPPLY AND UTILIZATION

Comprehensive projections of the supply and utilization of doctoral scientists and engineers are prepared currently by only two groups, both Federal agencies: the Bureau of Labor Statistics (BLS) and the National Science Foundation (NSF).[1] In spite of differences in concepts and techniques, the two agencies generally agree that a larger number of these scientists and engineers will be employed in non-S/E activities by the mid-1980's.

BLS projects to 1985 the "traditional" employment for doctorates, including those in science and engineering (S/E). Such utilization is defined in terms of the proportions of the labor force in a field that is comprised of doctoral S/E's in a past period when doctoral supply and utilization were assumed to have been in balance. As estimate of "traditional" doctoral employment in 1985 is derived by first extrapolating 1966-1970 trends in the proportional representation of doctorates in a field. The extrapolated fraction for 1985 is multiplied by the BLS projection of total labor requirements in that field for 1985 to obtain the number of traditional jobs for doctoral S/E's.

In contrast, NSF uses econometric modeling and trend extrapolation to estimate the number of science-and-engineering-related positions which may be available by field for doctorates in 1987. This concept of utilization is based on the type of activities in which doctorates are engaged. NSF projects the two largest categories of S/E employment, academic and industrial R&D, through the use of demand equations that are derived from regression analysis. Demand variables include R&D spending and the number of S/E baccalaureates awarded (an index of teaching loads) in a year. Other categories of S/E employment are projected through extrapolation.

In addition to agreement on the overall balance between supply and utilization, both agencies expect growing imbalances in the broad fields of science. More specifically, the two differ by only a few thousand on both the future supply and utilization of doctoral physical scientists and mathematicians. Also, NSF and BLS agree closely on future utilization in the life and social sciences, but BLS projects about 15,000 more doctoral life scientists and about 5,000 more social science doctorate holders than does NSF. Only for engineering do the two sets of projections differ on the future nature of the labor market. BLS foresees a small shortage of doctoral engineers, whereas NSF estimates that about 15,000 of this group will hold non-S/E positions in 1987.

Most of the divergence between the two agencies on the outlook for engineering and almost all of the differences on the extent of the future imbalances in the life and social sciences can be traced to how NSF and BLS account for future additions to the supply. The National Center for Education Statistics (NCES) provides the degree projections used by BLS.[2] NCES derives its estimates of future degrees from extrapolation of trends in (1) the ratios of total doctoral awards to the college-age population, and (2) the ratios of degrees in a field to total doctorates. Examination of NCES projections reveals that future degree totals generally differ not only in magnitude but also in direction of change from those generated by the NSF model. These divergencies highlight the roles in the recursive NSF model of (1) feedback from the market to the number of doctorate graduates and (2) expectations concerning demand factors.[3] In the NSF model, poor employment opportunities in a given year result in lower graduate school entrance and completion rates whereas better market conditions induce higher rates. (It should be noted that although NSF found very strong statistical evidence for the existence of such feedback, NSF analyses indicate that it is not sufficient to prevent market imbalances.) In the NSF model, projected

[1] Douglas Braddock, "The Oversupply of Ph.D.'s to Continue Through 1985," *Monthly Labor Review* (October 1978), p. 48-50; National Science Foundation, *Projections of The Supply and Utilization of Science and Engineering Doctorates, 1982 and 1987* (NSF 79-303).

[2] NCES *Projections of Education Statistics to 1985-86*, U.S. Department of Health, Education and Welfare, National Center for Education Statistics (NCES 77-402).

[3] In a separate effort under an NSF grant, the Center for Policy Analysis at the Massachusetts Institute of Technology has also studied the application of market feedback models to degree projections, an area pioneered by Richard B. Freeman. See *The Overeducated American*, (New York: Academic Press, 1976).

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market conditions and hence, doctoral awards, depend upon the interaction of supply and demand variables.[1] In the case of engineering, NSF projects a reversal in the current downward trend in doctorates, which NCES expects to continue, in large part because projected increases in industrial R&D funding induce higher projected numbers of engineering doctorates.

MINORITY COMMENT ON PROJECTIONS OF THE SUPPLY AND UTILIZATION OF DOCTORAL SCIENTISTS AND ENGINEERS

By Dr. Saunders Mac Lane, Member
National Science Board

Ever since the beginning of recorded history, man has tried to foresee what the future might bring. Soothsayers, oracles, and prophets have made predictions, wise or obscure, wrong or suggestive, as the case may be. Now we are more cautious; it is the current fashion not to "predict" but to "project". But prediction or projection, when put in quantitative form, is an attempt to pin down with numbers our hazy view of the future. That view may still be wrong.

Projections, in my opinion, do not belong in a volume on science indicators, where one expects rather to find careful indications from definite data about the past. This is not the case in the chapter on Scientific and Engineering Personnel in this volume, where there is a projection which reads:

> . . . from 185,000 to 210,000 students are projected to receive science and engineering doctorates from American universities roughly over the next decade . . . . The difference between supply and utilization in the mid-1980's is projected by BLS and NSF to be in the 60,000-to-80,000 range. This difference represents an estimate of doctoral S/E's who are likely to find it necessary to accept non-S/E or non-traditional employment. Based on historical evidence, it is likely that only a small proportion of this group will actually be unemployed. By contrast, only about 23,000 doctoral S/E's were in full-time, non-S/E positions in 1977.[2]

In other words, these projections suggest that about 30 to 40 percent of new Ph.D.'s or their equivalent are unlikely to find positions in science and engineering.

This striking figure requires analysis. To this end, I have studied a draft of the NSF report making this estimate: *Projections of the Supply and Utilization of Science and Engineering Doctorates, 1982 and 1987* (NSF 79-303).

The fundamental difficulty is that any extrapolation to future time is likely to be made by assuming that something measured now will be the same in the future. This assumption may be fine for a little time, but it is not likely to be good for long—and this method cannot foresee qualitative changes.

These projections of the supply and utilization of doctorates are in the same style: they assume something constant. In projecting the number of new doctorates, the state of the market for science doctorates is an important variable. Here it is called SEEK, to indicate a proportion of new science doctorates still searching for science jobs. This quantity (if it be that) is allowed to *vary*, but it depends in *constant* ways on other quantities, such as R and D expenditures, and via an equation such as

$$SEEK = 77 - (0.1 \times R\&D)$$

In other words, the *rate* at which R and D affects SEEK is constant; in this case, the rate coefficient 0.1 means that 20 percent increase in R and D gives 2 percent decrease in the number of doctoral S/E's still seeking jobs at the time of the survey. The actual equations used are more complex, in that SEEK is taken to depend on other quantities besides R and D—but the whole projection depends on those constant *rate coefficients* and hence basically makes the same assumption that "some things will be the same."

The constant coefficients in such equations are picked to fit the past data, as best may be. The picking is done by regression (e.g. "least squares"). This method, first discovered by mathematicians and astronomers, has been used cautiously by statisticians in cases where the results can be compared with the facts. Of late,

[1] Demand variable values are exogenous, i.e., the estimated future values of demand factors are not affected by operation of the model.
[2] See pp. 124-125.

given a general enthusiasm for projections and estimates, economists and econometricians have used regressions widely. There are substantial difficulties with the method. On what quantities (independent variables) does the state of the market really depend? R and D and what else? How can we measure the what else? If we use too many such other quantities, will they interfere with each other? Will they misrepresent each other? Regression, unless checked against data, is more art than science.

This particular regression has an added serious trouble. It depends heavily on the variable SEEK, which is first regressed on other quantities and *then* used as an independent variable to determine (by a second regression) how many new students will enroll for graduate degrees, all to enter into the final projections.

SEEK is defined from the annual NSF Survey of Earned Doctorates. This reports the proportion, by fields of individuals who are about to receive doctorates and who are seeking but have not found a definite position *at the time of the survey* (my emphasis). Thus, the data for SEEK simply record how many hurried Ph.D. candidates may have checked this box at the time—probably the time just before getting the degree when an official, perhaps the graduate dean at their university, asked them to fill out that survey questionnaire. Hence, the numbers are subject to some of the usual troubles with hastily executed surveys.

Filled out *at the time of the survey*! What does this mean? Each survey, as conducted by the Commission on Human Relations, National Research Council (NRC), covers one academic year (July 1 to June 30). It turns out that the graduate dean gets a good supply of survey forms at the start of the year. Students fill them out from time to time. They flow into the NRC offices at a more or less steady rate all year, and a bit into the next year as the NRC attempts to catch up with the laggards. In other words, there is *no* one definite "time of the survey", so this index doesn't measure the market (or anything much else) at *any* definite time. Some responses are early on, others are late, and the sum is a great obscurity. And on *this* one obscurity the *whole projection rests:* SEEK, whatever it means, is one of the central variables in all the regressions used for these projections of new doctorates.

This uncertainty of *time* has other consequences. In some years the market for positions in science begins to be active earlier in the year—with the result that few new Ph.D.'s will still be seeking positions when they fill out those forms. In other words, a low value for the percentage SEEK in any one year measures some (unknown) combination of at least two different effects: the market for Ph.D.'s starts earlier; the market for Ph.D.'s is better.

"Feedback" is also a problem. When the market for positions in science is poor, it seems likely that fewer young people will enter graduate school in the sciences and also that fewer of those already entered will persevere to finish the doctorate. Hence any effective "model" of the situation would do well to incorporate some feedback from the state of the market to the numbers of new and continuing graduate students. The Indicators Appendix, which describes the various projection methodologies states that the NSF model uses "feedback from the market to the number of doctorate graduates."

Reading this led me to think that the massive difference of 60,000 to 80,000 between projected supply and utilization would be "fed back" in the model and would soon have massive effects on the supply. That apparently is not the feedback used. Instead, the values of that rather uncertain variable SEEK activate the "feedback"—when in my judgment a real feedback of the imbalance in 1987 (60,000-80,000) to the input would have been likely to produce a much more realistic measure.

On these and other grounds, this *quantitative* prediction of supply and utilization of doctoral scientists and engineers seems to me very uncertain.

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INDEX OF DATA FOR SELECTED POLICY ISSUES

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USER SURVEY

The judgments and inputs of users of this report are valuable elements for the planning of *Science Indicators—1980.* In addition to providing responses to the following questions, users are encouraged to communicate further with the Science Indicators Unit of the National Science Foundation.

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3. Please elabora[illegible]e weaknesses checked in Item 2 and other areas of improvement.

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