Industrial R&D and Innovation

employing less than 1,000; small firms (those with less than 100 employees and those with 100-999 employees) produced more innovations per unit sales than larger firms throughout the period.

- The largest percentage of the sample of technological innovations produced during the 1953-73 period represented improvements in existing technology (41 percent), followed by those representing major technological advances (32 percent) and radical breakthroughs (27 percent); the fraction of radical innovations declined 50 percent between 1953-59 and 1967-73, while those rated as major technological advances increased proportionately.

- The most frequently cited sources of the underlying technology for the major innovations were research (applied and basic), followed by the transfer of technology from existing product lines of the innovating firm, licensing, and the purchase of technical "know-how" from other firms.

- Basic research was more often involved in product innovations characterized as radical breakthroughs (68 percent) than in those rated as major technological advances (48 percent) or improvements in existing technology (45 percent); applied research occurred with nearly equal frequency in all categories of the innovations studied.

Research and development is increasingly the basis and impetus for technological innovation in industry. The results of innovation are new and improved products, processes, and services. These are the elements of technological progress, through which many of the advances in the Nation's productivity, economic status (domestic and foreign), and standard of living take place.

While R&D is increasingly important in innovation, it is not sufficient by itself. Innovation is a complex process which occurs within a broad economic and social context, and which requires successful efforts in areas such as product design, engineering, manufacturing, and marketing. Although the innovation process is complex, expensive, and risky, the failure of a firm or an industry to be innovative may mean failure of the firm or industry itself, with consequent implications for the general economy.

As an activity, industrial R&D ranges from basic research, consisting of original investigations for the acquisition of scientific knowledge—to development, which attempts to translate acquired knowledge into new and improved products and processes. The character and extent of industrial R&D activity vary considerably, both in terms of the industry and size of the company involved. In general, R&D is viewed as an investment which competes for funds and other resources with alternative investments. For many firms, R&D is regarded as a necessary investment whose returns are believed to be competitive with those from other areas of potential resource allocation.

Indicators of the state of industrial R&D and innovation presented in this chapter consist of selected financial and human resources invested in R&D and measures of the outputs from such investment. The "input" indicators deal primarily with expenditures and scientific and engineering personnel involved in R&D, including trends in the R&D intensity of particular industries. "Output" indicators include measures of patents and technological innovations produced by R&D-performing industries, as well as factors which influence these activities. These measures, combined with R&D intensity and other characteristics, provide indicators of the relative inventiveness and innovativeness of different industries. The chapter concludes with a summary of the major findings from studies of the relationship of R&D and innovation to productivity and economic growth.

The present set of indicators provides a more comprehensive description of the state of industrial R&D than was provided by the first report in this series. The indicators, however, are still deficient in several respects, as discussed in later sections of this chapter.

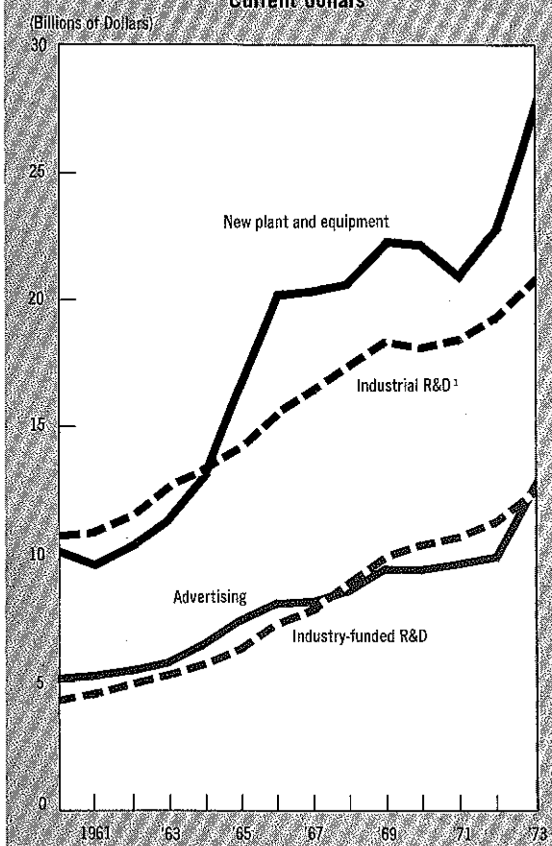
RESOURCES FOR INDUSTRIAL R&D

Financial and human resources directed to industrial R&D represent principal "inputs" to R&D as well as approximate indicators of the years. As a result, total expenditures in constant dollars for industrial R&D were 11 percent lower in 1974 than in 1968-69, the years of highest funding, and approximately equivalent to the funding level of 1965.

Some perspective on the size of the investment in industrial R&D can be obtained by comparing it to other major investments by industry, such as those for new plant and equipment and for advertising. Such comparison is not intended to imply that identical factors determine levels of investment among the three areas. Indeed, the mix of investments in these areas varies from industry to industry.

Trends in expenditures for the three purposes are shown in figure 4-2 for manufacturing industries which, as discussed later in this chapter, account for almost all industrial R&D expenditures. Total funds for industrial R&D were close in size to those for new plant and equipment during the early 1960's, but the latter grew more rapidly in subsequent years and by 1973 had exceeded total R&D expenditures in industry by approximately one-third. Expenditures for R&D from industry's own funds and for advertising[4] were closely comparable throughout the 1960-73 period.

Figure 4-2
Expenditures for industrial R&D, advertising, and new plant and equipment by manufacturing industries, 1960-73



[1] Includes funds from all sources.
SOURCE: National Science Foundation and Department of Commerce.

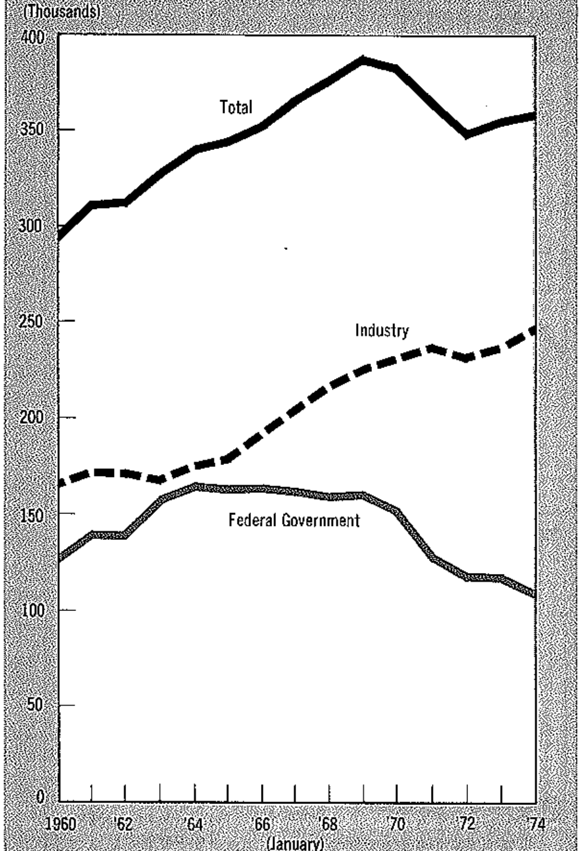
Sources of funds for industrial R&D

As a consequence of increasing funds from industry and a leveling off of Government funds, industry replaced the Federal Government after 1967 as the major source of funds for industrial R&D (figure 4-3). By 1974, industry supplied 62 percent of all such funds, compared with only 42 percent in 1960. Federal funds for industrial R&D—principally from the Department of Defense (DOD) and the National Aeronautics and Space Administration (NASA)—reached a plateau in the late 1960's, dropped some 10 percent in the early 1970's as NASA and DOD support declined, and recovered in later years as DOD funding rose. These changes were reflected most prominently in the aircraft and missiles industry, and to a lesser extent in the electrical equipment and communication industry.

The extent of Federal support for industrial R&D differs substantially from one industry to

[4] Includes expenditures by manufacturing corporations for newspaper, radio, television, magazine, and other miscellaneous local and national forms of advertising.

Figure 4-4
Scientists and engineers[1] engaged in industrial R&D, by source of funds, 1960-74



[1] Full-time equivalent basis.
SOURCE: National Science Foundation.

Trends in the total number of R&D scientists and engineers in industry paralleled constant dollar expenditures for industrial R&D throughout most of the 1960-74 period (see figures 4-1 and 4-3). Such a correlation might be expected since the cost to industry for these personnel—a cost which represents a large fraction of the total cost of industrial R&D—has increased at approximately the same rate as inflation. Thus, the similarity of the two trends provides support for the use of the GNP implicit price deflator as a gross adjustment of current dollar expenditures to reflect more accurately the real level of financial input and the magnitude of effort.[6]

[6] A more complete discussion of the use of deflators for R&D expenditures appears in the chapter entitled "Resources for R&D" in this report.

R&D expenditures by specific industries

The extent to which a specific industry invests in R&D is dependent upon a diversity of factors, including competition within the industry and from other industries, government regulations requiring improved performance of products, the need of substitutes for and the conservation of natural resources, and the availability of funds and personnel for R&D. Nearly all manufacturing industries engage in some type of R&D activity. A few nonmanufacturing industries[7] also perform R&D, but their effort represents less than 5 percent of all industrial R&D spending.[8]

Expenditures for R&D in current dollars rose steadily in most industries from 1960 to 1973. In recent years, R&D spending has grown at a rate comparable to the early and mid-1960's, averaging over 7 percent per year between 1971 and 1973. The industries principally responsible for this growth are electrical equipment and communications, motor vehicles and other transportation equipment, machinery,[9] and chemicals and allied products. These four industries accounted for approximately 80 percent of the total increase in current dollar expenditures for R&D between 1971 and 1973.

Trends in expenditures for R&D in these and other major R&D-performing industries are shown in figure 4-5. In five of the seven specific industries, 1973 was the peak funding year for R&D in both current and constant dollars. The only major industry experiencing a large decline in R&D spending in either current or constant dollars during the 1960-73 period was aircraft and missiles, which dropped sharply after the late 1960's. Other industries, not shown in the figure, in which R&D expenditures in current and constant dollars were at their highest level in 1973 are: drugs and medicine, rubber products, fabricated metal products, communication equipment and electronic components, and optical, surgical and photographic instruments.

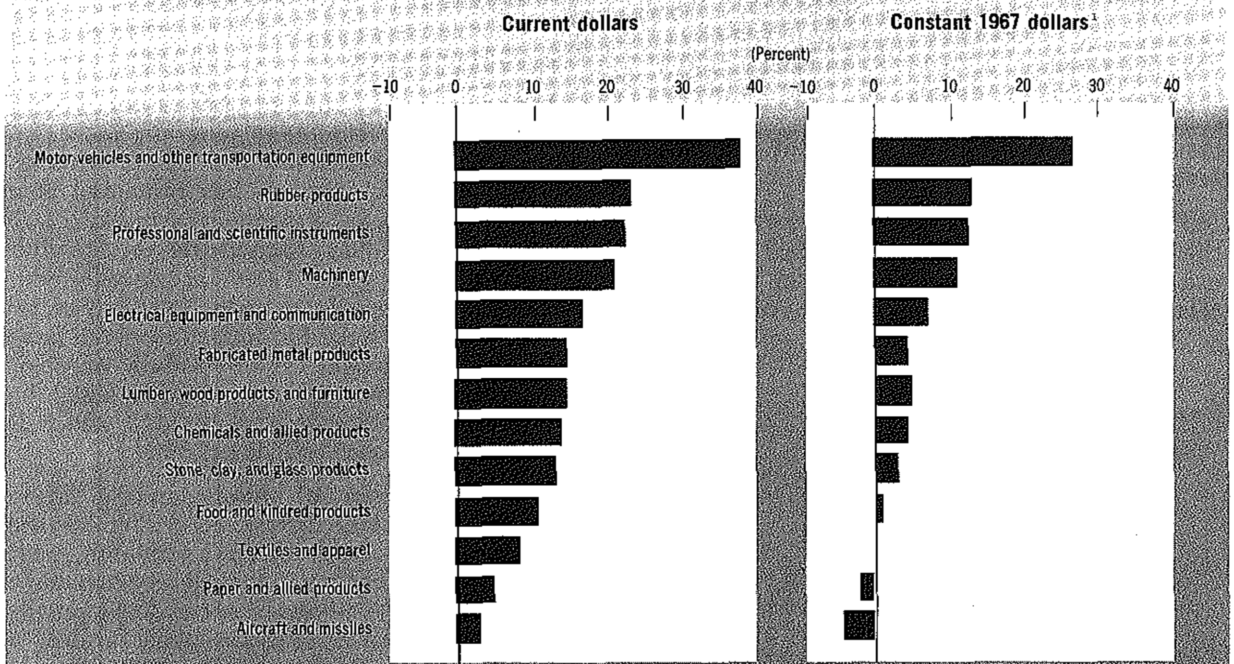
[7] These include, but are not limited to, agriculture, public utilities, finance, insurance, business services, medical and dental laboratories, and engineering and architectural services.

[8] *Research and Development in Industry, 1973*, National Science Foundation (NSF 75-315).

[9] Includes office, computing, and accounting machines; metal-working machinery; engines and turbines; farm machinery; construction, mining, and materials handling machinery.

Figure 4-6

Industrial R&D expenditures, percent change, 1971-73



[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

and improvement of the quality of the environment.[11] [12]

Energy is one of the civilian areas in which R&D expenditures have grown and are expected to increase still further in the years ahead. The exploration and development of new and alternative sources of energy for their own needs and the needs of the Nation as a whole have become important for many industries. As a result, expenditures by industry for energy-related R&D have risen almost 50 percent since 1972, reaching an estimated $1.1 billion in 1974.[13]

The petroleum industry is the leading performer of energy R&D, with expenditures of $325 million in 1973 and an estimated increase of 25 percent in 1974. The electrical equipment and communication industry is the second largest performer; these two industries combined accounted for over 65 percent of all energy-related R&D activities in industry in 1973. Advances in technology in the use of fossil fuels (particularly oil and coal) and nuclear energy are the principal objectives of the industrial R&D effort in this area.

[11] A similar shift of federally funded R&D toward civilian areas is discussed in more detail in "Resources for R&D" in this report.

[12] Historically, the Federal Government's role in industrial R&D dates from World War II, during which the principal emphasis was on defense-related R&D. Prior to that time, Federal support for industrial R&D was miniscule. (See Helen Wood, *Scientific Research and Development in American Industry*, Bureau of Labor Statistics, 1953; and Vannevar Bush, *Science—The Endless Frontier*, a report to the President, 1945.)

[13] "20-Percent Increase in Energy Activity Paces Industrial R&D Spending in 1973", *Science Resources Studies Highlights*, National Science Foundation (NSF 74-319), December 4, 1974.

the total applied R&D expenditures each received in 1973, are shown in the table below.[17]

Distribution of applied R&D expenditures, by selected product field, 1973

Product field	Percent
Communication equipment and electronic components	17
Aircraft and parts	12
Guided missiles and spacecraft	12
Machinery	11
Motor vehicles and other transportation equipment	10
Chemicals[18]	7

Substantial changes in applied R&D expenditures have occurred in more specific product fields in recent years. Fields with an overall increase or decrease in constant dollar expenditures of 10 percent or more during the 1971-73 period are cited below.

Concentration of industrial R&D

The U.S. industrial R&D effort is concentrated within relatively few industries, and within a small number of large companies within these industries. Throughout the 1960's and early 1970's, over 80 percent of all industrial R&D expenditures and over 77 percent of industrial scientific personnel engaged in R&D were concentrated in only five industries—aircraft and missiles, electrical equipment and communications, chemicals and allied products, machinery, and motor vehicles and other transportation equipment (figure 4-8). The largest change over the period occurred in the aircraft and missiles industry, where R&D expenditures declined significantly in relative terms after the mid-1960's.

Similar trends are evident in the concentration of R&D scientists and engineers in these same five industries. The aircraft and missiles industry is seen to account for a declining proportion of the total industrial R&D personnel resources beginning in 1963. This industry, however, in combination with the electrical equipment and communications industry employed over 46 percent of all scientists and engineers engaged in industrial R&D in 1973 (figure 4-9).

To a significant degree, the concentration of industrial R&D in a few industries reflects the influence of Federal R&D contract work, primarily in the defense and space areas. In 1973, for example, almost 92 percent of all federally funded R&D in industry went to these five industries. Federal funds to these industries ranged from about 10 percent of the total R&D expenditures in the chemicals and allied products industry, to some 50 percent in electrical equipment and communications, and to over 80 percent in the aircraft and missiles industry. Together, Federal funding for R&D in these five industries represented over 35 percent of the total expenditures for industrial R&D in 1973.

A similar pattern is observed in regard to the concentration of scientific personnel. The five industries cited above employed 90 percent of all

Percent change in constant dollar applied R&D expenditures, by product field, 1971-73

Increases of more than 25 percent		Increases of 10-25 percent		Decreases of 10 percent or more	
Ferrous metals & products	87	Electrical industrial apparatus	24	Guided missiles	-20
Transportation equipment, except motor vehicles	59	Farm machinery & equipment	19	Metalworking machinery and equipment	-20
Textile mill products	36	Office, computing, and accounting machines	19	Nonferrous metals & products	-19
Motor vehicles & equipment	35	Ordnance, except guided missiles	11	Agricultural chemicals	-19
Professional & scientific instruments	32	Stone, clay, & glass products	10	Plastics materials & synthetic resins	-10
Engines & turbines	30	Communication equipment & electronic components	10		
Rubber & plastics products	26				

[17] For additional data on these and other product fields, see *Research and Development in Industry, 1973,* National Science Foundation (NSF 75-315).

[18] Except drugs and medicine.

turing sector alone, the number of individual companies with a formal R&D program is comparatively small. For example, in 1967 (the latest year for which Census data on the total number of manufacturing companies is available) only 11,200 companies, or less than 5 percent of all manufacturing companies, reported having any R&D program. Furthermore, the proportion of companies conducting R&D differed substantially by company-size groups. In 1967, only 4 percent of all manufacturing companies with under 1,000 employees conducted any R&D, while 55 percent of companies employing between 1,000 and 5,000 persons, and 88 percent of companies with 5,000 or more employees reported such efforts.

Among the performers of R&D is a subset of the small company group which consists of "high technology" firms whose main objective is the performance of R&D and the development of new products. These new research-based enterprises represent only a small percentage of the total industrial R&D effort, but they have often evolved into large firms that dominate market segments and, in some cases, entire industries. These science-based firms are predominantly located in industries such as electronics, communications, computers, aircraft, and nuclear and medical instruments.[20]

R&D intensity

The proportion of an industry's human and financial resources which are utilized for R&D may be regarded as a measure of the "R&D intensity" of that industry. The indices used frequently for quantifying the level of R&D intensity are (1) total and company funds expended for R&D as a percentage of net sales and (2) the number of R&D scientists and engineers per 1,000 employees. Based on these indices, each of the 15 largest R&D-performing industries in the manufacturing sector was

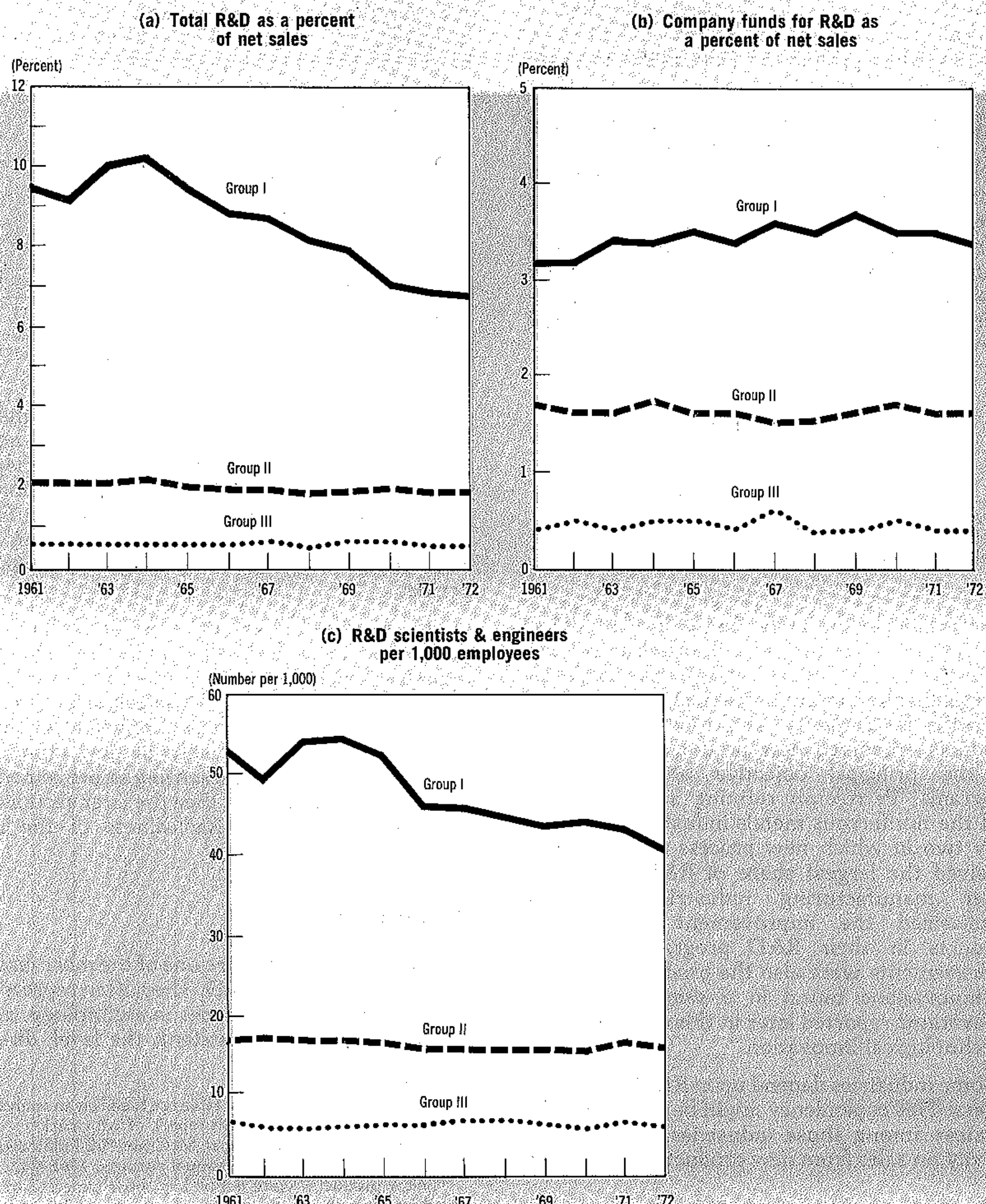
Measures of R&D intensity, by industry, 1961-72

Industry	Mean over the 1961-72 period: R&D scientists & engineers per 1,000 employees	Total funds for R&D as a percent of net sales[21]	Company funds for R&D as a percent of net sales[21]
Group I			
Chemicals & allied products	37.8	4.0	3.5
Machinery	25.9	3.9	3.1
Electrical equipment & communications	47.2	8.5	3.6
Aircraft & missiles	88.6	20.9	3.5
Professional & scientific instruments	33.9	5.9	4.1
Mean for group I	47.1	8.2	3.5
Group II			
Petroleum refining & extraction	15.8	0.9	0.9
Rubber products	17.8	2.0	1.7
Stone, clay & glass products	10.7	1.6	1.5
Fabricated metal products	12.8	1.3	1.2
Motor vehicles & other transportation equipment	19.4	3.3	2.5
Mean for group II	16.4	1.9	1.6
Group III			
Food & kindred products	7.2	0.4	0.4
Textiles & apparel	3.1	0.5	0.5
Lumber, wood products & furniture	4.7	0.5	0.4
Paper & allied products	8.5	0.9	0.8
Primary metals	5.6	0.8	0.8
Mean for group III	6.0	0.6	0.6

[20] For further information on R&D in small companies, see Thomas Hogan and John Chirichiello, "The Role of Research and Development in Small Firms", in *The Vital Majority: Small Business in the American Economy*, Small Business Administration, 1974.

[21] Total net sales by Group I industries over the entire 1961-72 period were only 25 percent larger than sales by industries in Group II and approximately 50 percent larger than those of Group III industries.

Figure 4-10
R&D intensity of U.S. manufacturing industries, 1961-72



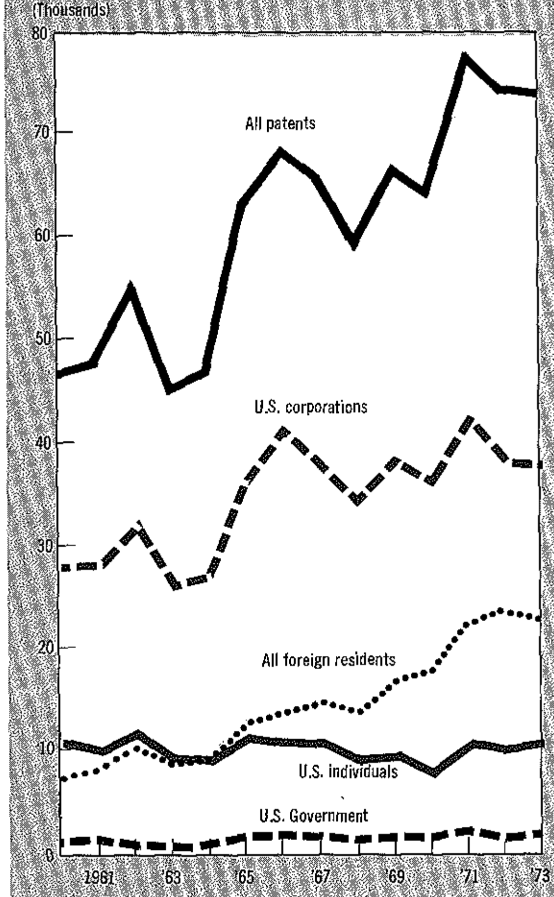
SOURCE: National Science Foundation.

tion, and success of inventive and innovative activity of a technological nature.[25] In some cases, the number of patents may understate the actual level of invention. For various reasons, an invention may never be patented; as for example, when the protection afforded by a patent is less important than the rapid introduction of a new product into the marketplace or where the expected protection does not offset the hazard of disclosure. Patent output may, on the other hand, overstate the level of invention to some extent. This situation may arise, for example, when numerous defensive patents are obtained around basic inventions. Finally, of course, patents vary greatly in their economic and technological significance. Many patented inventions become embodied in new and improved products, processes, and services—only some of which eventually lead to substantial economic returns.

The majority of patented inventions now come from R&D programs in large industrial laboratories. Many of the others, including some of the more significant ones, come from "independent" inventors.[26] As indicated in the "Basic Research" chapter of this report, major patented inventions from all sources appear to be based increasingly upon R&D.

The number of U.S. patents granted increased between 1960 and 1973, though fluctuating from year to year[27] (figure 4-11). Two principal sources of patents were responsible for the overall increase—U.S. corporations and residents of foreign countries. The patent output of U.S. individuals and the Federal Government remained at relatively low and constant levels during the period. The number of U.S. patents granted to residents of foreign countries showed the greatest overall gain, with the largest increases occurring after 1968. In 1973, foreign residents were granted over 30 percent of all U.S. patents, as compared with 16 percent in 1960. (The significance of foreign patent activity in the U.S. is discussed in the chapter entitled "International Indicators of Science and Technology" in this report).

Figure 4-11
U.S. patents granted for inventions, 1960-73



SOURCE: U.S. Patent Office.

The patent output of U.S. industry (i.e., patents assigned to U.S. corporations) accounted for the largest proportion of total patents granted throughout the 1960-73 period.[28] The

[25] A major study on this topic was published in 1966 by Jacob Schmookler, *Invention and Economic Growth* (Cambridge: Harvard University Press). A recent reappraisal of this work by Nathan Rosenberg is presented in "Science, Invention and Economic Growth", *Economic Journal*, Vol. 84 (March 1974), pp 90-108.

[26] For more detailed information on this topic, see David Hamberg, "Invention in the Industrial Research Laboratory", *Journal of Political Economy*, Vol. 71 (April 1963). See also, "Concentration, Invention, and Innovation", U.S. Senate Antitrust Subcommittee, 89th Congress, Part III; and *Technological Innovation: Its Environment and Management*, Department of Commerce, 1967.

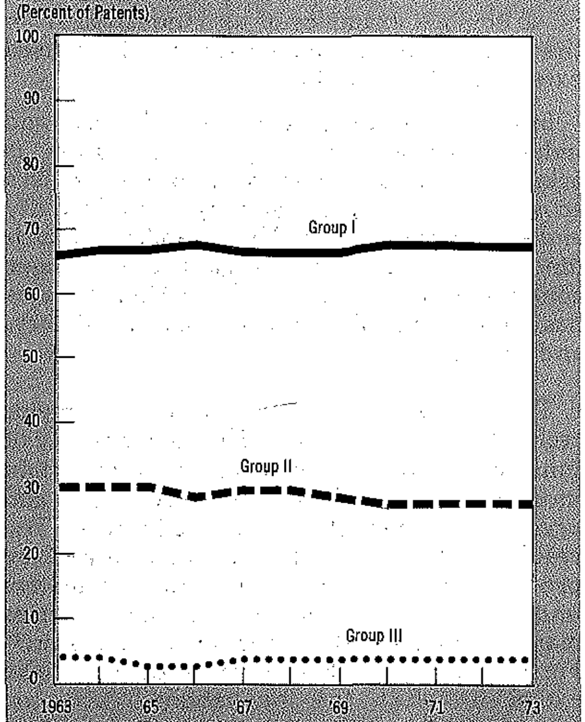
[27] The year to year fluctuations are associated primarily with the processing and examination of patent applications by the U.S. Patent Office, rather than variations in the number of patent applications *per se*.

[28] A recent report, *A Review of Patent Ownership*, Office of Technology Assessment and Forecast, U.S. Patent Office, January 1975, identified specific companies involved in active technological areas.

Patent output by product field and R&D intensity. Patents can also serve as an indicator of the inventive output of specific industries. An approximate correspondence exists between product fields of patent activity and the industries which produce the patented invention. The correspondence is less than perfect, since many companies in a specific industry may be active in a number of diverse product areas. An invention produced by the electrical equipment industry, for example, may have its principal application in the aircraft product field.[32]

The relationship between patent output and R&D intensity is shown in figure 4-13.[33] Those industries which devote the largest proportion of their resources to R&D (Group I industries) are by far the largest producers of patented inventions, accounting for 67 percent of all U.S. patents granted between 1963 and 1973. Group II industries—lower in R&D intensity than Group I—produced about 29 percent of the patents over the period, while the least R&D-intensive industries (Group III) produced only 4 percent.[34] During the same period (1963-73), Group I industries were responsible for 80 percent of the total expenditures for industrial R&D; Group II industries, 16 percent; and Group III industries, 4 percent.

Figure 4-13
U.S. patents granted for inventions in major product fields by groups of R&D-intensive industries, 1963-73



SOURCE: Office of Technology Assessment and Forecast, U.S. Patent Office.

Technological innovation

Technological innovation occurs when new or improved products, processes, or services embodying advances in technology are introduced into the market. Although R&D has a major role in the process, innovation takes place in a broad context in which economic, social, and political factors may be crucial.[35] It has been estimated, for example, that of every ten products emerging from R&D, five fail in product and market tests, and only two become commercial successes.[36]

Technological innovation is integral to the operation of many industries and crucial to their survival and growth. Innovation in these industries may be the principal means for acquiring new markets and maintaining existing ones, as well as for improving internal production processes and reducing costs.[37] Other industries, while producing few major innovations themselves, purchase goods which embody innovations from the first group of

[32] The lack of correspondence, however, was reduced by grouping industries according to their R&D intensity; these groups produced patented inventions which tended to be utilized by industries within the same group.

[33] For a concise review of the relationship between R&D and patents, see Dennis Mueller, "Patents, Research and Development and the Measurement of Inventive Activity," *Journal of Industrial Economics*, Vol. 15 (November 1966).

[34] The patent totals upon which these percentages are based include some multiple counts, but only those which occur across the three groups. The extent of this multiple counting is approximately 8 percent of the total patents granted.

[35] P. Kelly, et al., *Technological Innovation: A Critical Review of Current Knowledge*, (Atlanta: Georgia Institute of Technology, 1975).

[36] E. A. Pessemier, *New Product Decision: An Analytical Approach*, (New York: McGraw-Hill, 1966).

[37] For a review of factors which determine a firm's effectiveness in innovation, see James M. Utterback, "Innovation in Industry and the Diffusion of Technology," *Science*, Vol. 183 (February 15, 1974), pp. 620-626.

Figure 4-14
Distribution of major U.S. innovations, by size of company, 1953-73

SOURCE: Gellman Research Associates, Inc.

definition, the small firm—rather than the large one—was the site of the greatest number of major innovations during the 1953-59 and 1960-66 periods, but not in the 1967-73 period.

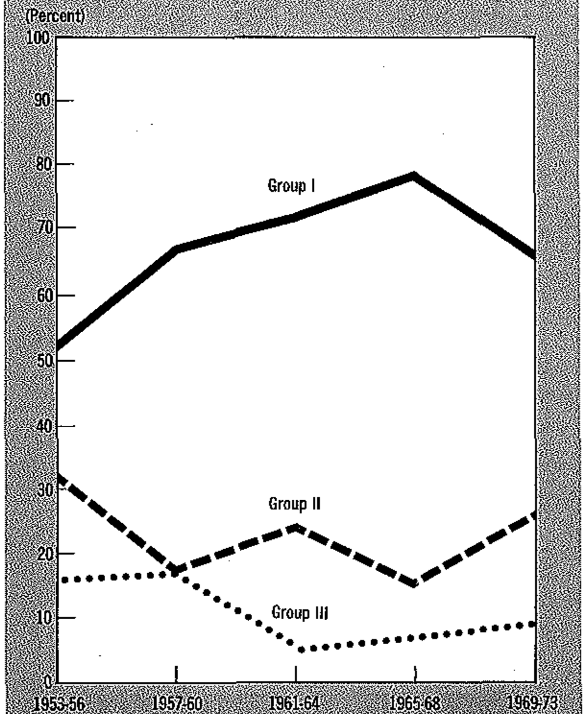
The matter of firm size and innovation can be viewed also with respect to the sales volume associated with companies of different size. When this aspect is considered, the smallest companies are found to produce proportionally more innovations per unit sales than larger companies (figure 4-15). Small firms, furthermore, have maintained a relatively higher level of innovative output per unit sales than larger companies in each of the time periods for which sales data are available.[45] (The decline in the number of innovations per unit sales, observed in each company size category, results from a combination of increasing company sales and a relatively constant number of innovations.)

These indicators shed some additional light on the question of the relationship between firm size and technological innovation. The indicators, however, are dependent on the particular set of innovations selected for study. Furthermore, all industries are treated as if they were alike, even though differences among them with respect to innovativeness may exceed the differences between small and large firms. Finally, the indicators offer no insights regarding the attributes, causal factors, and dynamics which determine the relative innovativeness of various size companies. For these and other reasons, interpretations of indicators presented here should be limited and tentative.

[45] Data on sales and receipts of manufacturing industries, in terms of company size, are available only for the years 1958, 1963 and 1967 and are taken from *Enterprise Statistics*, Department of Commerce, Bureau of the Census, 1968 and 1972.

Figure 4-16

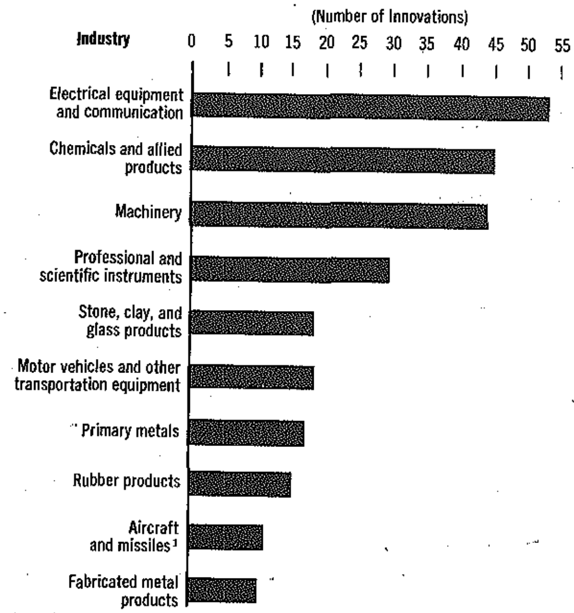
Percent distribution of major U.S. innovations, by groups of R&D intensive industries, 1953-73



SOURCE: Gellman Research Associates, Inc.

Figure 4-17

Major U.S. innovations in selected industries, 1953-73



[1] Innovations in the defense and space areas are not included unless they were introduced into the commercial market.
SOURCE: Gellman Research Associates, Inc.

1953-59

Medicinal chemicals & pharmaceutical products
Industrial organic chemicals
Electronic components and accessories
Electronic calculating and computing machinery
Metalworking machinery and equipment
Machinery for specific industries
Photographic equipment and supplies

1960-66

Electronic components and accessories
Communications equipment
Electronic calculating and computing machinery
Synthetic materials
Plastic films, sheets, and cellulose products
Medical instruments and supplies
Abrasives, asbestos & nonmetallic mineral products

1967-73

Electronic components and accessories
Photographic equipment and supplies
Motor vehicles and other transportation equipment
Machinery for specific industries
Abrasives, asbestos & nonmetallic mineral products
Communications equipment
Synthetic materials

The prominent role of electronics is evident in each of the three periods, particularly during the early 1960's. The relatively large number of innovations in this area is due, in part, to significant advances in scientific knowledge in fields closely related to electronics.[47] In-

[47] Richard R. Nelson, et al., *Technology, Economic Growth, and Public Policy*, (Washington, D.C.: The Brookings Institution, 1967).

In a study of a selected number of major innovations,[49] the interval between invention and innovation appeared to decrease over time, as suggested by the following gross historical trends.[50]

Average time between invention and innovation

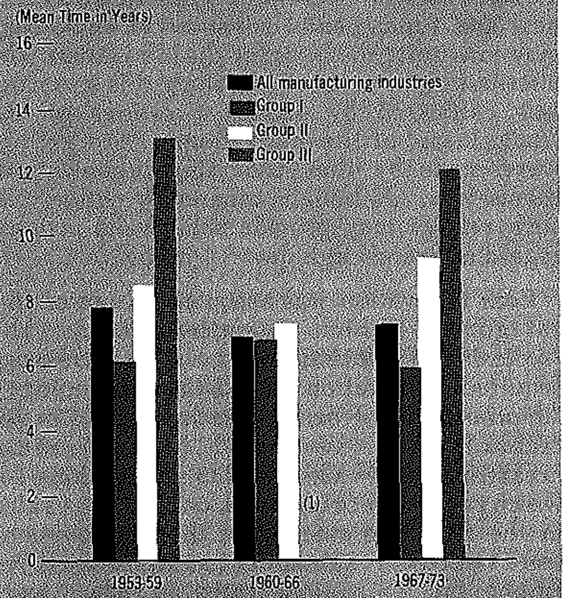
Time period	Years
Early 20th century (1885-1919)	37
Post-World War I (1920-1944)	24
Post-World War II (1945-1964)	14

It is generally advantageous for an industrial firm to minimize the time between invention (i.e., the first conception of an innovation) and its introduction into the market. Competing firms may introduce similar products earlier, giving them a favored position in the market; the cost of capital may increase; or a loss in sales and profits may be experienced due to a lag in the introduction of innovations into the market. These and other considerations usually encourage rapid innovation in order to reduce risk and increase profitability.

Trends in the time between invention and innovation were calculated from a set of 277 innovations[51] associated with the three groups of manufacturing industries which varied in respect to R&D intensity. The invention-innovation intervals, which ranged from less than one year to 82 years, were determined for each industry group and for all manufacturing industries combined. The results are shown in figure 4-19 in terms of the mean number of years between invention and innovation for three time periods between 1953 and 1973.

These data suggest that the invention-innovation interval was shorter in recent years (7.2 years during the 1967-73 period) than in the 1950's (7.8 years), but generally somewhat longer than in the early 1960's (6.9 years).[52] [53] Furthermore, the time between invention and innovation appears to correlate with R&D intensity. Industries with the largest fraction of financial and human resources for R&D tend to translate inventions into innovations more quickly than industries which are less R&D-intensive. In each of the three periods, the mean invention-innovation interval for industries of Group I was shorter than the interval for Group II which, in turn, was shorter than that for Group III industries.

Figure 4-19
Mean time in years between invention and innovation, by groups of R&D-intensive industries, 1953-73



[1] Insufficient number of innovations for determining mean of Group III industries.

SOURCE: Gellman Research Associates, Inc.

[49] Frank Lynn, "An Investigation of the Rate of Development and Diffusion of Technology in Our Modern Industrial Society", *Report of the National Commission on Technology, Automation, and Economic Progress*, 1966.

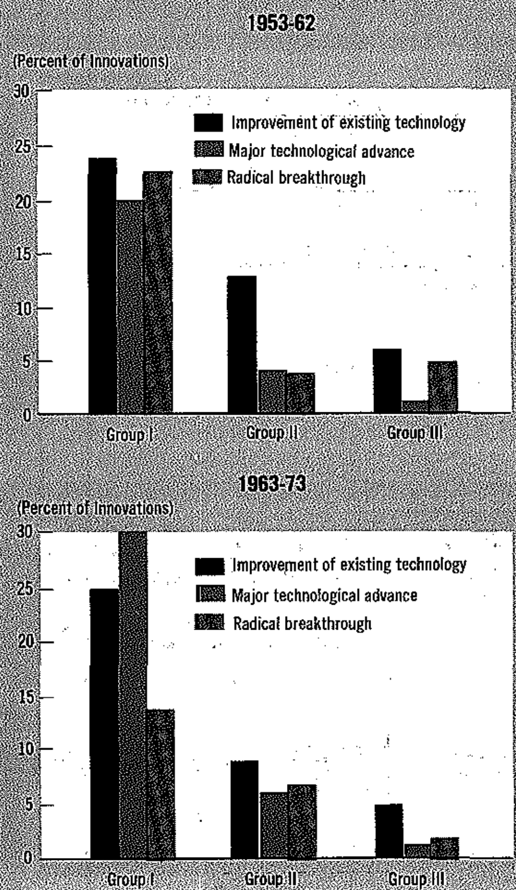
[50] For other studies of the invention-innovation interval, see Edwin Mansfield, *The Economics of Technological Change*, (New York: W. W. Norton, 1968), and *Interactions of Science and Technology in the Innovative Process: Some Case Studies*, Battelle Columbus Laboratories for the National Science Foundation, March 1973.

[51] The 277 U.S. innovations are among those identified in *Indicators of International Trends in Technological Innovation*, Gellman Research Associates, 1975.

[52] It has been suggested that the actions of Federal regulatory agencies may be responsible, in part, for the lengthening of the invention-innovation interval in recent years.

[53] These data differ from those presented for the U.S. in the chapter, "International Indicators of Science and Technology"; the invention-innovation intervals in that chapter are based upon all industries rather than the smaller set of selected manufacturing industries encompassed in this section.

Figure 4-21
"Radicalness" of major U.S. innovations, by groups of R&D-intensive industries, 1953-62 and 1963-73



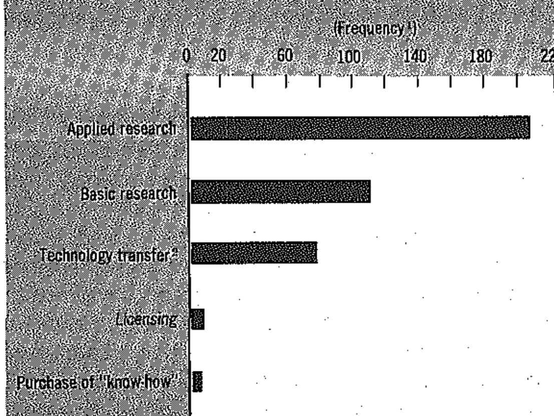
SOURCE: Gellman Research Associates, Inc.

obtained through a variety of means. These include basic research, applied research, licensing, merger or acquisition of other concerns, and the transfer of technology from another product line. Various combinations of these means may be involved in the case of a single innovation. For example, the underlying technology for the light-emitting diode was acquired through a combination of internally generated basic and applied research, coupled with the transfer of technology from one of the firm's existing product lines.

The modes by which the technology was acquired for the innovations in this study are shown in figure 4-22. These data, supplied by the innovating firms, represent the number of innovations in which the various acquisition modes were involved. Each mode is counted separately, even if the underlying technology involved a combination of sources; and each mode, and all instances of its occurrence, are treated as equally important in the innovation process. It should be noted also that the information collected regarding the underlying technology applies only to the period between conception and realization of the innovation and does not include prior research activities. These several limitations require that the indicators be regarded as gross measures only.

The dependence of innovation on research[55]—applied and basic—is evident from figure 4-22; applied research was involved in almost 75 percent of the innovations, and basic research in almost 40 percent. Aside from research, the only other acquisition mode of significance was the transfer of technology from existing product lines. Actually, research is involved even more extensively in innovation than the figure

Figure 4-22
Sources of technology underlying major U.S. innovations, 1953-73



¹ Multiple responses were accepted.
² From within the innovating company.
SOURCE: Gellman Research Associates, Inc.

[55] See the chapter in this report entitled "Basic Research" for additional information on the relationship between research and innovation.

Scientific field	Industries and products	Illustrative innovations
Polymer chemistry	Chemicals and allied products Plastic materials and synthetic resins Industrial organic chemicals Rubber and miscellaneous plastics products	acrylic adhesives double-knit synthetics polyoryl ether phenolic adhesives epoxy cement
Atomic electron and molecular physics	Electrical and electronic machinery and equipment Communication equipment and services Electronic components and accessories Electrical industrial apparatus Machinery Office, computing, and accounting machines Special industrial machinery Professional and scientific instruments	microwave transmission lasers weather satellites magnetic computer cores video tape
Metallurgy	Primary metals Fabricated metal products Machinery Transportation equipment	permanent magnetic alloys transparent stainless steel superconducting magnets Niobium Beryllium
Inorganic chemistry	Chemicals and allied products Industrial inorganic chemicals Stone, clay, glass, and concrete products Electrical and electronic machinery and equipment Electrical industrial apparatus	Borazon oil slick emulsifiers synthetic cryolite Pyroceram synthetic diamonds
Optics	Professional and scientific instruments Optical instruments and lenses Surgical, medical, and dental instruments Photographic equipment and supplies Electrical and electronic machinery and equipment Electronic components and accessories	optical scanners Polaroid camera holography via laser fiber optics
Organic chemistry	Chemicals and allied products Industrial organic chemicals Agricultural chemicals Drugs and medicines Food and kindred products	liquid chromatography textured granular protein benzene—phenol process phenyldimethylurea (herbicide)
Solid-state physics	Electrical and electronic machinery and equipment Electronic components and accessories Communication equipment and services Electrical industrial apparatus Machinery Office, computing, and accounting machines Professional and scientific instruments	light-emitting diodes minicomputers printed circuits integrated circuits silicon-controlled rectifiers
Acoustics	Machinery Special industrial machinery Office, computing, and accounting machines Electrical and electronic machinery and equipment Electronic components Communication equipment and services Professional and scientific instruments	long range sonar Xerox Telecopier II sonic pile drivers ultrasonic sealers acoustic couplers (telephone-computer)
Biology and bioengineering	Professional and scientific instruments Surgical, medical, and dental instruments Electrical and electronic machinery and equipment	kidney transplants heart pacemakers muscle-activated prosthetics surgery by laser
Pharmacology	Drugs and medicines	Ketalar (anesthetic) L-Dopa (Parkinson's disease) Terramycin cortisone synthesis

machinery requiring less maintenance or longer-lasting automobile tires) may not be represented adequately in common economic indices. In fact, innovations of this kind may contribute less to economic growth as commonly measured than was contributed by the unimproved products. Finally, in present economic accounting, goods and services provided to the public sector through nonmarket channels are valued at cost, rather than at market prices. Thus, benefits from R&D and innovation in areas such as public education and national defense may be underestimated by a considerable margin in conventional economic indices.

While the benefits from innovation are only partially accounted for by economic indicators, little if any of the associated societal costs are reflected. These costs in human and social terms, as discussed earlier in this chapter, may be substantial, especially when the full range of adverse effects such as loss of jobs and potential health hazards are considered.

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Science and Engineering Personnel

for all science and engineering fields by 14 percent between 1968 and 1974.

- Annual awards of bachelor's and first-professional degrees in the sciences and engineering doubled between 1963 and 1972; as a fraction of first degrees awarded in all fields, however, those in science and engineering remained essentially constant at nearly 30 percent during the period, due in large part to a rapid growth in the number of social science degrees awarded. Awards of master's level degrees in science and engineering followed a similar trend, but declined in recent years to 21 percent of all master's degrees awarded.

- Annual awards of doctoral degrees in science and engineering began to level off in 1971, decreasing for the first time in a decade to a level in 1974 of approximately 18,000; the largest declines occurred in the number of physical science doctorates awarded; science and engineering doctorates as a fraction of all doctorates declined from 64 percent in 1965 to 56 percent in 1974.

- The proportion of science and engineering graduate students receiving Federal support declined from 42 percent in 1967 to 25 percent in 1974; this decrease was compensated primarily by increases in self-support (up 13 percent) and institutional support (up 6 percent).

- Women comprised 5 percent of the persons employed in science and engineering occupations in 1974, and were primarily involved in psychology, social sciences, and mathematics; in the academic sector, women represented 15 percent of all scientists and engineers employed full-time in 1974.

- The predominant proportion of all scientists and engineers in 1972 were Caucasian (96 percent), while 2 percent were Asian, and 1 percent each were Black or were of other nonwhite background; the smallest proportional representation of minorities is in engineering (3 percent) and the largest is in mathematics (8 percent).

The country's scientists and engineers are an important national asset. They provide instruction and training in the various fields of science and engineering, conduct basic research to advance the understanding of nature, and perform applied research and development in a diversity of areas such as health, defense, energy, and industrial technology. In addition, persons trained in the sciences and engineering are employed throughout the economy—from industrial management to agricultural production—to provide the knowledge and skills which are essential in a technologically advanced society. The role of scientists and engineers in helping to meet the changing needs of the Nation, coupled with the extended time and high cost involved in their training, requires that continuous attention be given to trends and patterns in the production and utilization of such personnel.

This chapter presents information on the magnitude and characteristics of the Nation's population of scientists and engineers. It considers trends in the supply and utilization of these personnel and examines developments which may affect their future supply.

Scientists and engineers, in this chapter, are defined as persons actually engaged in scientific or engineering work at a level which requires knowledge of the physical, life, social, mathematical, or engineering sciences equivalent at least to that acquired through completion of a four-year college program with a major in one of these fields, regardless of whether a college degree is actually obtained in the field. In regard to data presented on employment, enrollments, and degrees awarded, the health professions are not included under "science and engineering", unless otherwise indicated.

Throughout the chapter, information is limited to certain quantitative aspects of scientists and engineers. These measures, it is recognized, provide only a partial indication of the characteristics of such personnel. Lacking are measures of the quality of their work, extent of "underutilization", and the increasingly important concerns of productivity and output. Furthermore, little is known about motivational factors that affect the supply and utilization of scientists and engineers, such as considerations which lead students to enter science and

Distribution of the 1970 science and engineering labor force by field, 1974

Field	Percent
Engineers	64
Physical scientists	14
Life scientists	7
Computer scientists	5
Social scientists	4
Psychologists	3
Mathematical scientists	3

The following are some additional characteristics of the 1970 science and engineering labor force, surveyed in 1974:[3]

— Approximately 35 percent of the employed scientists and engineers are engaged in work supported with Federal funds.

— Industry and business are the employers of most scientists and engineers, 65 percent of the total in 1974.

— Scientists and engineers holding doctoral degrees account for some 15 percent of the scientific and engineering population, master's and professional degree holders almost 25 percent, and baccalaureates nearly 60 percent.

— Management or administration was the most common work activity in which scientists and engineers were engaged in 1974; this activity was reported by about 30 percent of the sample, with about one-third (10 percent of the total employed group) involved in the management or administration of R&D.

— Research and development was the primary work activity of almost 30 percent of the employed scientific and engineering population, with almost 10 percent involved in research (applied and basic).

Doctoral scientists and engineers

Those scientists and engineers holding doctoral degrees represent, as a group, the most highly trained men and women in their professions. The investment of resources in their education and training is significant in both monetary terms and in the amount of time involved. The characteristics and activities of this group warrant careful monitoring, since doctoral level scientists and engineers provide leadership for the entire scientific community.

It is estimated that in 1973 there were 245,000 doctoral scientists and engineers in the United States.[4] This number is over twice that reported in 1963, and represents about 14 percent of all scientists and engineers. Approximately 9 percent of the 245,000 doctoral scientists and engineers were women and 6 percent were foreign citizens. Scientists and engineers of oriental background made up 5 percent of the doctorate science and engineering population; Blacks, 1 percent; and other groups, 94 percent.[5]

The physical and life sciences were the two largest fields represented in the 1973 population of doctoral scientists and engineers, as shown below.[6]

Distribution of doctoral scientists and engineers, by field, 1973

Field	Percent
Life scientists	26
Physical scientists	26
Engineers	15
Social scientists	13
Psychologists	12
Mathematical scientists	6
Computer scientists	1

Among doctoral scientists, the proportion accounted for by physical scientists declined over the 1966-73 period while the life scientists' share increased. Other fields remained relatively constant over the period in terms of their relative proportions (figure 5-1).

Sectors of doctoral employment. The pattern of employment of doctoral scientists and engineers in 1973 is shown in figure 5-2. Doctoral scientists are predominantly employed by educational institutions (64 percent); within

[3] "National Sample of Scientists and Engineers: Changes in Employment 1970-72 and 1972-74", *Science Resources Studies Highlights*, National Science Foundation (NSF 75-309), May 19, 1975.

[4] *Doctoral Scientists and Engineers in the United States, 1973 Profile,* National Academy of Sciences, 1974.

[5] For further information on this topic, see the subsequent section in this chapter entitled "Women and Minorities in Science and Engineering."

[6] *Characteristics of Doctoral Scientists and Engineers in the United States, 1973*, National Science Foundation (NSF 75-312).

this group 61 percent are employed by four-year colleges and universities and 2 percent by two-year colleges. During the period 1966-70, there was a shift in the proportion of doctoral scientists employed by business and educational institutions, the former declining and the latter increasing. However, in view of enrollment trends and financial problems of institutions of higher education, this shift is not expected to continue.

Doctoral engineers as a separate group exhibit a different pattern of employment from scientists, with nearly half of them employed in the industrial sector.

Primary work activities of doctoral scientists and engineers. The activities in which doctoral scientists and engineers were primarily involved are indicated in figure 5-3. The data do not show the time allocated among the several activities of doctoral scientists and engineers, but rather the activity reported as occupying the largest portion of their time. Teaching and R&D represent the primary work activities of doctoral scientists, the majority of whom are employed in universities and colleges. A declining proportion of the doctoral scientists, however, were involved in R&D as a primary work activity during the period 1966-73. This decline of about 10 percent was accompanied by a relatively larger increase in the fraction reported as primarily teaching[7] (figure 5-4).

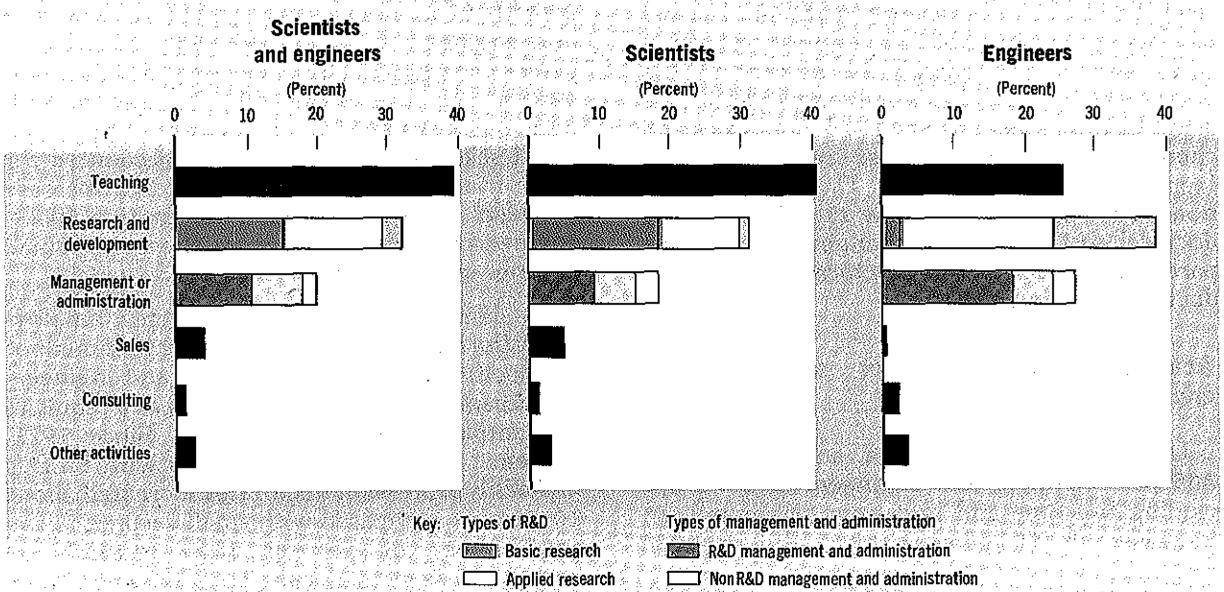
Of the 32 percent of the doctoral scientists primarily engaged in R&D, over one-half were working in basic research, over one-third were involved in applied research, and only a small percentage in development and design. The number of such scientists primarily engaged in management activities, however, was nearly the same as the total number primarily involved in basic research (30,851 versus 31,213).

The preceding discussion concerning the utilization of doctoral scientists and engineers provides, for the most part, a description of the characteristics of these doctorate holders in 1973. Over time, however, there has been movement from initial doctoral disciplines into other fields of science, while others have shifted

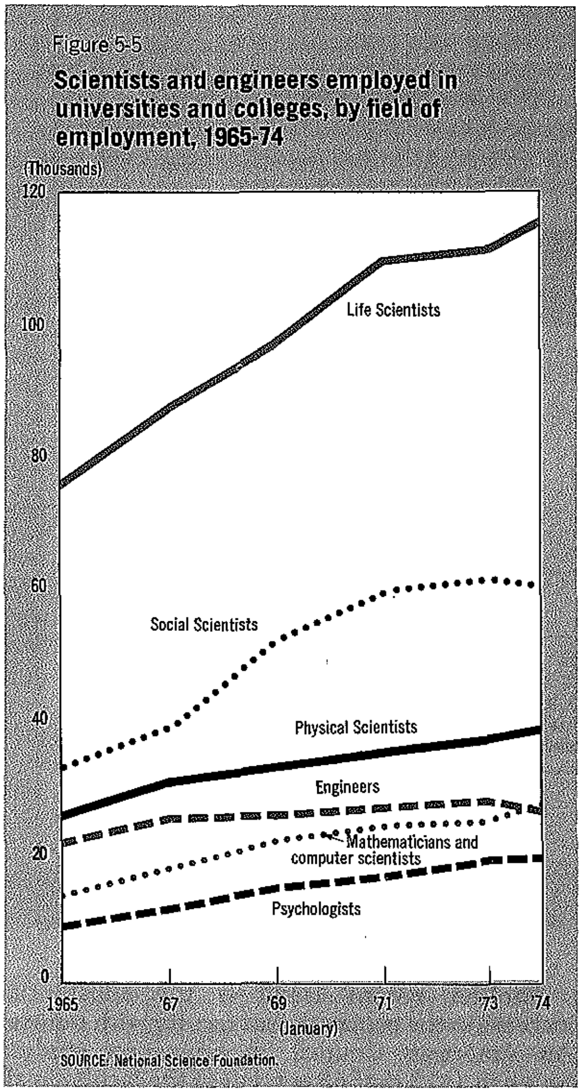
[7] This topic is discussed in more detail later in this chapter.

Figure 5-3

Percent distribution of employed doctoral scientists and engineers, by primary work activity, 1973



SOURCE: National Science Foundation.



percent, with the result that by 1974, 65 percent of all academic scientists and engineers had doctorate degrees, compared with 60 percent in 1965.

Primary work activities among academic scientists and engineers have shifted toward more teaching and less R&D (figure 5-7). In 1974, 17 percent of all science and engineering professionals working in institutions of higher education were primarily engaged in R&D, compared with 22 percent in 1965. A part of this shift is due to the rapid growth of two-year academic institutions where teaching is the primary activity of almost all the faculty. Other academic institutions, including the large research universities, also experienced the shift toward more teaching. During 1969-74, four-year institutions reported an average annual percentage rise of 4.7 percent in the number of scientists and engineers working primarily as teachers, compared with only a 0.4 percent average annual growth of those working primarily in R&D.[9]

This shift in utilization occurred at the same time as the reduction in the rate of growth in Federal support for academic R&D. From 1968 to 1974, annual increases in Federal R&D support to universities and colleges have not kept pace with increases in inflation; such support in constant dollars has declined about 8 percent in this six-year period. The financial status of R&D in this sector might have been worse except for substantial increases in separately budgeted R&D support by the institutions themselves, and by State and local governments. Funds from the latter increased some 6 percent annually in constant dollars between 1968 and 1974 for a total growth of nearly $70 million. Support from the institutions' own funds rose at an average annual rate of 2.5 percent over the period for a total of almost $35 million. Federal support over the same period, on the other hand, declined by more than $60 million in constant dollars.[10]

Selected characteristics of higher education faculty. Significant changes have occurred in recent years in the characteristics of the faculty of academic institutions, in terms of their median age, tenure status, and number of years since receipt of doctorate.

Between 1968 and 1974, the overall proportion of young[11] doctoral faculty in doctorate-level science and engineering departments decreased substantially, dropping from 42 percent to 28 percent of the total doctoral faculty.[12] For the fields shown in the table below, the total number of full-time faculty increased

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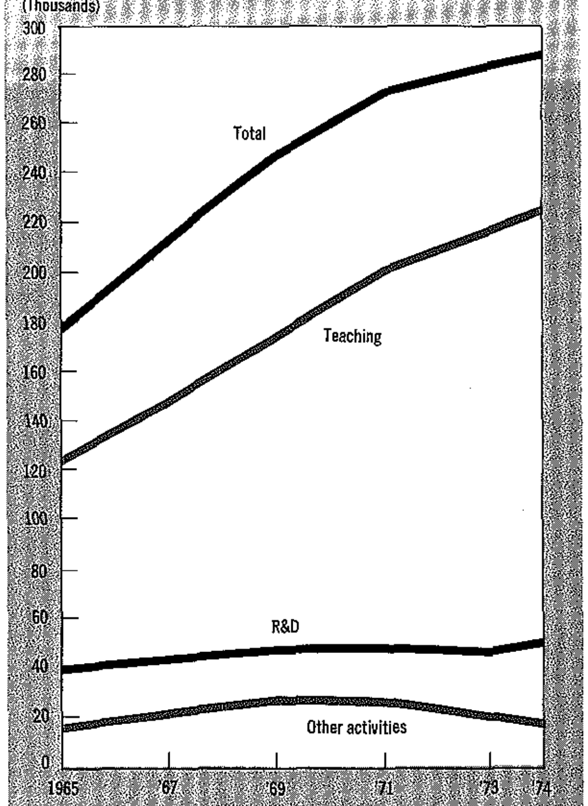
[9] *Manpower Resources for Scientific Activities at Universities and Colleges, January 1974*, Detailed Statistical Tables, National Science Foundation (NSF 75-300-A), and earlier volumes.

[10] "Separately Budgeted Academic R&D Expenditures Decline in Real Terms in FY 1974", *Science Resources Studies Highlights*, National Science Foundation (NSF 75-306), April 21, 1975.

[11] Those who had held doctorates for seven years or less at the time of each study.

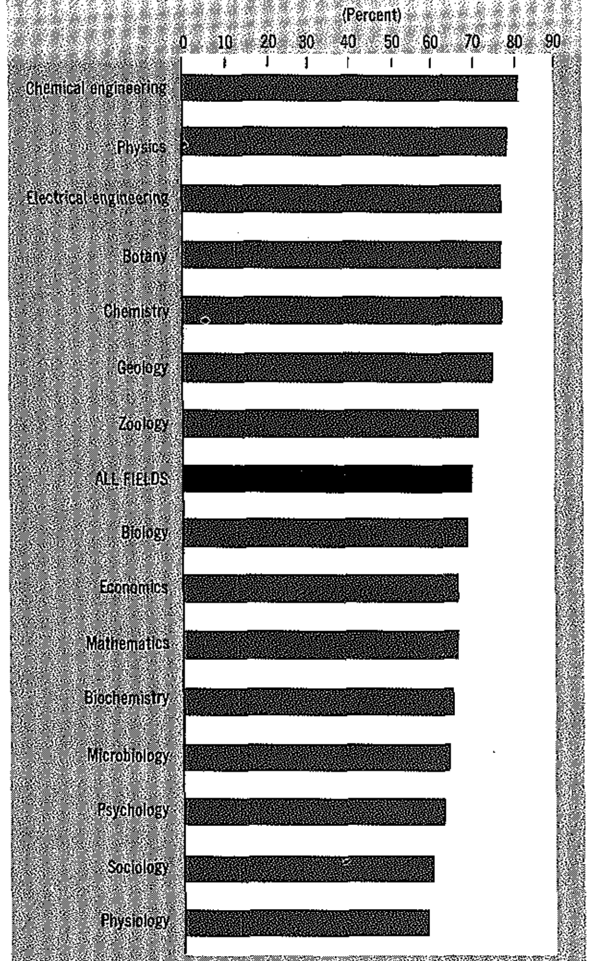
[12] *Young and Senior Science and Engineering Faculty, 1974: Support, Research Participation, and Tenure*, National Science Foundation (NSF 75-302).

Figure 5-7
Academic scientists and engineers, by primary work activity, 1965-74



SOURCE: National Science Foundation.

Figure 5-8
Tenured faculty as a percent of all faculty in doctorate-level science and engineering departments, by field, 1974



SOURCE: National Science Foundation.

median age of faculty for several science and engineering fields are presented in the table below.

Median ages of science and engineering faculty in doctorate-granting universities and colleges, 1969 and 1973[16]

Field	1969	1973
All science and engineering fields ...	41	44
Biological sciences	43	46
Chemistry	39	43
Earth sciences	40	43
Engineering	41	47
Mathematics	37	39
Physics	39	43
Psychology	39	43
Social sciences	39	43

[16] National Science Foundation and American Council on Education, special tabulations.

It should be noted that age distributions among academic science and engineering doctorate faculties do not differ greatly from those for doctoral scientists and engineers in other employment sectors (figure 5-9). While the older age pattern displayed by science and engineering faculty is related to the decreasing number of new faculty appointments, the relatively small proportion of employed doctorates under the age of 30 may be accounted for in part by the time required to attain a doctorate. In recent years, the median time-lapse between the postdoctoral appointments as part of the general academic science expansion. Between the late 1960's and the early 1970's, however, academic science funding from the Federal Government leveled off (in constant dollar terms), while the employment market for new doctorates, especially in academic institutions, declined markedly.

Although fewer academic R&D funds were available, there are at least two possible reasons for increases in the postdoctoral population between 1967 and 1974. Both new doctorates and the universities at which they worked may have used the postdoctoral appointments as a "holding pattern" until new Ph.D.'s could find desirable positions. This reason was given by over 35 percent of science and engineering postdoctorals in a recent study.[19] A second possible reason is the interest of academic researchers in maximizing their research effectiveness in periods of financial stress. One way to accomplish this may have been to substitute postdoctorals for research assistants during the earlier years of the 1967-74 period, a pattern which is suggested by the data in figure 5-10.

A high in the number of academic postdoctoral appointments was reached in 1972 followed by a decline resulting primarily from decreases in the number of postdoctoral appointments of 'recent" doctorates (i.e., those who had earned their doctorates within four years of the study). In 1972 these recent degree recipients comprised 72 percent of all postdoctorals, compared with 58 percent in 1974.

Industrial employment of scientists and engineers

The industrial sector is by far the largest employer of scientists and engineers.[20] There was, however, some fluctuation in the level of employment during the 1970-74 period, reflecting first the layoffs of scientific and technical personnel in industry in 1971-72, and then the general upturn in the economy during late 1973 and early 1974. Scientists and engineers employed in industry in 1970 constituted almost two-thirds of all such personnel employed in that year, but increased in the two subsequent years so that the level in early 1974 was near that of 1970.

Engineers accounted for nearly 80 percent of the scientists and engineers employed in the industrial sector in 1974. Physical scientists (including those in the environmental sciences) accounted for 11 percent of the total and computer scientists, 6 percent.

In 1974, R&D and its management constituted the largest primary activity of industrial scientists and engineers, involving almost 30 percent of the total group. However, as shown in the table below, there were some differences between the activity patterns of scientists and engineers. A larger fraction of industrial scientists were primarily engaged in R&D and management of R&D (36 percent) than was the case for engineers (26 percent). The next most common activity of industrial engineers was management of non-R&D activities, while for scientists it was the area of computer applications.

Percent distribution of the 1970 science and engineering labor force employed in industry, by primary work activity, 1974[a]

Primary work activity	Total	Scientists	Engineers
R&D and R&D management	29	36	26
Management of non-R&D activities	19	15	20
Production and inspection	16	13	17
Design	14	NA	18
Computer applications	6	19	2
Other activities	16	17	17

[a] NSF, special tabulations

The Federal Government provided support for 23 percent of all industrial scientists and engineers in 1974 versus 28 percent in 1972. This decrease was evident among most fields. In both years, much of the Federal support was for industrial R&D activities. The estimated relative level of support varied widely among the different science fields. In 1974, 26 percent of the engineers and 22 percent of the mathematical scientists received Federal support; the same was true for only 10 percent of the physical scientists and approximately 5 percent of the life and environmental scientists.

Over half—52 percent—of all Federal support of scientists and engineers in 1974 came from

[19] *Characteristics of Doctoral Scientists and Engineers in the United States, 1973*, National Science Foundation (NSF 75-312-A).

[20] "National Sample of Scientists and Engineers: Changes in Employment, 1970-72 and 1972-74", *Science Resources Studies Highlights*, National Science Foundation (NSF 75-309), May 19, 1975.

involved in R&D-related work exceeded 40 percent.

The 1973 distribution of these scientists and engineers by field of science and work activity is shown in figure 5-11. Engineers represent the major portion of those with development as a primary work activity, while physical and life science doctorates constitute the major portion of those involved in research. A relatively large proportion of R&D doctorates spend the major part of their time in R&D administration.

The 1973 distribution of R&D doctorates by type of employer is shown in figure 5-12. In contrast to the pattern for all R&D scientists and engineers, the doctorates are about equally concentrated in industry and educational institutions, for all fields combined. Information on the distribution by type of employer for major fields of science is presented in figure 5-13. Physical science and engineering R&D doctorates are most heavily concentrated in industry, while life scientists, mathematical scientists, and social scientists are located predominantly in educational institutions.

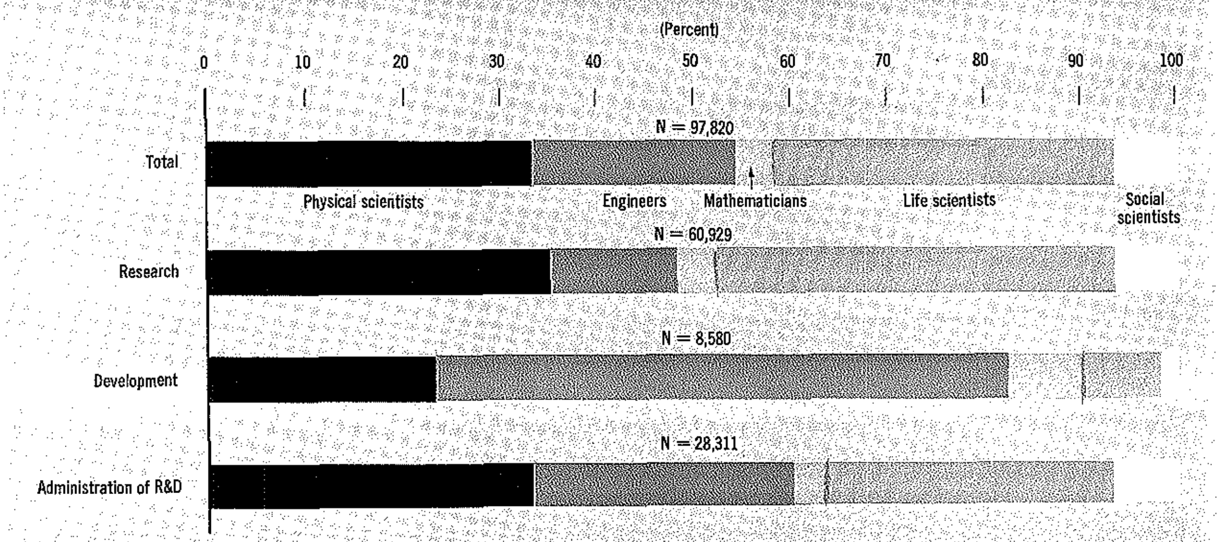
The concentration of R&D doctorates by employment sector varies considerably. Almost three-quarters of the doctorates employed in industry are engaged primarily in R&D or R&D management, while the R&D involvement of doctorates employed in government is slightly higher. In academic institutions, where teaching is the chief activity, only one-fourth of the doctorates work primarily in R&D.

R&D in the academic sector

Some 67,000 or 13 percent of the Nation's full-time equivalent R&D scientists and engineers were employed in universities and colleges in 1974;[26] approximately 26 percent (18,000) of these are graduate students working as scientists and engineers. In contrast to other sectors of employment, university and college personnel involved in R&D are usually primarily engaged in teaching. Thus, the actual number of faculty members engaged in R&D may be considerably greater than the reported FTE number of 67,000. A 1973 survey of U.S. science and engineering doctorates showed that about 80,000 of the science and engineering doctorates employed by universities and colleges considered

[26] *National Patterns of R&D Resources, 1953-75*, National Science Foundation (NSF 75-307).

Figure 5-11
Distribution of doctoral scientists and engineers within R&D activities, by field, 1973



SOURCE: National Science Foundation.

themselves involved in R&D as a primary or a secondary activity.[27]

The type of R&D carried out by these academic scientists and engineers is heavily focused in the research area. An indicator of the extent of this concentration is R&D expenditures; in 1974, 96 percent of academic R&D funding was expended for research activities (basic and applied), with only 4 percent reported for development activities.[26]

The extent of the involvement in research by scientists and engineers who have recently received doctoral degrees is indicated in figure 5-14. This figure applies to those faculty spending 20 percent or more of their time in R&D; young investigators are defined as those who had held their doctorate seven years or less at the time of each of the studies. The proportion of young investigators in relationship to the total number of faculty investigators has decreased significantly. These decreases, however, match the overall changes in faculty age distribution, regardless of activity. The physical sciences and electrical engineering have been most affected, while the decreases in young investigators have been least pronounced in biology and psychology.

In 1974, more than one-half of the faculty investigators[28] in the fifteen fields listed in the table below were performing R&D directly connected with project grants and contracts awarded by Federal agencies.[29] This represents a considerable decrease from 1968, when two-thirds of faculty investigators were involved in Federal projects. There were large differences among the several scientific fields, however. For

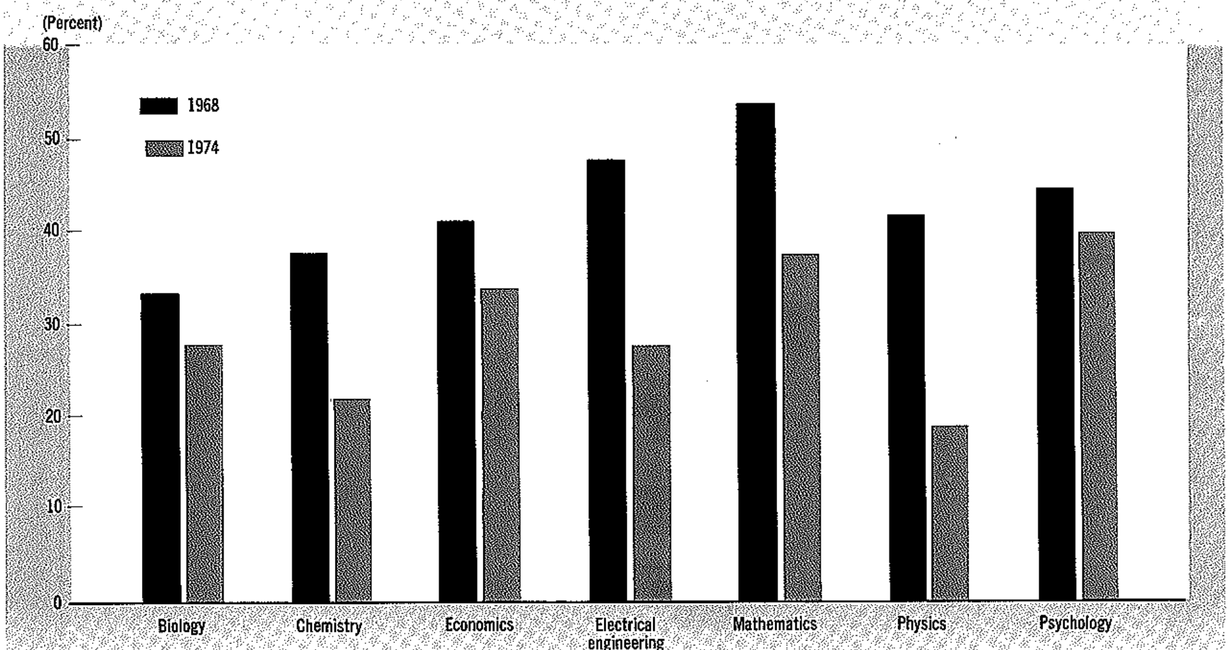
[27] National Science Foundation, special tabulations.

[28] "Investigators" were defined as those spending at least 20 percent of their time in research.

[29] *Young and Senior Science and Engineering Faculty, 1974: Support, Participation, and Tenure,* National Science Foundation (NSF 75-302).

Figure 5-14

Young doctorate faculty[1] investigators[2] as a percent of all faculty investigators, 1968 and 1974



[1] Those who had held doctorates seven years or less at the time of each study.
[2] Spending 20 percent or more of their time in research.
SOURCE: National Science Foundation.

However, this represents a significant decrease from 1967 when the Federal share amounted to 44 percent. The relative decrease in federally supported R&D scientists and engineers is most evident in the machinery, aircraft, and motor vehicle industries. As shown in the figure, almost 80 percent of the federally supported R&D scientists and engineers are employed in the electrical equipment and aircraft and missiles industries, both of which are heavily involved in space and defense R&D.

UNEMPLOYMENT AMONG SCIENTISTS AND ENGINEERS

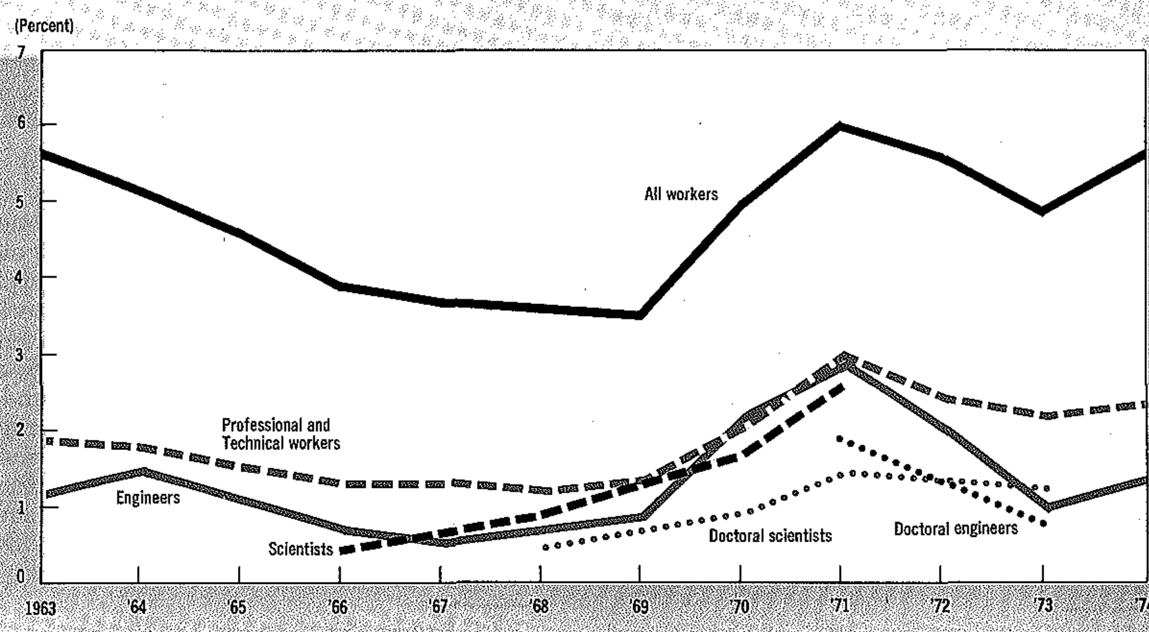
Employment of scientists and engineers during most of the 1960's rose substantially in all sectors. Unemployment was low, ranging around 1 percent, and for most of the period remained about three-fourths of the level for all professional, technical, and kindred workers, and no more than one-fourth the rate for all workers in the country (figure 5-16). However, starting in the early 1970's, changes in the labor market for both scientists and engineers were brought about by a series of factors—cut-backs in defense and other R&D programs, the general economic downturn, and the beginning of the decline in academic recruiting. Thus, unemployment rates for scientists and engineers reached a level of around 3 percent at the beginning of 1971. At that point, the rate was nearly as high as that for all professional workers but only one-half that for all workers. Early in 1972 the employment situation began to improve. The unemployment rate for engineers alone dropped from 3.2 percent in the first quarter of 1971 to under 1 percent at the end of 1973—a rate similar to that of the mid-1960's.

In mid-1974 the unemployment rate for a sample of scientists and engineers was 1.1 percent.[32] Of those employed, 97 percent held full-time positions while 3 percent were working

[32] "National Sample of Scientists and Engineers: Changes in Employment 1970-72 and 1972-74", *Science Resources Studies Highlights*, National Science Foundation (NSF 75-309), May 19, 1975.

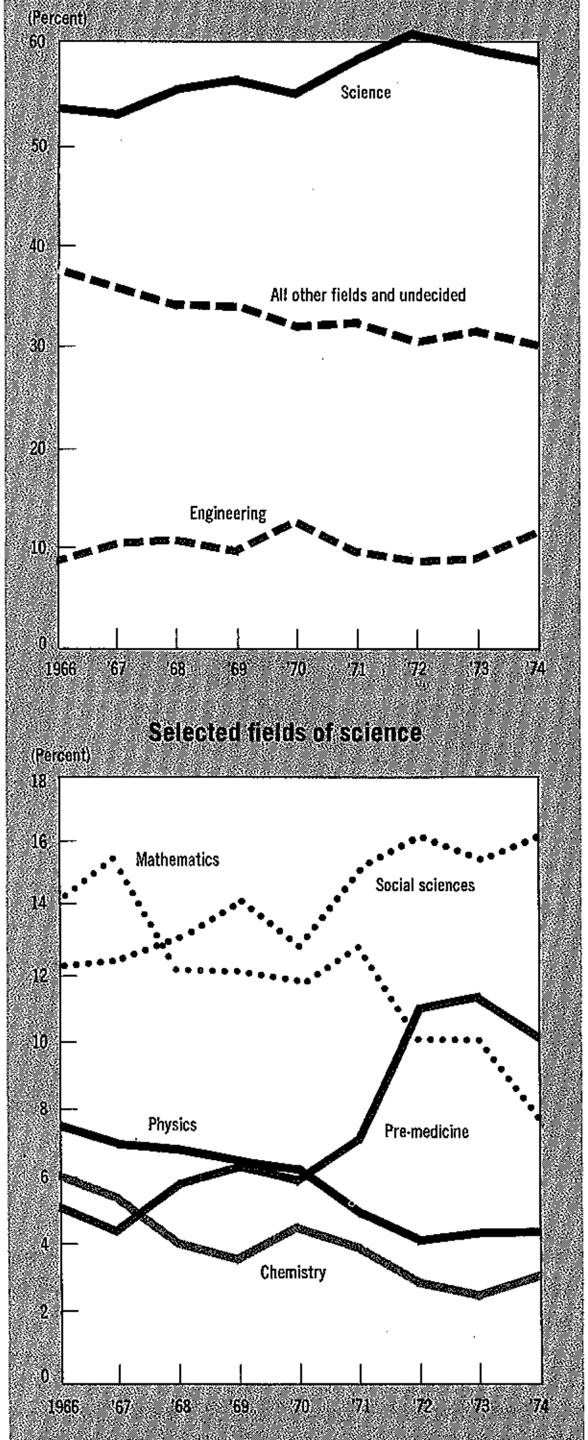
Figure 5-16

Average unemployment rates, 1963-74[1]



[1] Not seasonally adjusted.
SOURCE: Bureau of Labor Statistics and National Science Foundation.

Figure 5-18.
College majors of National Merit Scholars, 1966-74



Source: National Merit Scholarship Corporation.

Bachelor's degrees awarded

Annual awards of bachelor's degrees in the sciences and engineering are shown in figure 5-19 for the years 1960 through 1972, the last year for which National Center for Educational Statistics data are available. Over the 1960-72 period, the annual recipients of science and engineering degrees doubled, including a tripling of the number of recipients of social science degrees. Social science degrees—as a proportion of all bachelor's degrees in science and engineering—rose from about 26 percent in 1960 to almost 50 percent in 1972.

Bachelor's degrees in science and engineering, as a fraction of bachelor's and first-professional degrees[35] in all fields, remained essentially constant at approximately 30 percent between 1960 and 1972. The large increases in annual recipients of social science degrees were responsible for maintaining the fraction at a constant level; engineering degrees, as a proportion of degrees in all fields, declined continuously from 10 percent to 5 percent during the period and the physical sciences fell from 4 percent to 2 percent.

Graduate enrollments in science and engineering

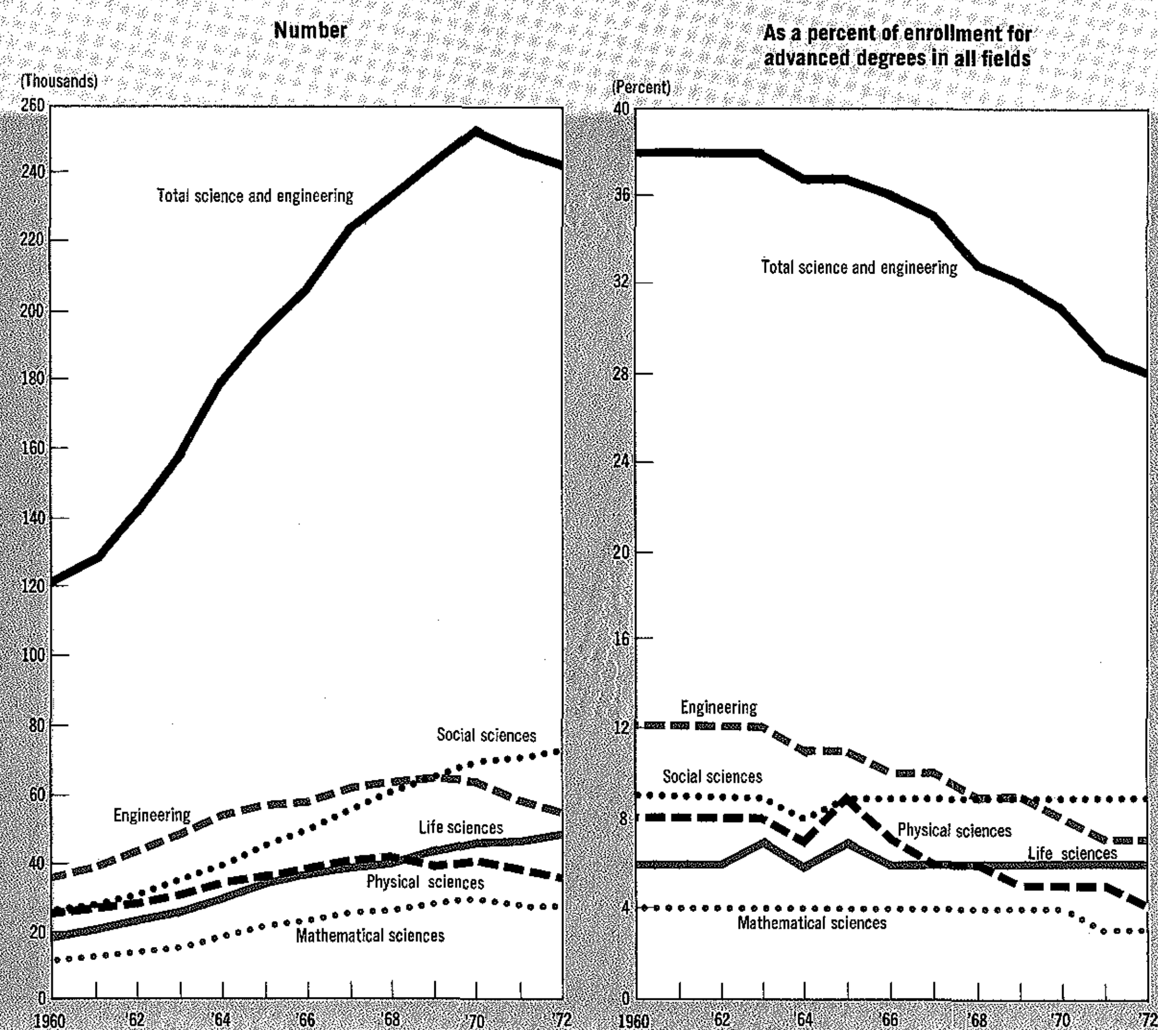
Enrollments in the various fields at the graduate level are affected by many complex factors, including population trends, attitudes and aspirations (such as the increasing career interests of women), military draft regulations, employment outlook, and financial capability of the students. The availability or lack of Federal support for fellowships, traineeships, and training grants has an obvious, though not precisely measurable influence on graduate enrollments in science and engineering.

Enrollments for advanced degrees in science and engineering fields, as shown by annual data from the National Center for Educational Statistics, have grown considerably over the long term, doubling from 1960 to 1972 (figure 5-20). Within the science and engineering fields, engineering had the largest enrollment from 1960 through 1968, but declined in later years.

During the 1960-72 period, however, the most rapid growth in enrollment for advanced degrees occurred in fields other than science and

[35] M.D., D.D.S., D.V.M., etc.

Figure 5-20
Enrollment for advanced degrees in science and engineering, 1960-72



SOURCE: National Center for Educational Statistics and National Science Foundation.

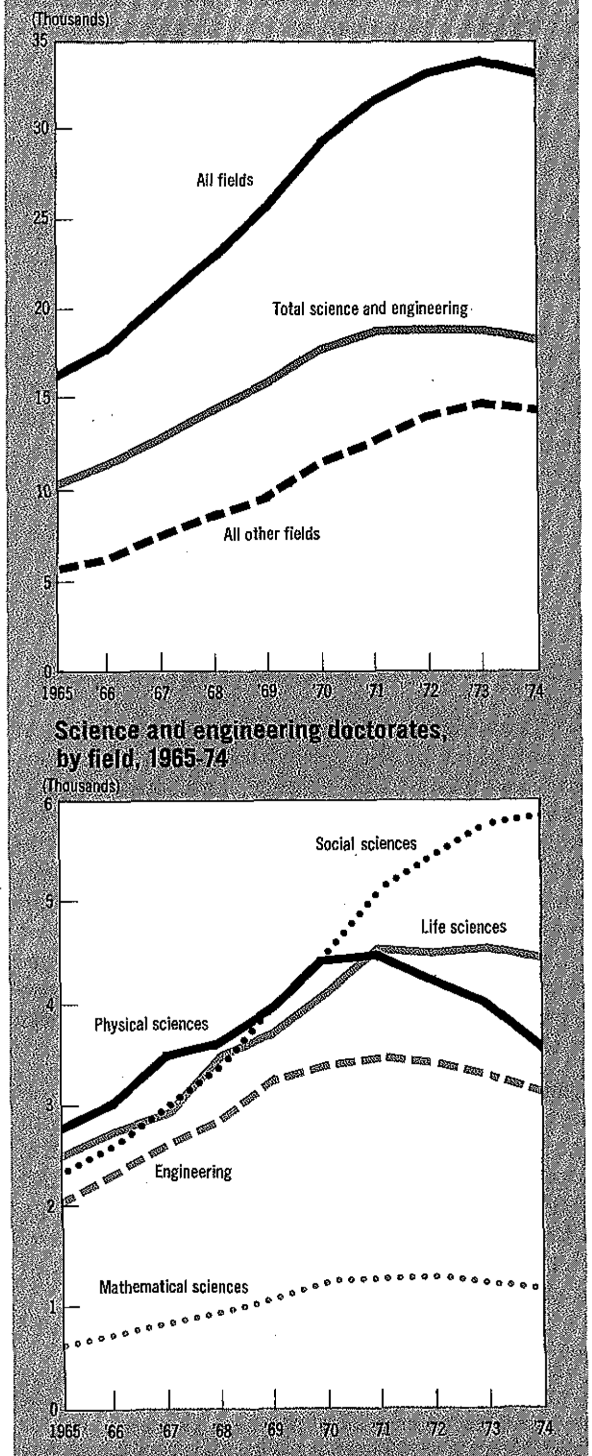
1969. The life sciences accounted for almost all of the overall increase.[36]

Master's degrees awarded

Annual awards of master's degrees in science and engineering for 1960 through 1972 are shown in figure 5-21. The number of these degrees awarded annually increased by over 150 percent between 1960 and 1972, with the largest percentage increases occurring in the mathematical sciences (307 percent) and the social sciences (263 percent), and the smallest in the physical sciences (86 percent). As a fraction of master's degrees in all fields, sciences and engineering degrees declined from a high of 30

[36] "Graduate Science Enrollment in 1974 Shows First Increase Since 1969", *Science Resources Studies Highlights*, National Science Foundation (NSF 75-328), October 22, 1975.

Figure 5-22
Doctoral degrees awarded, 1965-74



SOURCE: National Academy of Sciences.

the sharp drop in physics and astronomy doctorate recipients, down 23 percent from 1971 through 1974, and to a nearly 20 percent decrease in chemistry doctorates over the same period.

Graduate student support

During the 1967-74 period, there were significant shifts in the patterns of support of graduate science students. In 1974, Federal support for full-time graduate science students in doctorate-granting institutions was provided at a level only slightly more than one-half that of 1967. While Federal support was being reduced, institutional and self-support increased, as shown in the table below.

Percent distribution of full-time graduate science students in doctorate departments, by source of major support, 1967 and 1974[37]

Major source of support	1967	1974
Federal support	42	25
Institutional support	34	40
Other outside support	10	9
Self-support	14	26

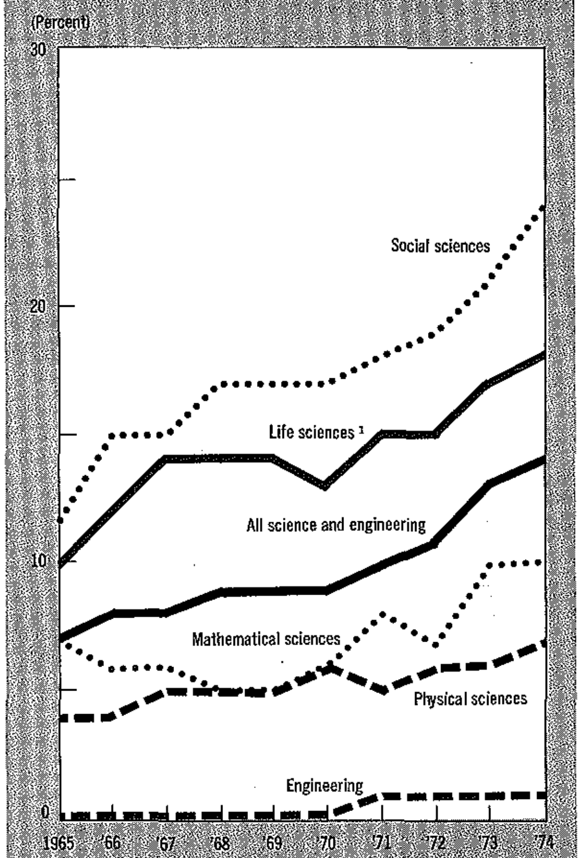
Among the various Federal programs for financial aid to graduate students, major reductions occurred in the number of awards for fellowships and traineeships.[38] By 1974, the number of graduate science students on federally supported fellowships and traineeships was reduced to approximately one-third of the 1967 level. There was also a decrease in the employment of graduate students on research projects, with the result that research assistants receiving Federal support declined by almost 20 percent during the same period. Since Federal R&D obligations to academic institutions rose 11 percent in constant dollars from the base year of 1967, it appears that occupational categories other than research assistants were given greater priority by these institutions.

There have been marked changes in patterns of Federal support of fellowships, traineeships,

[37] *Graduate Student Support and Manpower Resources in Science Education, 1969,* National Science Foundation (NSF 70-40) and *Graduate Science Education: Student Support and Postdoctorals, Fall 1974,* National Science Foundation (NSF 75-322).

[38] *Graduate Science Education: Student Support and Postdoctorals,* National Science Foundation, annual series, and special tabulations.

Figure 5-23
Women as a percent of total science and engineering doctorate recipients, by field, 1965-74



[1] Includes environmental sciences.
SOURCE: National Academy of Sciences.

advanced degrees in science and engineering, as reported by the Office of Education, also increased markedly, by 73 percent overall between 1966 and 1972. In 1972 (the latest year for which data are available) women represented varying proportions of the total enrollments of each of the fields below.

Proportion of women enrolled for advanced degrees, by field, 1966 and 1972

Field	Percent of total	
	1966	1972
All science and engineering fields ...	13	19
Social sciences	24	31
Life sciences	20	24
Mathematical sciences	18	22
Physical sciences	8	12

One factor which may affect the participation of women in science and engineering is the substantial difference in salary levels for men and women in science occupations. Among doctoral scientists and engineers, the 1973 median salary for women ($17,600) was 17 percent lower than that for men ($21,200). Women's salaries are consistently below men's at each age level, but the gap widens considerably after age 40.[47]

Racial minorities in science and engineering

Information concerning the racial identification of members of the scientific community has been made available only in recent years. Data are presented here concerning the racial composition of the national pool of scientists and engineers, the characteristics of minority doctoral scientists and engineers by field, and the representation of minority students in each field of graduate science study.

Caucasians represent the predominant portion of all scientists and engineers (96 percent); those of Asian background account for over 2 percent, Blacks comprise about 1 percent, and other nonwhites (e.g., American Indians) the remainder (figure 5-24).

The field of mathematics has the largest proportion of racial minorities (8 percent), followed by the physical sciences (6 percent) and the life sciences (6 percent). Blacks have the highest level of participation in mathematics,

[47] *Doctoral Scientists and Engineers in the U.S., 1973 Profile,* National Academy of Sciences, 1974.

representing 5 percent of all mathematicians, Orientals in the physical sciences (4 percent), and other races in the life sciences (1 percent). The largest absolute number of minorities, by total and for each group, are found in engineering, although minorities have the smallest proportional representation in this field.

The representation of minorities among doctoral scientists and engineers in 1973 is shown in the table below.[48]

[48] *Characteristics of Doctoral Scientists and Engineers in the United States, 1973*, National Science Foundation (NSF 75-312).
[49] Less than 0.05 percent.

Proportion of minority doctoral scientists and engineers, by field, 1973

Field	Percent in each field		
	Black	American Indian	Asian
All scientists and engineers	0.8	(49)	4.5
Physical scientists	.8	(49)	4.7
Mathematical scientists	.8	NA	4.8
Environmental scientists	.2	NA	2.8
Engineers	.2	(49)	8.4
Life scientists	.9	(49)	4.3
Psychologists	.9	(49)	1.1
Social scientists	1.1	.1	3.6

Figure 5-24

Minority representation among scientists and engineers, by field, 1972

SOURCE: National Science Foundation

Public Attitudes Toward Science and Technology

Public attitudes affect science and technology in many ways. Public opinion sets the general environment and climate for scientific research and technological development. It is influential in determining the broad directions of research and innovation, and through the political process, the allocation of resources for these activities. In addition, public attitudes toward scientists and engineers and their efforts affect the career choices of the young by influencing their decision to enter these fields.

The survey of public attitudes toward science and technology summarized in *Science Indicators—1972* was repeated for this report.[1] The 1974 replication of the earlier survey serves both as a check on the findings of the previous survey and as the beginning of a time series of data for tracking trends in attitudes and opinions.

A personal interview survey was conducted in July and August 1974 among 2,074 persons 18 years of age and older. The sampling techniques used in the survey permit the results to be projected to the entire U.S. population.

The survey was designed to explore three aspects of public attitudes and opinions: the public's regard for science and technology; the public's sense of the impact of those activities; and the public's expectations and desires regarding the role of science and technology in dealing with national problems. Results are reported first for the total sample of respondents, and then for demographic groups.

TOTAL GROUP RESPONSES

Public regard for science and technology

Three aspects of attitudes were explored under this heading: how the public feels science and technology have affected the quality of life; the general emotional reaction associated with science and technology; and where scientists and engineers rank in prestige among nine professions and occupations.

[1] Both surveys were conducted by the Opinion Research Corporation, Princeton, N.J. For more complete information concerning the survey results and methodology, including a description of the reliability of the results and the differences required for statistical significance, see: *Attitudes of the U.S. Public Toward Science and Technology, Study II*, Opinion Research Corporation, 1974 (A study commissioned specifically for this report).

In 1974, 75 percent of the public felt that science and technology have changed life for the better, compared with 70 percent in 1972. This gain is concurrent with a decline in the "worse" and the "no opinion" responses.

Do You Feel That Science and Technology Have Changed Life for the Better or for the Worse?

Response	Percent 1972	Percent 1974
Better	70	75
Worse	8	5
Both	11	11
No effect	2	3
No opinion	9	6

The reaction of "satisfaction or hope" to science and technology was expressed by 56 percent of the people in 1974, versus 49 percent in 1972. In both years, a reaction of "excitement or wonder" was shared by 22 to 23 percent of the public. Fewer respondents expressed "No opinion" in 1974 than in 1972.

Which One of These Items Best Describes Your General Reaction to Science and Technology?

Response	Percent 1972	Percent 1974
Satisfaction or hope	49	56
Excitement or wonder	23	22
Fear or alarm	6	5
Indifference or lack of interest	6	7
No opinion	16	11

For a further indication of the regard for science and technology, people were asked to rate each of nine professions and occupations in terms of the "prestige or general standing that each job has." The rating categories used were "excellent," "good," "average," "below average," and "poor." These categories were assigned weights, and the resulting rankings are shown below, not only for the 1972 and 1974 surveys but also for comparable studies in 1947 and 1963.

Harmful Effects of Science and Technology (Cited by group responding "About the same")

Response	Percent citing[a] 1972	1974
Lack of concern for the environment	27	25
Development of military weapons	9	11
Space research	16	9
Dangerous drugs and medicines	3	9
Depletion of natural resources	2	2
Other	16	19
Don't know	27	32

[a] Multiple responses were accepted.

As shown in the following three tables, the public's views remained stable over the 1972-74 period on questions regarding the relationship of science and technology with society.

Science and technology are thought to cause some of today's problems by about half the public, and as the source of few or none of the problems by some 40 percent.

Do You Feel that Science and Technology Have Caused Most of our Problems, Some of our Problems, Few of our Problems, or None of our Problems?

Response	Percent 1972	1974
Most	7	6
Some	48	50
Few	27	29
None	9	9
No opinion	9	6

A slight majority of the public continued to feel that science and technology produce change at a pace "about right". Remaining opinion is almost evenly divided between "too fast" and "too slowly".

Do You Feel That Science and Technology Change Things Too Fast, Too Slowly, or Just About Right?

Response	Percent 1972	1974
Too fast	22	20
About right	51	53
Too slowly	16	18
No opinion	11	9

Almost half of those polled felt that the extent of control society should have over science and technology should "remain as it is," and nearly 30 percent felt that greater control was needed.

Do You Feel That the Degree of Control that Society Has Over Science and Technology Should be Increased, Decreased, or Remain As It is Now?

Response	Percent 1972	1974
Should be increased	28	28
Remain as it is	48	46
Should be decreased	7	8
No opinion	17	18

Expectations and directions for science and technology

About three-fourths of the public remained confident that science and technology will eventually solve at least some of the major problems, examples of which were named in the question. But the expectation that most problems would yield to such solution declined, falling from 30 percent in 1972 to 23 percent in 1974. The trend toward a lower level of confidence is evident in the larger percentage of those who expect science and technology to solve only "some" and "few" such problems.

Do You Feel That Science and Technology Will Eventually Solve Most Problems Such as Pollution, Disease, Drug Abuse, and Crime, Some of These Problems, or Few, if Any of These Problems?

Response	Percent 1972	1974
Most problems	30	23
Some problems	47	53
Few problems	16	20
No opinion	7	4

Areas in which the public would "most like" to see their tax money for science and technology spent are "health care," "reducing crime," "reducing and controlling pollution," "preventing and treating drug addiction," and "improving education."[2] Two major shifts in public preferences occurred in these areas between 1972 and 1974: "reducing and controlling pollution" declined considerably in the frequency of selection, whereas "improving education" increased. Among the less highly ranked areas,

[2] Selection was made from a list of 12 areas snown in the next tabulation.

DEMOGRAPHIC RESPONSES

The responses of demographic groups, although similar, were not identical. Examination of these differences is limited in this report to two of the questions covered in the survey. The pattern of responses to these two is similar to the attitudes and opinions expressed by the demographic groups to the other survey questions.

The response of "no opinion" is relatively high in all groups,[3] but is especially so among the oldest, lower income, and least educated subgroups. Such responses mask differences in expressed opinion toward science and technology and for this reason, comparisons of subgroups in the following two tables are based on percentages of those expressing an opinion.

Differences of sex and age

Responses of men were somewhat more positive than women to science and technology in both questions. Men appear to judge past contributions of science and technology more favorably, and to express more confidence in future accomplishments. Both groups, however, were less confident in 1974 that science and technology would "eventually solve most problems."

In general, people between 30-59 years of age expressed the most favorable attitudes toward science and technology, followed by the young (18-29 years), and the older group (60 and above). All age groups recorded less confidence in 1974 in expecting problems to be solved by science and technology. (Major differences between responses of the youngest group and those of the total are noted below for all questions in the survey.)

Differences in education and family income

Attitudes and opinions toward science and technology appear to correlate closely with education: the greater the amount of formal education, the more favorable the response. For example, 54 percent of those with less than a high school education felt in 1974 that science and technology do more good than harm, compared with 67 percent of those who had completed high school, and 71 percent of those with some college education.

Attitudes and family income appear to correlate to some extent on both the overall impact of science and technology and future contributions toward solving problems. Some 70

Overall, Would You Say That Science and Technology Do More Good Than Harm, More Harm Than Good, or About the Same of Each?

Percentage of group expressing

	"More good"		"About same"		"More harm"		"No opinion"	
	1972	1974	1972	1974	1972	1974	1972	1974
All	61	63	35	35	4	2	11	10
Men	64	67	32	31	4	2	8	8
Women	59	59	38	39	3	2	13	12
18-29 yrs.	55	59	39	38	5	3	8	4
30-39	69	71	29	28	2	1	7	10
40-49	66	64	29	33	5	3	7	8
50-59	60	67	35	31	4	2	9	8
60 +	57	55	39	41	4	4	19	20
Less than high school	51	54	43	43	6	3	18	19
High school	63	67	35	31	2	2	5	4
Some college	74	71	22	27	4	2	5	4
Family income:								
Under $5,000	44	56	39	41	7	3	18	21
$5,000-$6,999	47	53	40	41	4	6	16	10
$7,000-$9,999	54	59	34	39	6	2	10	7
$10,000-$14,999	61	71	34	28	2	1	4	5
$15,000 or over	71	69	27	30	2	1	3	6

[3] A high frequency of "no opinion" responses occurs typically in surveys concerned with science and technology, as discussed in Amitai Etzioni and Clyde Nunn, "The Public Appreciation of Science in Contemporary America," *Daedalus*, Vol. 103 (1974), pp. 191-206.

areas for expenditures, 45 percent of the young group cited "developing and improving weapons for national defense," as against 30 percent of the total group. Similarly, "weather control and prediction" was cited as "least liked" by 24 percent of the group versus 16 percent of the total sample.

OTHER SURVEYS

Surveys on public attitudes toward science and technology were recently reviewed by Etzioni and Nunn.[4] Results from the survey conducted for this report appear to be consistent with earlier studies, to the extent that direct comparisons can be made.

The results of the present survey (1972 and 1974) with respect to the public's general regard for science may be placed in a broader context by reference to comparable surveys: a Harris poll in 1972 and one by the National Opinion Research Center (NORC) in 1973 and a replication in 1974. These surveys explored levels of public confidence in "the people who are running" 11 institutions.[5] In the Harris Poll, science as an institution ranked second among the 11 in terms of the percentage of the public indicating "a great deal of confidence." In 1973, the NORC survey[6] also showed science ranking second, with education, in public confidence. The percentage expressing a great deal of confidence in science rose from 37 to 45 in 1974, but because of an even larger gain for education, from 37 to 49, the rank of science dropped to third among the 11 institutions in 1974.

A more recent survey by LaPorte and Metlay[7] found a "reasonably high degree of correspondence" in responses to several items which were included in the survey reported in *Science Indicators—1972*. Similar attitudes, for example, were found in both surveys regarding the confidence and prestige associated with scientists and engineers, the desired extent of social control of science and technology, and ratings of benefits in different areas, such as health and space exploration. The LaPorte and Metlay survey, in addition, found that attitudes toward science differ from those toward technology; "there was considerable agreement that scientific activities are intrinsically beneficial and should not be controlled", whereas "the public reaction to the impact of technology upon society is one of wariness and some skepticism".

[4] *Ibid.*

[5] The institutions for which data were available over the three years included medicine, science, education, the military, Supreme Court, Federal executive branch, Congress, major U.S. companies, the press, television, and labor.

[6] *Codebook of the General Social Survey*, National Opinion Research Center, 1973 and 1974.

[7] Todd LaPorte and Daniel Metlay, "Technology Observed: Attitudes of a Wary Public," *Science*, Vol. 188 (1975), pp. 121-127.

Appendix

Table 1-2. Scientists and engineers[1] engaged in R&D, by country, 1963-73

Country	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
	Scientists and engineers[1] engaged in R&D per 10,000 population										
United States	NA	24.7	25.4	NA	NA	27.4	27.5	26.8	25.6	25.0	24.9
U.S.S.R.	18.8	20.3	21.6	25.2	25.8	27.3	29.1	30.7	32.6	34.3	37.2
Japan	12.0	NA	NA	NA	15.8	NA	16.9	NA	18.9	NA	NA
West Germany	NA	5.7	NA	NA	10.3	NA	12.5	NA	14.9	16.2	17.8
France	6.7	NA	NA	NA	9.9	NA	10.9	NA	11.1	NA	NA
	Scientists and engineers engaged in R&D (in thousands)										
United States	NA	474.5	494.1	NA	NA	550.4	558.2	549.5	529.7	521.5	523.1
U.S.S.R.	422.8	463.2	499.4	558.4	605.6	651.5	698.9	746.2	797.8	848.8	931.0
Japan	114.8	NA	NA	NA	157.6	NA	172.0	NA	198.1	NA	NA
West Germany	NA	33.4	NA	NA	61.6	NA	76.3	NA	90.0	100.0	110.0
France	32.2	NA	NA	NA	49.2	NA	54.7	NA	56.7	NA	NA
	Population (in thousands)										
United States	189,242	191,889	194,303	196,560	198,712	200,706	202,677	204,875	207,045	208,842	210,396
U.S.S.R.	225,060	228,150	230,940	233,530	235,990	238,320	240,550	242,760	245,090	247,460	250,000
Japan	95,900	96,900	97,950	98,850	99,870	101,000	102,200	103,390	104,650	105,990	108,710
West Germany	57,610	58,290	59,040	59,680	59,870	60,170	60,840	60,650	61,290	61,690	61,970
France	47,820	48,310	48,760	49,160	49,550	49,910	50,320	50,770	51,250	51,700	51,915

[1] Includes all scientists and engineers (full-time equivalent basis). Data for the United Kingdom are not available.

SOURCE: Organisation for Economic Co-operation and Development, *International Survey of Resources Devoted to R&D by OECD Member Countries*, for 1963, 1964, 1967, 1969, and 1971; United Nations, *Demographic Yearbook, 1972* and UN estimates for 1973; U.S.S.R. estimates by Robert W. Campbell, Department of Economics, Indiana University.

Table 1-4. Percent of the scientific literature[1] citing countries other than the author's own country, by selected fields,[2] 1973

Fields	Total citations from the 6 major countries	Citations to countries other than the author's country	Citations to the author's country	Percent foreign citations
Chemistry	338,993	233,176	105,817	69
Physics	270,090	170,985	99,105	63
Biology and biomedical research	440,215	246,471	193,744	56
Engineering	80,654	43,523	37,131	54
Clinical medicine	604,858	320,158	284,700	53
Mathematics	25,759	13,355	12,404	52
Earth & space sciences	73,248	35,384	37,864	48
Psychology	42,298	11,934	30,364	28
Eight field total	1,876,115	1,074,986	801,129	57

[1] Based on 2,121 of the journals in the *Science Citation Index* for 1973. Included is the literature of the first six countries ranked by the number of their scientific publications: United States, United Kingdom, West Germany, France, U.S.S.R. and Japan.
[2] See Appendix table 1-7a for the description of fields and subfields. The social sciences are excluded because comparable data are not available.

SOURCE: Computer Horizons, Inc., *Indicators of the Quantity and Quality of the Scientific Literature*, 1975 (A study commissioned specifically for this report).

Table 1-5. Participation in international scientific congresses, by the United States and other countries, 1960-74

Year	Total participants	U.S. participants	Non-U.S. participants
1960-62	33,082	9,033	24,049
1963-65	37,964	10,012	27,952
1966-68	59,748	12,297	47,451
1969-71	55,711	12,956	42,755
1972-74	73,819	18,630	55,189

SOURCE: National Academy of Sciences, special tabulations.

Table 1-7. Percent distribution of scientific literature[1] by selected field,[2] for each country, 1973

Fields	United States	United Kingdom	West Germany	France	U.S.S.R.	Japan	Other countries	World total
	Percent in each field							
All fields	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Clinical medicine	29.9	31.1	31.9	28.7	9.9	18.5	28.5	27.3
Biology and biomedical research	24.9	23.8	20.1	25.0	12.4	20.4	25.1	23.2
Chemistry	9.8	13.9	16.9	20.0	33.1	29.6	18.7	16.5
Physics	10.8	11.1	11.9	12.8	25.5	16.4	11.7	12.8
Earth and space sciences	5.1	3.8	2.3	3.8	4.7	1.7	3.9	4.2
Engineering	10.8	12.0	13.2	5.3	13.4	10.8	7.8	10.2
Psychology	5.1	1.8	0.4	0.5	0.1	0.3	1.5	2.6
Mathematics	3.8	2.5	3.5	4.0	0.9	2.4	2.9	3.1
	Total number of publications							
Total count of literature	109,320	25,462	16,461	15,184	24,435	14,309	73,723	278,894
Percent distribution	39.2	9.1	5.9	5.4	8.8	5.1	26.4	100.0

[1] Includes 278,894 articles, letters and notes from a sample of 2,121 scientific journals. Because of the way in which this sample of journals was chosen, these profiles may understate certain fields; e.g., Russian mathematics articles may be understated here.

[2] See Appendix table 1-7a for the description of fields and subfields. The social sciences are excluded because comparable data are not available.

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

SOURCE: Computer Horizons, Inc., *Indicators of the Quantity and Quality of the Scientific Literature*, 1975 (A study commissioned specifically for this report).

Table 1-7b. Citation indices of scientific literature[1] in selected fields,[2] by selected countries, 1973

Cited country	Citing country	Field of science: Clinical medicine	Biology and biomedical research	Chemistry	Physics	Earth and space science	Engi-neering	Psy-chology	Mathe-matics
United States	United States	1.52	1.45	1.97	1.60	1.42	1.49	1.05	1.25
	World	1.31	1.29	1.54	1.38	1.31	1.07	1.03	1.17
	Non-U.S.	1.15	1.15	1.38	1.26	1.18	0.90	0.97	1.07
United Kingdom	United Kingdom	2.26	1.91	2.11	1.37	1.59	1.75	1.87	1.80
	World	1.26	1.17	1.40	0.93	0.97	1.04	0.93	1.08
	Non-U.K.	1.13	1.09	1.30	0.87	0.92	0.86	0.86	0.99
West Germany	West Germany	2.31	1.82	3.62	1.54	1.72	4.03	(3)	1.85
	World	0.55	0.79	1.46	1.03	0.71	0.87	(3)	0.91
	Non-W. Germany	0.41	0.73	1.29	1.00	0.68	0.58	(3)	0.83
France[4]	France	2.62	2.10	2.14	1.14	1.56	10.37	(3)	2.24
	World	0.50	0.64	0.66	0.80	0.57	1.08	(3)	0.77
	Non-France	0.36	0.58	0.56	0.78	0.53	0.67	(3)	0.73
U.S.S.R.	U.S.S.R.	9.44	4.78	2.54	2.51	3.14	6.18	(3)	13.25
	World	0.18	0.29	0.42	0.61	0.35	1.02	(3)	0.53
	Non-U.S.S.R.	0.05	0.14	0.16	0.32	0.21	0.12	(3)	0.31
Japan	Japan	4.66	3.62	1.48	2.14	3.75	3.58	(3)	3.61
	World	0.57	0.82	0.69	0.75	0.73	0.76	(3)	0.65

[1] Based on 278,894 articles, letters and notes in a sample of 2,121 journals.
[2] See Appendix table 1-7a for a description of the fields. The social sciences are excluded because comparable data are not available.
[3] Because these countries had less than 2 percent of the world's literature total in psychology, reliable citation ratios cannot be calculated.
[4] Although French scientific journals may have severe space restrictions which discourage complete citations, the articles themselves tend to be more specific, covering less substantive material. For this reason, there may be an inflation of French publications in the scientific literature, making them more subject to citation than their significance warrants.

SOURCE: Computer Horizons, Inc., *Indicators of the Quantity and Quality of the Scientific Literature*, 1975 (A study commissioned specifically for this report).

Table 1-8. Nobel Prizes awarded in science, for selected countries, 1901-74

Date	United States	United Kingdom	Germany[1]	France	U.S.S.R.
	Number of Nobel Prizes per 10 million population				
1901-1910	0.12	1.24	2.80	1.47	0.15
1911-1920	0.20	0.71	2.00	1.01	—
1921-1930	0.26	1.56	2.21	0.75	—
1931-1940	0.70	1.49	2.05	0.49	—
1941-1950	0.98	1.42	0.91	—	—
1951-1960	1.74	1.75	0.59	—	0.20
1961-1970	1.35	2.23	0.91	1.05	0.13
1971-1974	0.63	1.08	0.17	—	—
	Number of Nobel Prizes awarded				
1901-1910	1	5	12	6	2
1911-1920	2	3	7	4	—
1921-1930	3	7	8	3	—
1931-1940	9	7	8	2	—
1941-1950	14	7	4	—	—
1951-1960	29	9	3	—	4
1961-1970	26	12	5	5	3
1971-1974	13	6	1	—	—
Total	97	56	48	20	9
	Population (In millions)				
1901-1910	84.25	40.31	42.81	40.79	133.06
1911-1920	99.44	42.58	35.00	39.43	147.89
1921-1930	114.77	44.79	36.25	39.95	167.15
1931-1940	127.84	47.05	39.05	41.23	187.00
1941-1950	142.43	49.42	44.22	41.52	187.50
1951-1960	166.47	51.56	50.54	43.71	197.20
1961-1970	192.77	53.80	54.91	47.59	230.05
1971-1974	207.64	55.52	59.29	50.71	247.85

[1] Before 1946, includes East Germany.

SOURCE: The Nobel Foundation, *Les Prix Nobel*, annual series.

Table 1-7a. Fields and subfields of scientific literature, 1973

- 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
- Biology and biomedical research
  - 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 & hydrobiology
  - Botany
  - Ecology
  - Agriculture & food science
  - Dairy & animal 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 1-6. Scientific literature[1] in selected fields[2] as a percent of total literature, by country, 1965-73

Selected field and year	Total literature (number)	Percent of total						
		United States	United Kingdom	West Germany[3]	France	U.S.S.R.	Japan	Other countries
Chemistry								
1965	34,657	25.9	7.7	8.2	3.9	30.9	4.1	19.3
1967	39,730	24.5	7.9	8.4	5.9	28.8	5.3	19.2
1969	43,362	24.2	8.2	7.9	5.7	28.5	6.4	19.2
1971	45,052	23.9	8.4	6.8	6.2	29.0	5.9	19.8
1972	45,665	22.4	7.0	5.4	6.0	30.1	6.0	23.2
1973	45,778	21.2	6.4	5.4	5.8	32.4	6.3	22.6
Engineering								
1965	10,006	49.9	11.2	4.7	1.4	12.6	2.4	17.8
1967	11,968	48.8	11.3	5.6	1.8	12.5	2.8	17.2
1969	13,222	48.3	11.0	6.2	1.8	12.5	2.9	17.4
1971	13,765	49.7	9.0	6.1	2.2	11.8	3.9	17.3
1972	11,992	44.6	9.7	6.4	2.4	11.4	3.9	21.7
1973	12,690	43.7	10.9	7.0	2.5	9.4	4.5	21.9
Mathematics								
1965	[4]2,971	23.9	6.6	6.3	5.6	22.4	4.2	31.8
1967	4,298	23.9	4.6	6.4	4.5	26.4	4.7	29.8
1969	3,024	26.9	6.4	6.0	6.9	20.0	5.2	27.1
1971	3,739	27.8	3.9	6.5	6.0	22.2	7.0	26.7
1972	3,599	29.3	3.9	6.8	5.6	28.6	5.0	20.8
1973	4,844	23.6	4.4	7.0	5.5	30.3	4.2	25.1
Molecular biology								
1965	24,321	46.6	9.5	4.8	9.4	3.0	4.2	22.4
1967	25,858	48.6	11.0	5.4	7.4	2.1	4.8	20.7
1969	29,359	47.6	9.3	5.5	9.0	1.8	4.9	21.8
1971	30,148	48.7	8.9	5.1	8.9	1.8	5.0	21.6
1972	31,032	45.9	9.7	4.4	9.6	1.8	5.4	23.3
1973	33,619	46.7	9.4	4.3	8.0	1.9	5.9	23.9
Physics								
1965	23,224	41.3	8.2	7.4	4.8	15.7	4.4	18.2
1967	27,121	42.1	8.6	7.5	5.3	13.8	5.2	17.5
1969	29,353	41.0	8.3	7.2	5.4	14.6	5.1	18.4
1971	29,824	42.4	8.1	5.8	5.1	13.8	6.0	18.7
1972	31,031	38.5	7.7	5.2	6.1	15.1	5.6	21.7
1973	31,548	38.4	7.2	5.7	5.7	14.4	6.5	22.0
Psychology								
1965	3,537	79.3	8.1	0.5	0.2	—	0.5	11.4
1967	3,967	79.2	6.4	0.5	0.2	—	0.6	13.2
1969	4,308	76.6	7.8	1.6	0.1	0.1	0.4	13.5
1971	4,075	76.5	7.9	0.8	0.2	—	0.5	14.1
1972	4,091	74.4	8.5	0.7	0.2	0.2	0.9	14.9
1973	4,443	74.4	8.1	0.6	0.6	—	0.8	15.5
Systematic biology								
1967	[4]6,201	35.8	6.1	4.1	4.4	8.3	3.5	37.8
1969	6,101	29.4	6.0	4.9	4.8	9.0	5.0	41.0
1971	7,050	33.3	7.2	5.3	5.2	6.4	4.3	38.2
1972	5,192	31.2	6.5	4.4	5.5	2.5	5.0	44.9
1973	3,342	30.8	6.5	5.1	5.3	10.4	4.6	37.4

[1] Includes articles, letters and notes from the sample of 492 scientific journals most heavily cited in 1965.
[2] The social sciences are excluded because comparable data are not available.
[3] Prior to 1972, data for East Germany were included in the fields of chemistry, engineering, molecular biology, physics, and psychology.
[4] For mathematics and systematic biology, these numbers are the size of the literature *sample* from which the percent distributions were derived, and should not be used as counts of articles.

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

SOURCE: Computer Horizons, Inc., *Indicators of the Quantity and Quality of the Scientific Literature,* 1975 (A study commissioned specifically for this report).

Table 1-3. Distribution of government R&D expenditures among areas by country, 1961-73

National objectives	National currency in millions			Percent distribution		
United States	1961-62	1966-67	1971-72	1961-62	1966-67	1971-72
National defense	7,338.5	8,264.8	8,584.7	70.7	49.0	52.6
Space	1,225.9	5,307.0	2,957.6	11.8	31.5	18.1
Nuclear energy	755.0	875.0	838.0	7.3	5.2	5.1
Economic development	339.1	792.3	1,322.1	3.3	4.7	8.1
Health	500.6	968.8	1,379.8	4.8	5.7	8.5
Community services	99.9	321.1	729.2	1.0	1.9	4.5
Advancement of science	118.2	308.6	465.4	1.1	1.8	2.9
United Kingdom	1961-62	1966-67	1972-73	1961-62	1966-67	1972-73
National defense	248.6	260.4	335.0	64.8	52.3	44.0
Space	2.7	21.4	11.9	0.7	4.3	1.6
Nuclear energy	56.5	65.2	67.3	14.7	13.1	8.8
Economic development	37.9	71.0	177.6	9.9	14.3	23.3
Health	5.7	13.0	32.8	1.5	2.6	4.3
Community services	0.7	1.3	4.5	0.2	0.3	0.6
Advancement of science	26.0	57.8	119.9	6.8	11.6	15.8
France	1961	1967	1972	1961	1967	1972
National defense	1,310.0	3,082.0	3,050.0	44.2	34.9	27.8
Space	16.5	522.8	730.0	0.6	5.9	6.7
Nuclear energy	735.0	1,723.2	1,600.0	24.8	19.5	14.6
Economic development	231.6	1,381.0	2,200.0	7.8	15.6	20.1
Health	13.0	116.1	200.0	0.4	1.3	1.8
Community services	12.7	81.0	170.0	0.4	0.9	1.6
Advancement of science	592.3	1,758.1	2,800.0	20.0	19.9	25.5
West Germany	1961	1966	1971	1961	1966	1971
National defense	381.0	803.0	1,180.0	22.3	19.0	15.0
Space	NA	177.0	522.0	NA	4.2	6.6
Nuclear energy	267.0	693.0	1,230.0	15.6	16.4	15.6
Economic development	NA	NA	1,057.0	NA	NA	13.4
Health	NA	NA	195.0	NA	NA	2.5
Community services	NA	NA	133.0	NA	NA	1.7
Advancement of science	639.0	1,488.0	3,190.0	37.4	35.3	40.6
Japan	1961-62	1965-66	1969-70	1961-62	1965-66	1969-70
National defense	3,162.0	4,495.0	6,523.0	3.7	2.7	2.2
Space	NA	141.0	2,083.0	NA	0.1	0.7
Nuclear energy	5,881.0	4,944.0	22,539.0	7.0	3.0	7.5
Economic development	25,446.0	44,898.0	69,987.0	30.1	27.2	23.2
Health	724.0	3,679.0	5,492.0	0.9	2.2	1.8
Community services	1,071.0	2,818.0	7,254.0	1.3	1.7	2.4
Advancement of science	47,321.0	103,163.0	185,376.0	55.9	62.5	61.4

SOURCE: Organisation for Economic Co-operation and Development, *Changing Priorities for Government R&D*, July, 1973.

Table 1-1. R&D expenditures as a percent of Gross National Product (GNP), by country, 1961-74

Country	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974 (est.)
	R&D expenditures as a percent of Gross National Product													
United States	2.75	2.75	2.90	2.99	2.93	2.92	2.92	2.86	2.76	2.66	2.53	2.45	2.35	2.29
France	1.38	1.43	1.53	1.78	1.99	2.07	2.16	2.11	1.96	1.88	1.87	1.82	1.73	NA
West Germany	1.08	1.23	1.38	1.54	1.70	1.78	1.94	1.93	1.99	2.12	2.29	2.37	2.36	2.41
United Kingdom	2.69	NA	NA	2.62	NA	2.79	2.75	2.70	2.73	NA	NA	NA	NA	NA
Japan	NA	NA	1.25	NA	NA	NA	1.34	NA	1.50	NA	1.65	1.89	1.92	NA
U.S.S.R.	NA	2.18	2.37	2.42	2.40	2.42	2.55	NA	2.82	2.73	2.79	3.04	3.10	3.06
	R&D expenditures (national currency in billions)													
United States[1]	14.3	15.4	17.1	18.9	20.1	21.9	23.2	24.7	25.7	26.0	26.7	28.4	30.4	32.0
France[2]	4.4	5.2	6.3	8.1	9.8	11.0	12.4	13.3	14.2	15.2	16.8	18.3	19.8	NA
West Germany[2]	3.6	4.4	5.3	6.5	7.8	8.7	9.6	10.4	12.1	14.5	17.4	19.8	22.0	24.0
United Kingdom[2]	.6	NA	NA	.8	NA	.9	1.0	1.0	1.1	NA	NA	NA	NA	NA
Japan[2]	NA	NA	321.1	NA	NA	NA	606.3	NA	933.2	NA	1,345.9	1,791.9	2,215.8	NA
U.S.S.R.[1]	3.8	4.3	4.9	5.4	5.8	6.3	7.2	7.9	9.3	9.9	11.0	12.2	13.3	13.9
	Gross National Product (national currency in billions)													
United States	520.1	560.3	590.5	632.4	684.9	749.9	793.9	864.2	930.3	977.1	1,054.9	1,158.0	1,294.9	1,396.7
France	320.0	367.2	412.0	456.7	490.0	532.0	574.0	629.0	723.0	808.0	899.0	1,007.6	1,145.6	NA
West Germany	332.6	360.1	384.0	420.9	460.4	490.7	495.5	540.0	605.2	685.6	761.9	834.6	930.3	995.0
United Kingdom	24.4	NA	NA	29.5	NA	33.2	35.0	37.7	39.7	NA	NA	NA	NA	NA
Japan	NA	NA	25,592.1	NA	NA	NA	45,296.7	NA	62,259.9	NA	81,577.0	94,726.5	115,263.1	NA
U.S.S.R.	NA	197.2	206.8	223.2	242.1	260.1	282.0	NA	329.6	362.6	394.8	401.8	429.4	453.7

[1] Expenditures for performance of R&D.
[2] Expenditures for performance of R&D plus associated capital expenditures.

SOURCES: Organisation for Economic Co-operation and Development, *International Survey of the Resources Devoted to R&D by OECD Member Countries* for 1963, 1967, 1969, and 1971.

France: Delegation Generale a la Recherche Scientifique et Technique, unpublished statistics.
Japan: Scientific Counselor, Embassy of Japan, Washington, D.C.
United Kingdom: Science and Technology Department, The British Embassy, Washington, D.C.
West Germany: Statistisches Bundesamt, unpublished statistics.
U.S.S.R.: Dr. Robert Campbell, Department of Economics, Indiana University.

percent of those with a family income of $10,000 or more in 1974 felt that science and technology do more good than harm, compared with an average of 58 percent for the groups having a lower income. With regard to solving problems in the future, groups with higher incomes tended to expect solutions from science and technology to a greater extent than the lower income groups. All groups generally expressed more satisfaction with science and technology in 1974 than in 1972, but felt less confident in their ability to solve major problems in the future.

in prestige than did the total sample. On the other hand, a somewhat larger percentage of the young in both surveys felt that science and technology have caused some of our problems--56 percent versus 50 percent of the total sample in 1974.

There are other differences, however, between the young and the total sample, but these do not bear so directly on matters or attitudes as on differences in concern and priority. The young in both surveys expressed

For The Most Part, Do You Feel That Science and Technology Will Eventually Solve Most Problems Such as Pollution, Disease, Drug Abuse, and Crime, Some of These Problems, or Few if Any of These Problems?

Percentage of group expressing

	"Most"		"Some"		"Few"		"No opinion"	
	1972	1974	1972	1974	1972	1974	1972	1974
All	32	24	51	55	17	21	7	4
Men	36	26	47	54	17	20	5	2
Women	29	23	54	59	18	20	9	5
18-29 yrs.	28	24	55	56	17	20	5	2
30-39	33	25	54	59	13	16	3	3
40-49	31	25	53	56	16	19	4	3
50-59	37	27	43	53	20	20	7	2
60 +	33	22	46	53	21	25	13	9
Less than high school	33	21	47	54	20	25	12	8
High school	29	25	55	56	16	19	4	2
Some college	35	28	51	58	14	14	3	1
Family income:								
Under $5,000	35	22	47	51	18	27	14	8
$5,000-$6,999	23	24	57	52	20	24	6	5
$7,000-$9,999	33	24	49	58	18	18	6	2
$10,000-$14,999	33	25	52	56	15	19	3	3
$15,000 or over	33	26	51	59	16	15	1	1

Attitudes of the young

The belief that young people of the Nation have negative attitudes toward science and technology gained considerable credence beginning in the late 1960's. To examine the current validity of this belief, responses of the young (18-29 years of age) to all questions of the survey were compared with responses of the total sample.

For the most part, attitudes of the young were closely similar to those of the total sample. Major differences from the sample as a whole were found in only two areas, one of which suggests a more positive attitude toward science and technology on the part of the young, whereas the other indicates a more negative assessment. In the first case, the young group (in both 1972 and 1974) rated "scientists" significantly higher

consistently more concern for the environment. The reduction and control of pollution was specified by 60 percent of the young group in 1974 as an area where they would most like to see their tax dollars spent, compared with 50 percent for the sample as a whole. "Lack of concern for the environment" was listed in 1974 as one of the "harmful" effects of science and technology by 31 percent of the young versus 25 percent of the total sample.

The young differed from the total sample in 1974 in their choice of areas for efforts in science and technology. "Improvement of education" was selected by 58 percent of the young compared with 48 percent of the total sample; "discovering new basic knowledge" was chosen by 29 percent versus 21 percent; and "finding better birth control methods" was selected by 25 percent versus 18 percent. In listing "least liked" "improving the safety of automobiles" fell from the choice of 38 percent of the public in 1972 to 29 percent in 1974.

Areas in which the public in 1974 indicated they would least like their taxes spent for science and technology were "space exploration," and "developing or improving weapons for national defense."

period. An increasingly large percentage of the public believed that science and technology had changed life for the better; a substantial and growing fraction expressed a feeling of satisfaction and hope with respect to science and technology; and scientists and engineers received high rankings among other occupations and professions, although the rankings of all groups were relatively high.

In Which of the Areas Listed Would You Most Like (and Least Like) to Have Your Taxes Spent for Science and Technology?

Response	*Percent choosing area*[a]			
	Most like		*Least like*	
	1972	*1974*	*1972*	*1974*
Improving health care	65	69	1	1
Reducing and controlling pollution	60	50	3	3
Reducing crime	59	58	2	2
Finding new methods for preventing and treating drug addiction	51	48	4	4
Improving education	41	48	4	3
Improving the safety of automobiles	38	29	5	8
Developing faster and safer public transportation for travel within and between cities	23	26	14	13
Finding better birth control methods	20	18	18	23
Discovering new basic knowledge about man and nature	19	21	15	14
Weather control and prediction	11	14	19	16
Space exploration	11	11	42	37
Developing or improving weapons for national defense	11	11	30	30
No opinion	6	3	13	7

[a] Multiple responses were accepted.

These opinions should be interpreted with caution. The relevance of science and technology for alleviating or solving the problems involved was not considered explicitly. Thus, the responses may reflect areas of general concern to the public without regard for the possible specific role of science and technology in dealing with them. Furthermore, the actual words used in describing the various areas may have a biasing effect; e.g., the word "weapons" in "developing or improving weapons for national defense" may have a negative connotation which accounts in part for the low preference for science and technology in this area.

Summary of the total group responses

The results of the survey provide reasonably clear answers to the three general questions addressed to the public. The regard for science and technology appears to be relatively high and to have grown slightly during the 1972-74 period. An increasingly large percentage of the public believed that science and technology had changed life for the better; a substantial and growing fraction expressed a feeling of satisfaction and hope with respect to science and technology; and scientists and engineers received high rankings among other occupations and professions, although the rankings of all groups were relatively high.

The results regarding the impact of science and technology are somewhat less positive, and differ little in the two surveys. A small majority expressed the belief that science and technology overall did more good than harm—although they were held responsible for at least some of our problems—while almost one-third thought the impact was about equally divided between beneficial and harmful effects. The extent of social control over science and technology, however, should remain as it is according to almost half those surveyed, whereas the need for greater control was expressed in nearly 30 percent of the responses.

The predominant expectation is for considerable achievement by science and technology in solving major problems, even though the level of expectation declined somewhat between 1972-74. In both years, slightly more than 75 percent of those surveyed expected science and technology to solve some or most of our current problems.

Rankings of Occupations

	1947[a]	1963[a]	1972	1974
Physician	1	1	1	1
Scientist	2	2	2	2
Engineer	7	6	3.5	3
Minister	4	5	3.5	4
Architect	5.5	4	6.5	5
Lawyer	5.5	3	5	6
Banker	3	7	6.5	7
Accountant	9	8	8	8
Businessman	8	9	9	9

[a] R. W. Hodge, *et al.*, "Occupational Prestige in the United States, 1925-63," *American Journal of Sociology*, Vol. 70 (1964), pp. 286-302.

In both 1972 and 1974, scientists held their relative ranking among occupations, second only to physicians, with engineers third. Against 1963 ratings, all occupations remained lower in both 1972 and 1974.

Impact of science and technology

This part of the survey explored several facets of the impact of science and technology as perceived by the public, including whether the overall impact is more positive than negative; identification of the science and technology activities which the public regards as good or harmful; the extent to which it feels science and technology cause problems; and whether the pace of change induced by science and technology is desirable. Following these questions, the public was asked to assess the adequacy of control that is exercised over science and technology.

Slightly more than half of those interviewed believed that science and technology do more good than harm. About one-third saw the extent of good and harm as being nearly the same, and only a negligible percentage said "more harm." Changes from 1972 to 1974 were slight.

Overall, Would You Say That Science and Technology Do More Good Than Harm, More Harm Than Good, or About The Same Each?

Response	Percent 1972	Percent 1974
More good	54	57
About the same	31	31
More harm	4	2
No opinion	11	10

Those responding "more good than harm" or "about the same" were asked, without prompting, to mention some "good thing" they thought science and technology had done, and the responses were then categorized. The results summarized below show that "medical advances" was by far the most frequently mentioned benefit, followed by "new and improved products" and "space research".

Benefits from Science and Technology (Cited by group responding "More good than harm")

Response	Percent citing[a] 1972	Percent citing[a] 1974
Medical advances	54	59
New and improved products	10	11
Space research	12	9
Environment and natural resources	6	4
Living and working conditions	5	3
Food and agriculture	4	2
Energy	1	2
Other	4	6
Don't know	4	4

Benefits from Science and Technology (Cited by group responding "About the same")

Response	Percent citing[a] 1972	Percent citing[a] 1974
Medical advances	50	48
New and improved products	8	15
Space research	9	9
Living and working conditions	5	6
Environment and natural resources	6	5
Food and agriculture	3	2
Energy	(b)	2
Other	3	6
Don't know	17	19

[a] Multiple responses were accepted.
[b] Less than 0.5 percent.

The group which believed that science and technology do about equal amounts of good and harm was asked, without prompting, to mention "one of the harmful things." These results, summarized below, show that "lack of concern for the environment" was most frequently mentioned as harmful, followed by "development of military weapons," "space research," and "dangerous drugs and medicines." Almost one-third of this group failed to offer an example of a harmful result from science and technology, whereas less than 20 percent of the same group failed to provide an example of a "good" result. (See the table just above).

Public Attitudes Toward Science and Technology

INDICATOR HIGHLIGHTS

- The belief that science and technology have changed life for the better was expressed by 75 percent of the public in 1974, compared with 70 percent in 1972; 5 percent saw the change as for the worse, down from 8 percent in 1972.
- In the public's ranking of nine professions and occupations, scientists were second only to physicians in both 1972 and 1974, with engineers in third place.
- Science and technology were believed to have done "more good" than "more harm" by 57 percent of the people in 1974, compared with 54 percent in 1972; 31 percent in both years saw the impact as about evenly divided between good and harm.
- Among people who believe science and technology do more good than harm, the largest group (59 percent in 1974 and 54 percent in 1972) cited improvements in medicine and medical research as the leading benefit; among those having the view that science and technology do more harm than good, "lack of concern for the environment" was the most frequently mentioned example (25 percent in 1974 and 27 percent in 1972).
- Science and technology were thought to have caused some of our problems by approximately half of the respondents in both 1972 and 1974; a smaller group (approximately 37 percent) believed that few or none of our problems were so caused, while a still smaller group (less than 8 percent) thought that science and technology were responsible for most of the problems.
- The pace of change produced by science and technology was viewed as "about right" by some 50 percent of the public in both 1972 and 1974, as too fast by about 20 percent of the people, and as too slow by a slightly smaller percentage.
- The public expects science and technology to solve, eventually, many of our major problems, although the fraction expecting most problems to be so solved declined from 30 percent in 1972 to 23 percent in 1974.
- Areas in which the public felt they would most like to have taxes spent for science and technology were health care, crime reduction, education, prevention of drug addiction, and pollution control; areas in which they would least like to have taxes spent for science and technology were "space exploration" and "developing and improving weapons for national defense."
- Demographic analysis of selected questions in the survey suggests that the most positive attitudes toward science and technology were held by men, persons between 30-59 years of age, those with some college education, and by people whose family income was $10,000 or more.

Among the black doctoral scientists and engineers, the largest proportion is involved primarily in teaching activities (40 percent), followed by administration (19 percent), and research and development (16 percent). This pattern of activity applies in each of the fields. Black doctoral scientists and engineers are employed for the most part by universities and four-year colleges (61 percent), with the next largest proportions employed by industry (13 percent) and the Federal Government (7 percent). This pattern is consistent across all fields. In comparison, about one-half of the white doctoral scientists and engineers are employed by universities and four-year colleges, with the next largest proportion (21 percent) employed by industry, and 8 percent employed by the Federal Government. Doctoral scientists and engineers who are American Indians also are primarily involved in teaching (69 percent) and employed by universities and four-year colleges.

Asian doctoral scientists and engineers exhibit quite different characteristics. They are primarily involved in research and development (41 percent), teaching (29 percent), and administration (7 percent). Compared with the other minorities, a greater proportion of Asians are employed by industry: 51 percent in universities and four-year colleges, 28 percent in industry, and 5 percent in the Federal Government.

These data suggest that there are characteristic patterns of involvement in science for selected minorities. Black scientists and engineers, for example, tend to be involved in social science and health science fields, and predominantly in teaching activities. In contrast, Asian Americans tend toward the physical sciences and engineering, and involvement in R&D activities.

An indication of the current participation of minority students in science and engineering graduate study is presented in the following table.[50] It should be pointed out that these data do not represent national totals, but they were reported by a significant proportion of doctorate-granting institutions.

Proportion of minorities in science and engineering graduate studies, by field, 1973

Field	Percent in each field		
	Black	American Indian	Asian
All science and engineering	2.5	0.3	2.1
Physical sciences	1.4	.2	2.6
Mathematical sciences	2.5	.2	2.1
Engineering	1.2	.1	3.3
Life sciences	1.5	.2	1.9
Health professions	5.5	.6	2.0
Social sciences and psychology	4.1	.3	1.1

In analyzing the proportion of black students enrolled in each field, it is apparent that the health professions and social sciences attract the largest percentage of black graduate students, while engineering, physical sciences, and life sciences attract the lowest proportion. In contrast, the Asian graduate students enroll in higher proportions to study engineering and the physical sciences, and are less involved in the social sciences.

[50] Elaine H. El-Khawas and Joan L. Kinzer, *Enrollment of Minority Graduate Students at Ph.D.-Granting Institutions*, (Washington, D.C.: American Council on Education, 1974).

Percent distribution of women scientists and engineers, by field, 1974[42]

Field	Percent of total
Psychologists	28
Social scientists	21
Mathematical scientists	15
Life scientists	13
Computer scientists	12
Physical scientists	8
Environmental scientists	3
Engineers	1

Women scientists and engineers were most likely to be involved in psychology and the social sciences, and least likely to work in engineering and in the environmental and physical sciences.

A somewhat different pattern of employment of women scientists and engineers exists in the academic sector. In 1974, 15 percent of the scientists and engineers employed full-time[43] at colleges and universities were women; 16 percent of the scientists and 1 percent of the engineers. The proportion of women in each field of science varies widely, as shown in the table below.

Women comprise 21 percent of both the life scientists and the psychologists, but less than 10 percent of both the physical and environmental scientists. In the case of doctorate-granting institutions alone, the level of employment of women is somewhat lower than in colleges and universities as a whole.

Women in graduate education

An increasing number of women are pursuing advanced studies in science and engineering (figure 5-23). Between 1965 and 1974, the number of women receiving doctoral degrees in science and engineering increased by almost 250 percent, from 744 to 2,590. This absolute growth also represents an increase in the share of science and engineering doctorates earned by women, the proportion growing from 7 percent in 1965 to 14 percent in 1974. By 1974, women were awarded 24 percent of the doctorates in the social sciences, and 18 percent in the life sciences, but 10 percent or less in the mathematical sciences, physical sciences and engineering.[46] The proportion of women students enrolled for

Full-time women scientists and engineers employed by universities and colleges, by field, 1974[44]

Field	All institutions		Doctorate institutions	
	Number of women	Percent women in each field	Number of women	Percent women in each field
All scientists and engineers	35,083	15	20,896	14
Engineers	311	1	260	2
Physical scientists	1,912	7	801	5
Chemists	1,378	10	526	7
Physicists	392	4	197	3
Other physical scientists	142	7	78	6
Environmental scientists[45]	319	5	195	5
Mathematical scientists	2,825	13	856	9
Life scientists	19,264	21	14,605	19
Agriculture	1,796	13	1,757	15
Biological	5,550	18	3,379	16
Medical	11,918	25	9,469	22
Psychologists	3,067	21	1,132	17
Social scientists	7,385	15	3,047	13

[42] National Science Foundation, special tabulations.

[43] Data for part-time women scientists and engineers are not available.

[44] *Manpower Resources for Scientific Activities at Universities and Colleges, January 1974*, Detailed Statistical Tables, National Science Foundation (NSF 75-300-A).

[45] Includes earth scientists, oceanographers, and atmospheric scientists.

[46] For further, more recent information on this topic see Joseph L. McCarthy and Dael Wolfle, "Doctorates Granted to Women and Minority Group Members", *Science*, Vol. 189, (1975), pp 856-859.

and training grants in recent years.[39] Rather than providing direct student aid, there has been a tendency to rely more heavily on graduate student participation in federally funded research projects that support areas of national concern. Thus, Federal obligations for fellowships, traineeships, and training grants declined from $421 million in 1971 to $287 million in 1973. These funds rose again in 1974 to $327 million, largely because approximately $85 million of funds impounded in 1973 were released to HEW in 1974.

Among Federal agency programs affected by the shifts in funding were the Office of Education's student programs under the National Defense Education Act, NSF's traineeship program, and NASA's traineeship program. As a result, obligations by the Office of Education declined from $52 million in 1971 to $41 million in 1972, and after the termination of National Defense Education Act awards, to $10 million in 1973. NSF's support of fellowships and traineeships dropped from $42 million in 1971 to $16 million in 1973, and NASA's traineeship program was virtually eliminated.

Reductions in Federal support of fellowships, traineeships, and training grants were spread across all fields of science. The largest absolute decrease occurred in the life sciences, which dropped from $225 million in 1971 to $179 million in 1973.

Immigrant scientists and engineers

Another source of supply of scientists and engineers are those persons achieving immigrant status in the United States. Approximately 6,600 scientists and engineers immigrated to the United States in 1973. These numbers (see the table below) represent a reduction from the high 1966-72 yearly inflows resulting from revisions in October 1965 in the national immigration laws.

Scientists and engineers immigrating to the United States, annual average, 1949-73[40]

Period	Total	Engineers	Natural scientists	Social scientists
1949-65 ..	4,053	2,851	1,048	154
1966-72 ..	11,531	7,993	2,973	565
1973	6,632	4,443	1,790	399

[39] *Federal Support to Universities, Colleges, and Selected Nonprofit Institutions,* National Science Foundation, annual series.

[40] "Immigration of Scientists and Engineers Drops Sharply in FY 1973; Physician Inflow Still Near FY 1972 Peak", *Science Resources Studies Highlights,* National Science Foundation (NSF 74-302), March 29, 1974, and earlier reports of the series.

In February 1971, the existing system of "precertification" of prospective immigrants came to an end under U.S. Department of Labor regulations. This change did not bring about an immediate reduction in immigration because large numbers of foreign scientists and engineers, in anticipation of this legislation, had become precertified for immigration and eligible to enter the United States. There were enough of these scientists and engineers "in the pipeline" to maintain a high inflow of immigration through 1972, but the number of immigrant scientists and engineers has fallen sharply since that year.

Over the period 1966-68, the largest numbers of immigrant scientists and engineers came to the United States from developed nations. After that time, the situation changed, with by far the largest numbers coming from the developing nations.

WOMEN AND MINORITIES IN SCIENCE AND ENGINEERING

Women employed in science and engineering

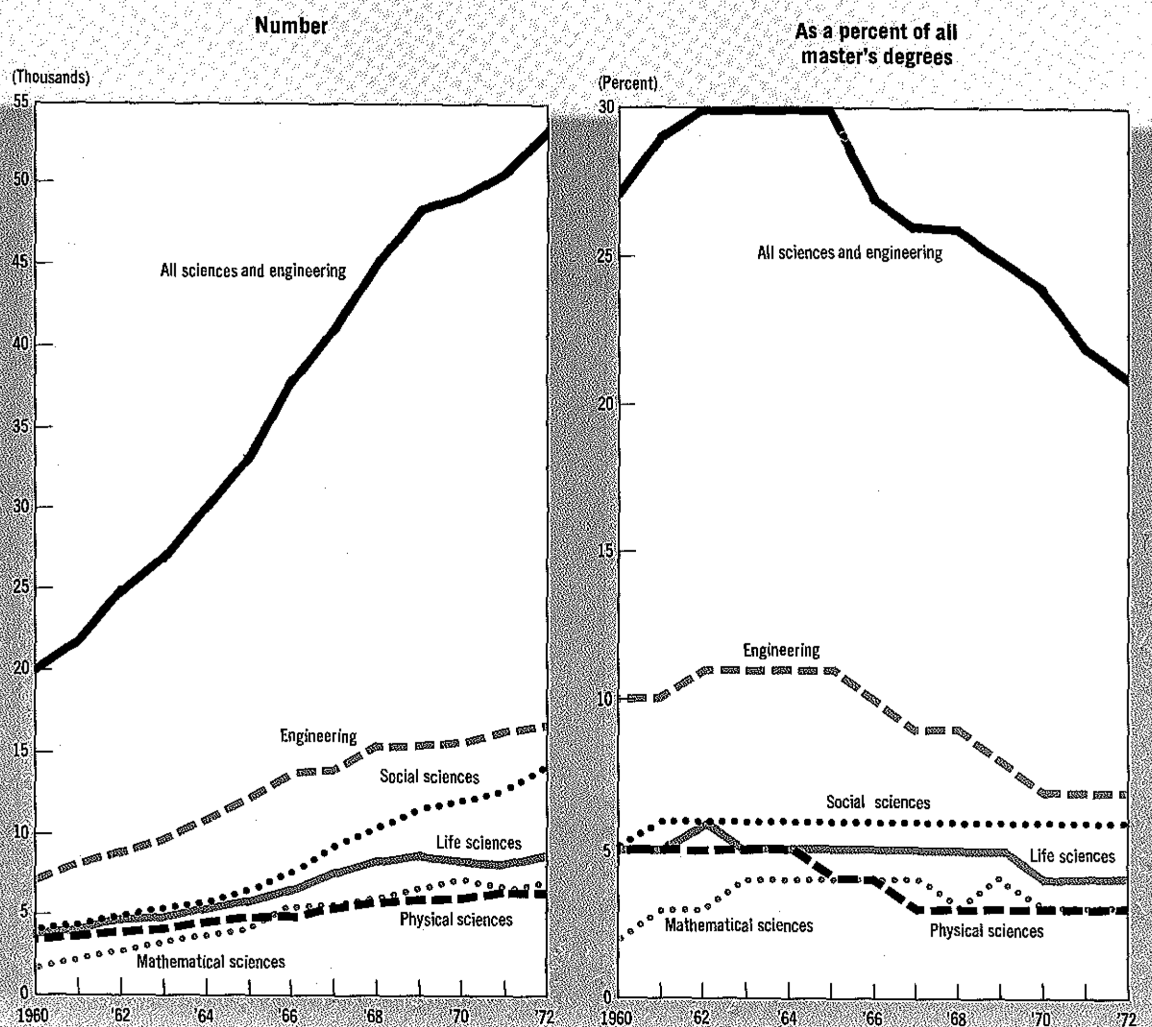
Increasing interest has been expressed in recent years in the opportunities for participation of women in science and engineering. Despite the widespread interest, however, relatively little information is available on the subject, particularly those that allow the examination of trends over time. This section presents some data concerning the employment of women in science and engineering occupations, women receiving doctorates in these areas, and women enrolled for advanced degrees in the sciences and engineering.

In 1974, women comprised 5 percent of the persons employed in science and engineering occupations, compared with 39 percent of the total civilian work force, and 41 percent of the professional and technical workers.[41] Large differences exist in the level of employment of women among the various fields of science and engineering, as shown in the table below.

[41] The category of professional and technical workers includes occupations such as accountant, lawyer, nurse, physician, and teacher. In 1970 (the most recent year for which comparable data are available), the proportions of all lawyers who were women (5 percent) and the proportion of all physicians who were women (9 percent) were relatively similar to that for scientists and engineers (5 percent).

Figure 5-21

Master's degrees in science and engineering, 1960-72



SOURCE: National Center for Educational Statistics and National Science Foundation.

percent in 1965 to 21 percent in 1972; the largest proportional declines occurred in engineering and the physical and life sciences.

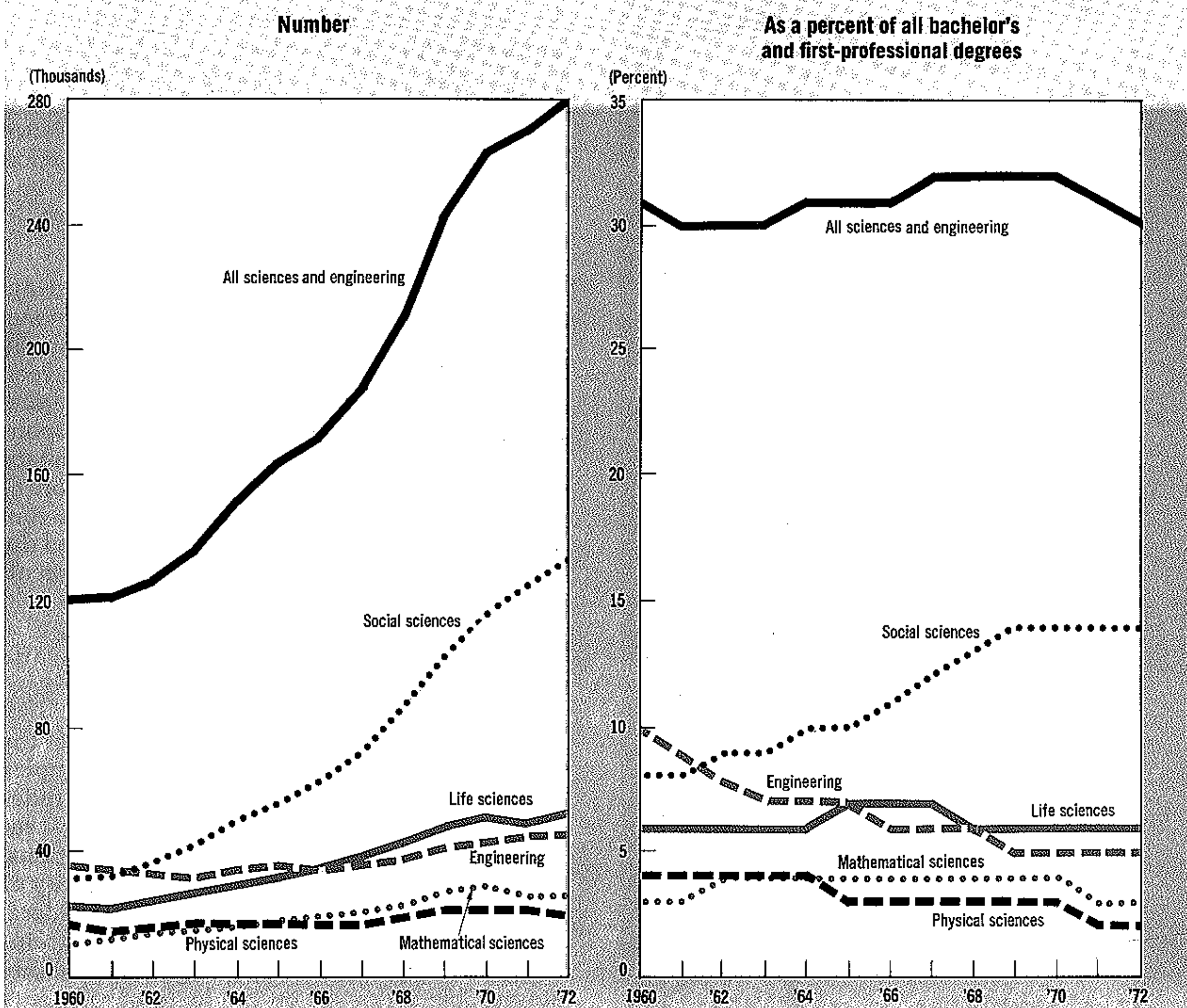
Doctoral degrees awarded

Annual awards of doctorates are shown in figure 5-22. Science and engineering degrees accounted for the majority of all doctorates awarded between 1965 and 1974, but their share fell from a high of 64 percent in 1964 to 56 percent in 1974. The number of men receiving doctoral degrees decreased in 1974, and although there was an increase in women doctorates it was not great enough to offset the drop for men.

Changes in major areas of science over the 1965-74 period are shown in figure 5-22. The physical sciences exhibited the slowest growth throughout the period and the largest decline in recent years; the number of physical science doctorates awarded dropped almost 20 percent from 1971 to 1974. Much of this decline is due to

Figure 5-19

Bachelor's degrees in science and engineering, 1960-72



SOURCE: National Center for Educational Statistics and National Science Foundation.

engineering. As a result, enrollment for advanced degrees in science and engineering fields as a proportion of all advanced degree enrollment declined from 38 percent in 1960 to 28 percent in 1972 (figure 5-20). Engineering and the physical sciences accounted for most of this decline.

Related data, though not strictly comparable to those of the National Center for Educational Statistics, illustrate the direction of more recent trends in graduate enrollment. Data collected by NSF from institutions granting science and engineering doctorates indicate that the number of full-time graduate students in these fields decreased steadily from 1969 to 1974. Data from this fall 1974 survey indicate that full-time graduate science enrollment increased about 5 percent over fall 1973, the first increase since part-time. In late 1974, the unemployment level for engineers alone was still only 1.9 percent.

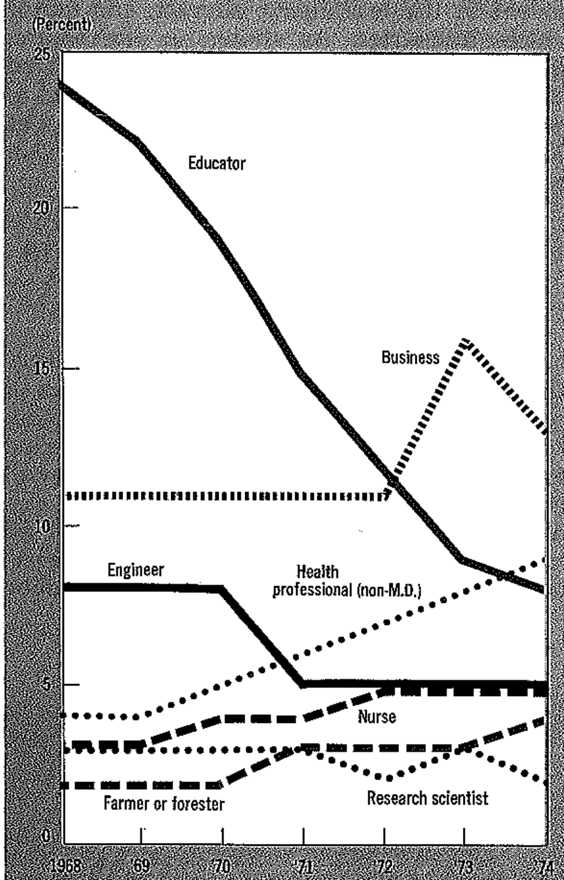
Unemployment rates express only a part of the overall situation. The national unemployment rate, for example, is expressed in terms of occupation last held. In some cases an individual scientist or engineer may have previously taken a nonscience or nonengineering job before becoming unemployed and would therefore not be reported as a scientist or engineer. Unemployment levels, furthermore, do not indicate the extent of employment (part-time employment may be involuntary) nor the degree of underutilization in positions requiring lesser skills than individuals possess. In addition, in most instances it has not been possible to measure the difficulty or the length of time required for obtaining employment for scientists and engineers who are first entering the job market or for those who are changing jobs.

SUPPLY OF SCIENTISTS AND ENGINEERS

Early student interest in science and engineering

Information concerning occupational preferences of college freshmen provides an early indicator of student interest in science and engineering.[33] In recent years, interest has decreased in the occupations of research scientist, engineer, and educator, while increasing in those of medical doctor, nurse, and non-M.D. health professional (figure 5-17).

Figure 5-17
Occupational preference of college freshmen, 1968-74



Source: American Council on Education and University of California, Los Angeles.

A second indicator of early interest in science and engineering is the choice of college majors by National Merit Scholars as they enter college (figure 5-18). The proportion of these students planning to enter science and engineering increased from 62 percent to 70 percent between 1966 and 1974. Between 1972 and 1974, however, there was a decline of two percentage points in the proportion of National Merit Scholars choosing science as a major, while over this same period, there was an increase of nearly three percentage points in those planning to major in engineering.

The earliest information about undergraduate enrollments by major field is obtainable in a student's junior year. One study shows that total junior-year undergraduate enrollment increased by 3.2 percent in the fall of 1972 over the fall of 1971.[34] The number of students majoring in various science and engineering fields increased about 4.5 percent. Life science majors increased by more than 12 percent. Social science majors increased about 6 percent, and in the fall of 1972, they accounted for 47 percent of the science and engineering majors. Fewer students chose majors in engineering, mathematical sciences, and physics, while small increases occurred in chemistry and other physical science majors in the fall of 1972.

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[33] *The American Freshman: National Norms,* American Council on Education and University of California, Los Angeles, annual series.

[34] J. E. Dutton and B. A. Blandford, *Enrollment of Junior-Year Students (1971 and 1972),* (Washington, D.C.: American Council on Education, 1973).

example, more than three-fourths of the faculty investigators in biochemistry, but only one-fourth of those in sociology, were doing research connected with federally supported projects in 1974.

Proportion of faculty investigators performing R&D connected with Federal grants and contracts, by field, 1974

Field	Percent whose research was federally supported
All fields	56
Biochemistry	78
Physiology	75
Microbiology	74
Physics	72
Electrical engineering	71
Chemical engineering	65
Biology	62
Geology	59
Chemistry	58
Zoology	52
Psychology	43
Mathematics	42
Botany	42
Economics	30
Sociology	26

R&D in industry

The number of R&D scientists and engineers (on a full-time equivalent basis) in industry was at its highest level in 1969, declined in later years through 1972, and then increased in 1973 and 1974, bringing the number to approximately its 1971 level (360,000, or 68 percent of all R&D scientists and engineers).[30] The recent increases occurred primarily in the chemical, machinery, and electrical equipment industries; the largest decline since 1969 occurred in the aircraft and missiles industry.[31] These four industries are among the leading industrial employers of R&D scientists and engineers, accounting for almost 70 percent of the industrial total in 1974.

The Federal Government is a major source of support for industrial R&D activities; 32 percent of industrial R&D scientists and engineers were supported by Federal funds in 1974 (figure 5-15).

[30] These and other aspects of industrial R&D are covered more fully in another chapter in this report entitled, "Industrial R&D and Innovation".

[31] See Appendix table 4-9b.

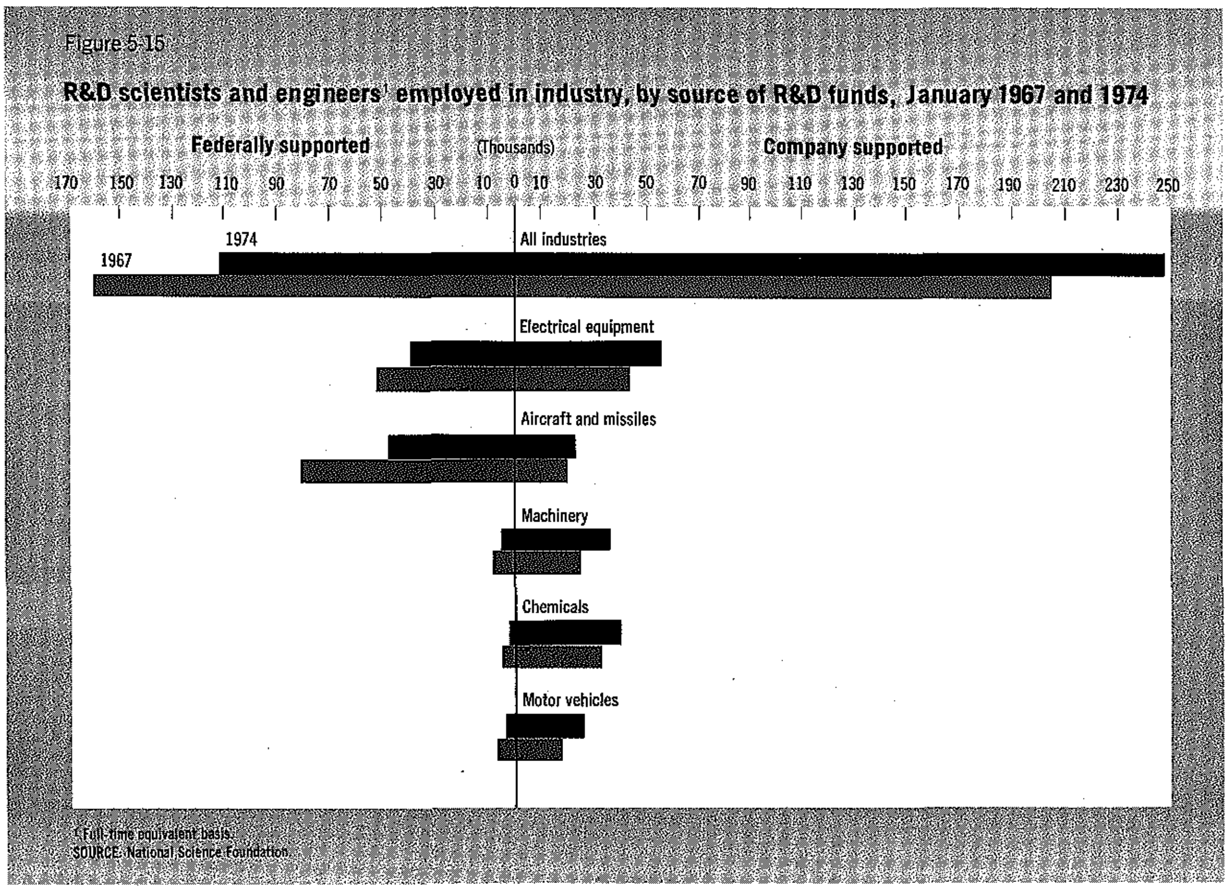
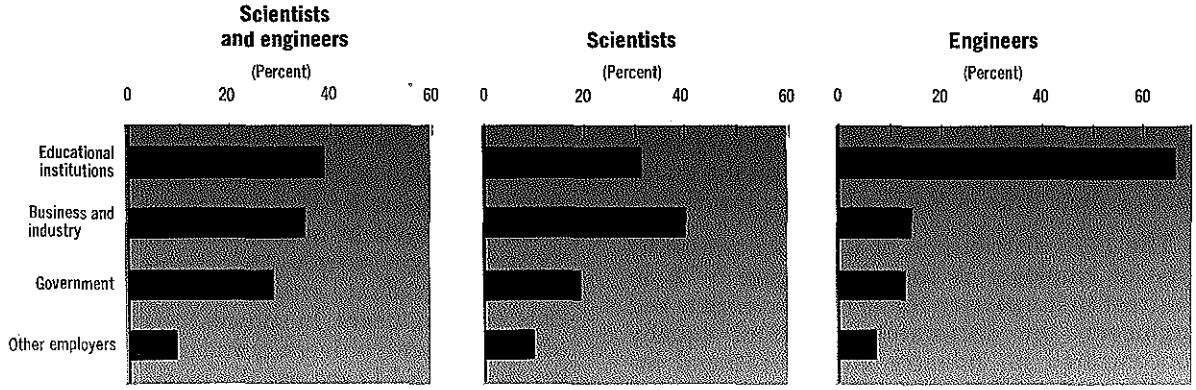


Figure 5-12

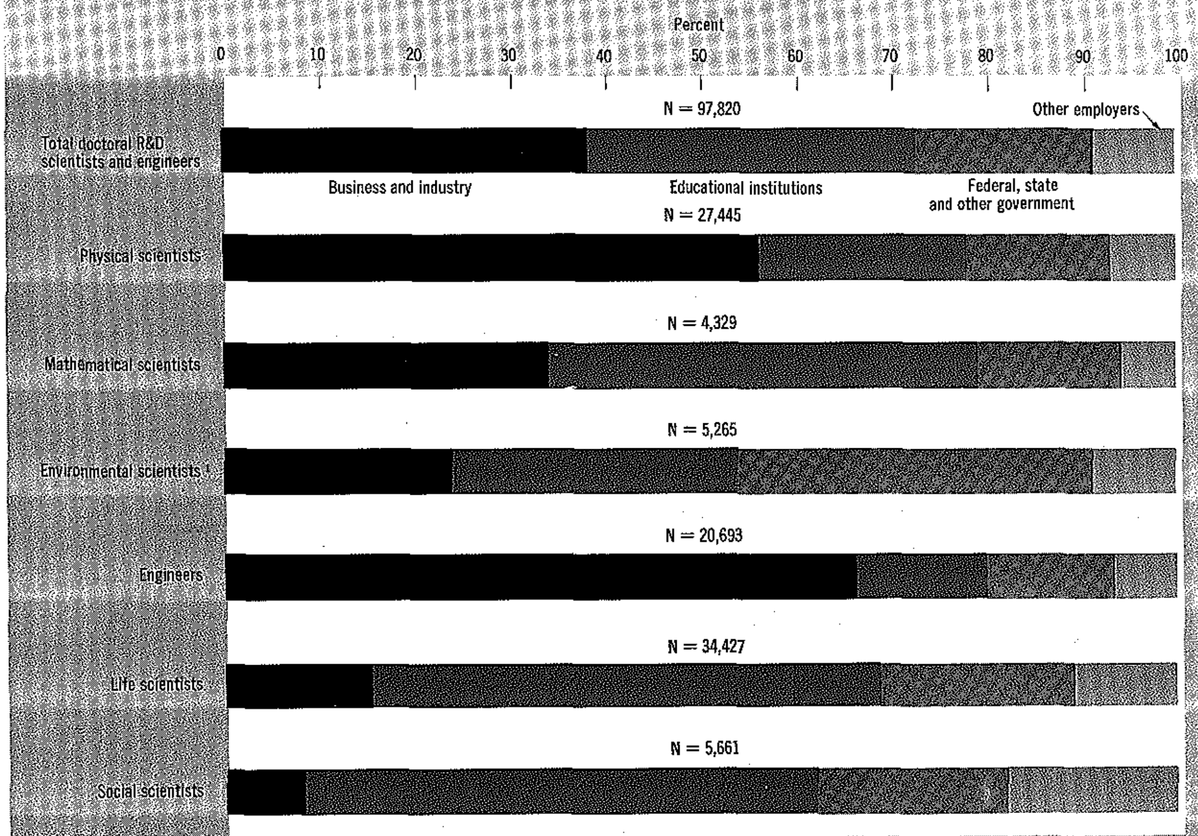
Doctoral R&D scientists and engineers, by type of employer, 1973



SOURCE: National Science Foundation.

Figure 5-13

Distribution of doctoral R&D scientists and engineers, by field and type of employer, 1973



[1] Includes earth scientists, oceanographers, and atmospheric scientists.
SOURCE: National Science Foundation.

the Department of Defense, with another 17 percent provided by the National Aeronautics and Space Administration. With the exception of life and environmental scientists, engineers and scientists in industry received their major Federal support from the Department of Defense.

Employment of scientists and engineers in the Federal Government

Nearly 10 percent of all scientists and engineers are employed by U.S. Government agencies. The number of Federal scientists and engineers in 1973 declined by 3 percent over 1972 to 162,000, the first sizable annual reduction since data were initially collected in 1954.[21]

The major agencies employing scientists and engineers are shown below in terms of the percentage of the total employed by each during 1973.

Distribution of Federal scientists and engineers, by agency, 1973

Agency	Percent
DOD	45
USDA	15
Interior	8
NASA	7
Commerce	4
HEW	4
All other agencies	16

Of all Federal scientists and engineers, some 30 percent were employed in R&D positions in 1973. Those engaged in research consisted of nearly 19,000 scientists and some 4,000 engineers, whereas development activities employed nearly 19,000 engineers and over 6,000 scientists.

Employment of scientists and engineers in nonprofit institutions

These institutions[22] employ only about 1 to 2 percent of the national total of scientists and engineers. By 1973, employment of scientists and engineers in this sector reached approximately 26,300, an increase of some 20 percent since 1965.[23] In contrast to trends reported in the academic sector, virtually all of the increase in independent nonprofit institutions was attributable to personnel who worked primarily in research and development; this group of personnel comprised nearly 90 percent of all scientists and engineers employed in such institutions.

RESEARCH AND DEVELOPMENT PERSONNEL

Total scientists and engineers in R&D

An estimated 530,000 scientists and engineers were engaged in R&D activities on a full-time equivalent basis in all sectors of the economy in 1974. This number accounts for approximately one-third of all employed scientists and engineers.[24]

Over the past two decades, the employment of these R&D scientists and engineers grew at an average annual rate of 4.1 percent, 1.6 times faster than the rate of growth of total civilian employment. In 1969-70, however, the long-term growth trend was reversed as the number of R&D scientists and engineers declined and national R&D expenditures in constant dollars decreased. Between 1973 and 1974, R&D scientist and engineer employment increased by nearly 5,000, reversing the downward trend slightly. The 1974 employment level, however, was over 30,000 short of the peak employment level reached in 1969.

Doctoral scientists and engineers in R&D

Approximately 90,000 of the science and engineering doctorates in the 1973 U.S. labor force cited R&D or R&D management as their primary work activity.[25] While some one-third of all scientists and engineers were engaged in R&D, the proportion of doctorates primarily

[21] "Federal Scientific and Technical Personnel Decline in 1973", *Science Resources Studies Highlights*, National Science Foundation (NSF 74-316), October 18, 1974.

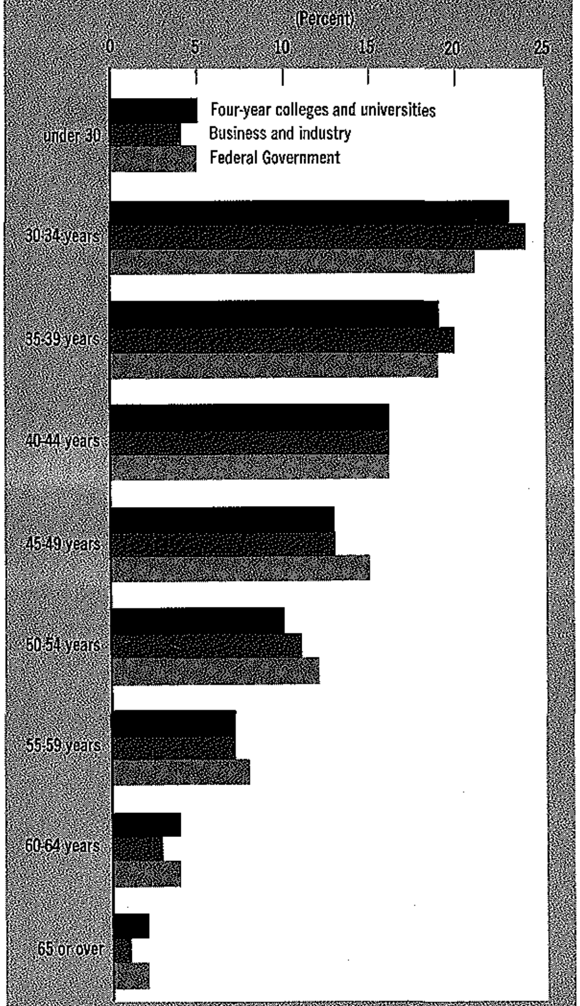
[22] Which include research institutes, hospitals, and Federally Funded Research and Development Centers administered by nonprofit institutions.

[23] *R&D Activities of Independent Nonprofit Institutions, 1973*, National Science Foundation (NSF 75-308).

[24] See Appendix table 2-2 and *National Patterns of R&D Resources, 1953-75*, National Science Foundation (NSF 75-307).

[25] *Characteristics of Doctoral Scientists and Engineers in the United States, 1973*, National Science Foundation (NSF 75-312).

Figure 5-9
Age distribution of doctoral scientists and engineers, by type of employer, 1973



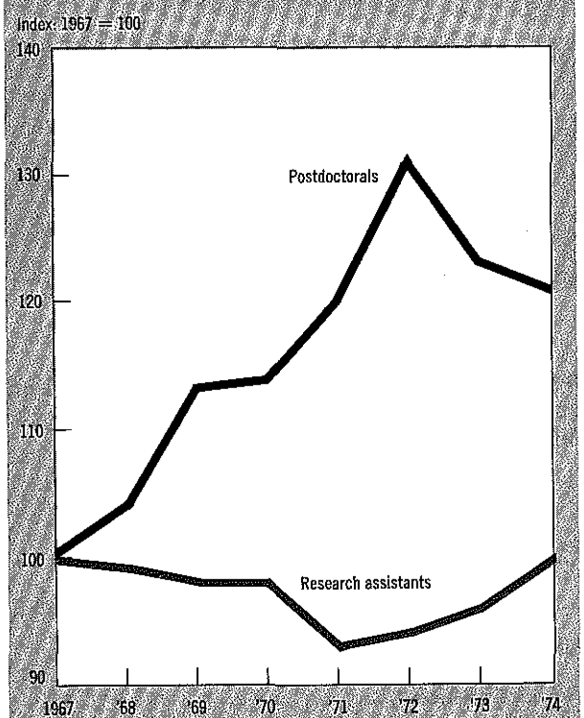
SOURCE: National Science Foundation.

baccalaureate and the doctorate has been approximately 7 to 8 years.[17]

Inherent in the age and tenure data is an implication that the pattern in many fields over the next 5 to 10 years may be that of a relatively senior faculty, the great majority of whom will be tenured. However, it is possible that for some fields these recent trends could be reversed if in the future, replacement openings for science and engineering faculty caused by death and retirement are filled extensively with new junior faculty on academic staffs.

Utilization of postdoctoral personnel. Between 1967 and 1974, the number of science and engineering postdoctorals, as indicated by a survey of representative science and engineering departments in doctorate-granting institutions, increased by 21 percent, reaching almost 17,000 in 1974 (figure 5-10).[18] The reasons for these increases may have changed midway during this period. In the late 1960's, universities provided increasing numbers of

Figure 5-10
Postdoctorals and research assistants in science and engineering departments at doctorate-granting institutions, 1967-74



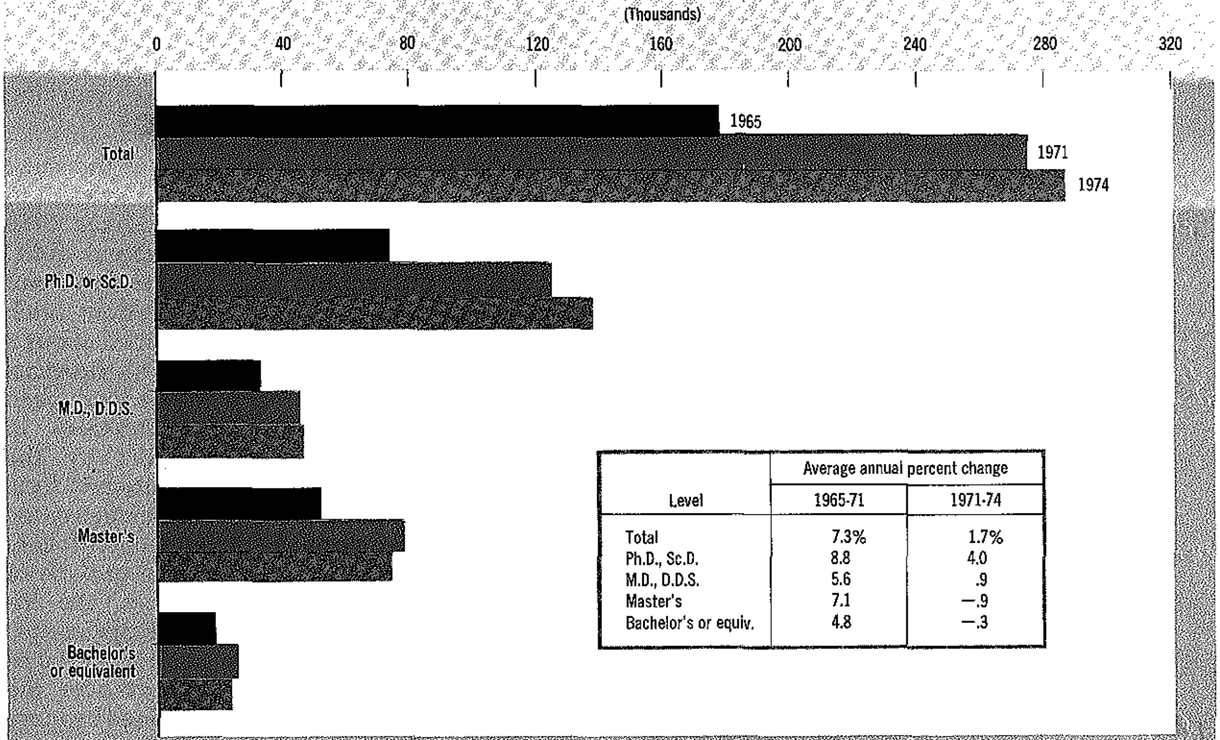
SOURCE: National Science Foundation.

[17] *Doctorate Recipients from U.S. Universities: Summary Report*, National Academy of Sciences, annual series.

[18] The indices for 1967-71 are estimates based on applications submitted to NSF for its departmental traineeship program. Indices after 1971 were collected by the "Survey of Graduate Science Student Support and Postdoctorals" for matched departments.

Figure 5-6

Employment of academic scientists and engineers, by level of attainment, 1965-74



Level	Average annual percent change 1965-71	1971-74
Total	7.3%	1.7%
Ph.D., Sc.D.	8.8	4.0
M.D., D.D.S.	5.6	.9
Master's	7.1	−.9
Bachelor's or equiv.	4.8	−.3

SOURCE: National Science Foundation.

by 8 percent from 1968 to 1974. However, the young doctorate faculty proportions declined in all seven fields, while even the absolute numbers of young doctorate faculty decreased in 5 of the fields, biology and psychology being the only exceptions.

Proportion of young[13] doctoral faculty in doctoral level science and engineering departments in universities and colleges, by selected fields, 1968 and 1974

Selected fields	Young doctoral faculty as a percent of all doctoral faculty 1968	1974
Biology	32	27
Chemistry	35	21
Economics	43	34
Electrical engineering	52	27
Mathematics	52	36
Physics	40	19
Psychology	43	37

[13] Those who had held doctorates for seven years or less at the time of each study.

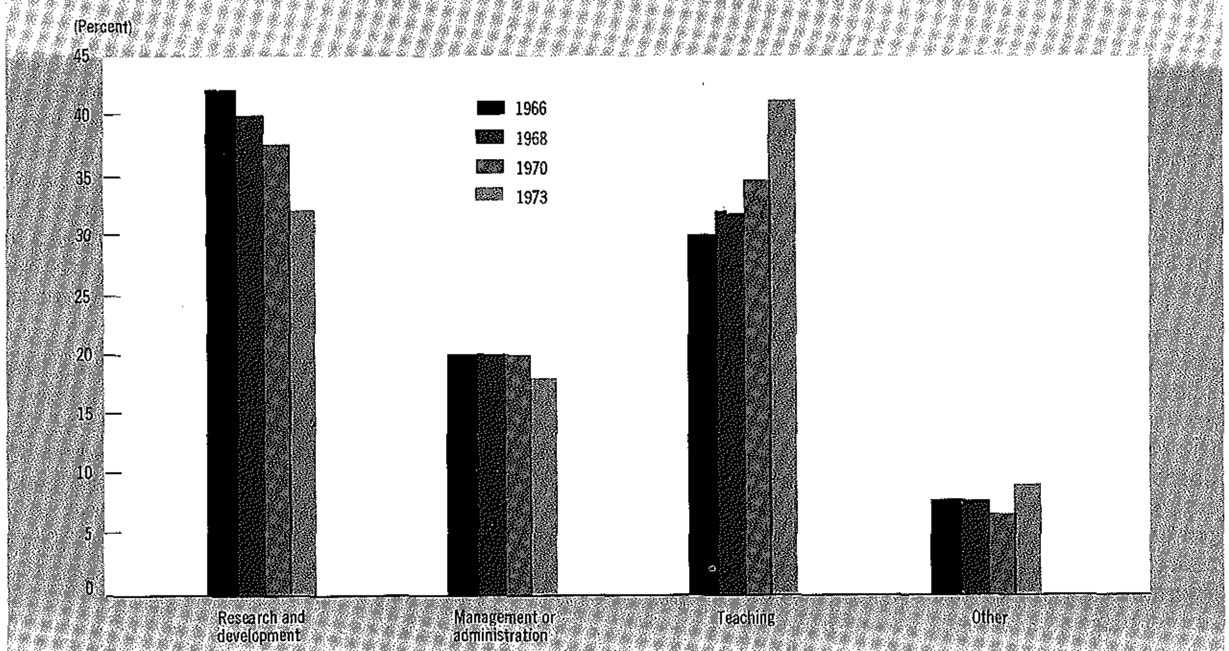
Another recent trend is the substantial increase in the proportion of faculty with tenure. An American Council on Education study[14] found in 1973 that 65 percent of the faculty in all fields were tenured, compared with 47 percent in 1969. Figure 5-8 presents more recent NSF data which show the 1974 proportions of tenured faculty in doctoral level science and engineering departments for 15 fields. Overall, 70 percent of these faculty have tenure, with the proportions ranging from a high of 81 percent in chemical engineering to 59 percent in physiology.

Between 1969 and 1973, the median age of faculty in science and engineering fields employed in doctorate-granting institutions rose from 41 to 44 years.[15] Changes in the

[14] Alan E. Bayer, *Teaching Faculty in Academe: 1972-73*, (Washington, D.C.: American Council on Education, 1973).

[15] Bayer, *Ibid.*, and Alan E. Bayer, *College and University Faculty: A Statistical Description*, (Washington, D.C.: American Council on Education, 1970).

Figure 5-4
Estimated percent distribution of doctoral scientists, by primary work activity, 1966-73



SOURCE: National Science Foundation.

to nonscience occupations. Between 10-30 percent of the doctorates in each field are employed in fields different from their doctorate field. The fields of bioscience, mathematics, and psychology experience the highest retention rates, with approximately 90 percent of the doctorates in these fields still employed in the same field of their doctorate, while physics and chemistry have the lowest retention rates (approximately 70 percent). Data on shifts to nonscience occupations show 11 percent of the doctoral social scientists changing fields, compared to 6 percent of the doctoral chemists and doctoral psychologists.[8]

Academic employment of scientists and engineers

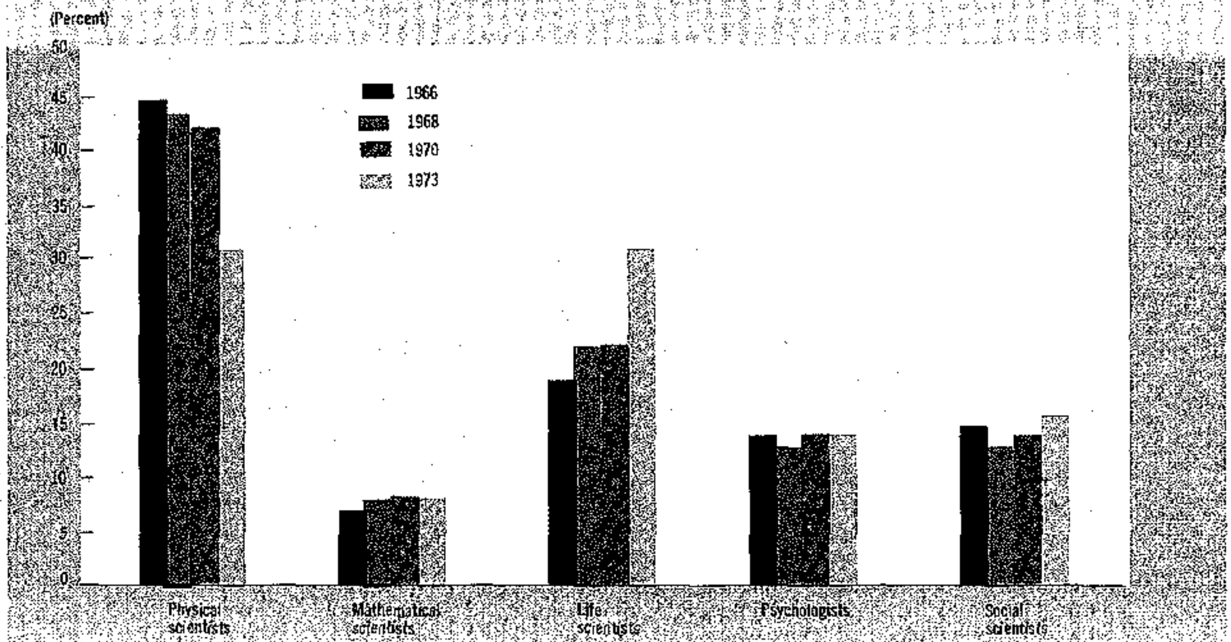
Universities and colleges employed about 288,100 scientists and engineers in 1974 (including full-time and part-time personnel), an increase of 61 percent over the 178,900 employed in 1965. Most of the growth occurred between 1965 and 1971, with increases in all scientific disciplines. The average annual rate of growth in academic employment of scientists and engineers between 1971-74 was only 1.7 percent compared with 7.3 percent during 1965-71. In absolute terms, the largest growth occurred in the employment of life scientists and social scientists, which together accounted for more than three-fifths of the overall increase between 1965-74 (figure 5-5). In two fields, engineering and social sciences, there were small declines in employment from 1973 to 1974.

As demand slackened for academic employment during the early 1970's, the attainment of the doctoral degree in the sciences and engineering became increasingly important as a requisite for employment in this sector. Since 1971, academic scientists and engineers with Ph.D.'s or health profession doctorates increased about 10 percent, compared with small declines in the employment of persons with master's or bachelor's degrees (figure 5-6). Between 1965 and 1974, employment of doctorates in universities and colleges increased by more than 60

[8] *Doctoral Scientists and Engineers in the United States, 1973 Profile*, National Academy of Sciences, 1974.

Figure 5-1

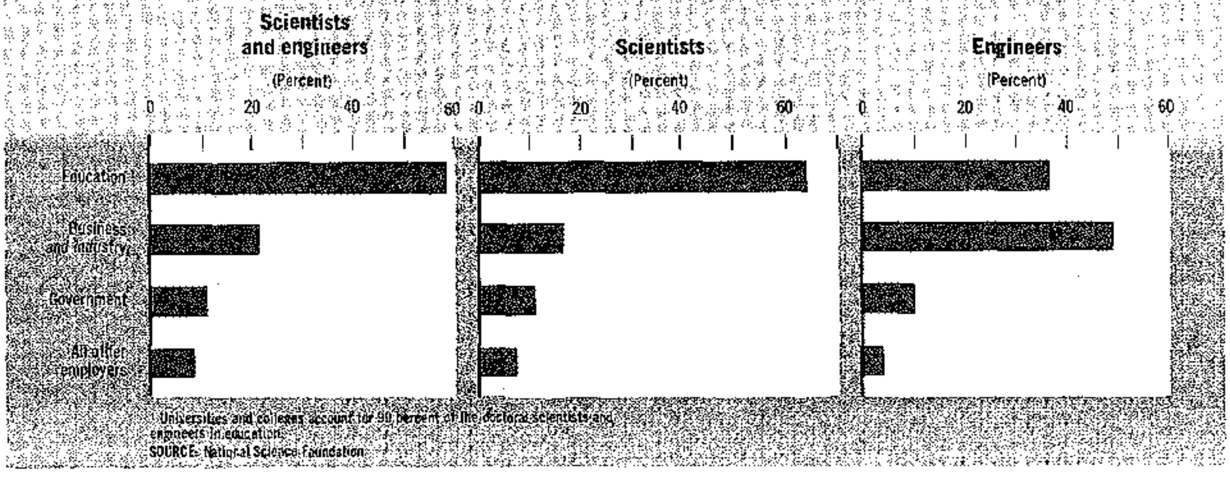
Estimated percent distribution of doctoral scientists, by field, 1966-73



SOURCE: National Science Foundation.

Figure 5-2

Percent distribution of employed doctoral scientists and engineers, by employment sector, 1973



[1] Universities and colleges account for 90 percent of the doctoral scientists and engineers in education.

SOURCE: National Science Foundation.

engineering, or influence those already in these fields to move from one type of employment to another. The present lack of such indicators, it is hoped, will be remedied in the future as improved methodologies are developed for measuring these aspects.

The measures of quantitative characteristics presented here are themselves less than complete.[1] In the case of the utilization of scientists and engineers, for example, data are not available after 1970 with respect to industrial employment. Data are also lacking on new baccalaureates and masters entering the market since 1970. Information on the specific activities of scientists and engineers, especially those in the academic sector, are limited by the current inability to obtain full-time equivalent (FTE) data on major activities such as R&D and teaching, by field of science. The surrogate measure of numbers of scientists and engineers "primarily involved" in an activity provides a useful but relatively crude measure of this factor. In the case of supply, the latest data on the production of baccalaureate and masters degrees from the National Center for Educational Statistics covers the 1972-73 period.

CHARACTERISTICS AND UTILIZATION OF SCIENCE AND ENGINEERING PERSONNEL

Employment of scientists and engineers

Employment of scientists and engineers stabilized in the first years of the 1970's, after increasing substantially for several decades.[2] During the 1950's, the number of scientists and engineers doubled, rising from about 600,000 to nearly 1.2 million. In the 1960's, employment grew by almost as much in absolute terms, from about 1.2 to over 1.7 million; the relative gain, however, was only about half that of the 1950-60 decade. Furthermore, between 1960 and 1970 the number of scientists grew significantly faster than the number of engineers (75 and 38 percent respectively), partially as a result of substantial gains in social science fields.

[1] Some of these deficiencies are expected to be corrected during the next year through the new National Science Foundation—Bureau of the Census surveys of industrial employment and the complete implementation of the National Science Foundation Manpower Characteristics System.

[2] *Employment of Scientists and Engineers, 1950-70*, Bureau of Labor Statistics, Department of Labor, 1973.

Beginning in 1969, growth in total employment of scientists and engineers slowed and then remained relatively level until about mid-1972. The factors underlying these changes include cutbacks in defense, space, and associated R&D spending in these areas, the general economic climate, and the beginning of a slowdown in academic hiring. Though employment in some sectors continued to increase—namely, higher education and government (particularly State and local)—little if any growth occurred in industry, the major sector of employment for scientists and engineers. Unfortunately, no specific measurements of industrial employment of scientific and technical personnel have been taken since 1970, though a survey is being reinstated by the National Science Foundation. However, by using information on past trends and relationships and several related sources of information, it has been possible to prepare estimates of the probable level of industrial employment of scientists and engineers for 1972. Using these estimates, together with information on nonindustrial sectors of employment, it is thus possible to estimate the total number of scientists and engineers employed in 1972. The available data do not permit estimates to be made for more recent years.

In 1972, estimated overall employment of scientists and engineers stood at about 1.7 million, approximately the same as in 1970. In the first years of the 1970's, employment in the sciences continued to grow slightly while engineering employment declined somewhat between 1970 and 1972. These overall patterns of change include minor shifts in the sectoral distribution, with university and college and Government employment gaining while the proportion declined for the industrial sector.

Although recent information is not available on an overall and detailed basis for scientists and engineers, selected information about such personnel is provided by the National Science Foundation's National Sample of individuals in science and engineering jobs. A sample was drawn from the 1970 Census of Population and used for the 1972 and 1974 surveys; the results provide information on a large portion of the Nation's science and engineering personnel.

An estimate of the distribution of these personnel among fields of science and engineering was obtained from the 1974 survey, and is shown below.

Science and Engineering Personnel

INDICATOR HIGHLIGHTS

- The total number of scientists and engineers employed in these occupations in 1974 was approximately 1.7 million, which is nearly the same as in 1970, with engineers representing nearly two-thirds of the total.
- The number of scientists and engineers with doctorates reached approximately 245,000 in 1973, representing almost 15 percent of all scientists and engineers; life and physical scientists each accounted for one-fourth of the doctoral total.
- The majority of doctoral scientists in 1973 were employed in educational institutions (64 percent), and primarily engaged in teaching, while doctoral engineers tended to be concentrated in business and industry (49 percent) and were primarily involved in R&D.
- Employment of scientists and engineers in universities and colleges increased between 1965 and 1974 by more than 60 percent, with most of the growth occurring prior to 1972; the largest increases in employment occurred for life and social scientists, bringing the total number of scientists and engineers employed in higher education to just over 288,000 in 1974.
- In recent years the proportion of young doctoral faculty in doctorate-level science and engineering departments has declined from approximately 42 percent in 1968 to some 28 percent in 1974; concurrently, median ages have increased from 41 to 44 years, and the proportion of faculty with tenure has risen from 47 percent to 65 percent.
- The largest number of the Nation's scientists and engineers were employed in industry, with engineers accounting for nearly 80 percent of the total in 1974; approximately 25 percent of the engineers were involved in R&D and its management, compared with some 35 percent of the industrial scientists.
- The Federal Government supported less than one-fourth of all industrial scientists and engineers in 1974, down from nearly 30 percent in 1972; most of the support was provided by DOD and NASA which together accounted for nearly 70 percent of all such Federal support.
- The number of scientists and engineers employed by the Federal Government declined in 1973 for the first time since the 1950's; employment in this sector comprised 10 percent of all employed scientists and engineers in 1973, with some 30 percent of the Federal total involved in R&D.
- The total number of scientists and engineers engaged in R&D (on a full-time equivalent basis) was 530,000 in 1974, down by more than 30,000 from the high in 1969; 68 percent of the total were employed in industry, 13 percent in the academic sector, and 12 percent in the Federal Government.
- Approximately 40 percent of all doctoral scientists and engineers were involved in R&D in 1973; in universities, physical and life scientists comprised the majority of doctorates who were involved primarily in basic and applied research; in the industrial sector, most doctorates were engineers working on development-related activities.
- The number of R&D scientists and engineers in industry increased in 1973 and 1974, reaching almost 360,000 (on a full-time equivalent basis) but nearly 7 percent less than the number employed in the peak year of 1969; the decline occurred primarily in the aircraft and missiles industry, and was confined mainly to those scientists and engineers supported by Federal funds.
- Academic R&D was conducted by 67,000 scientists and engineers (on a full-time equivalent basis) in 1973, and was heavily focused on research (basic and applied). Of all the doctoral faculty involved in R&D, the proportion of young investigators decreased

21. Mansfield, *op. cit., Industrial Research and Technological Innovation.*
22. Griliches, Z., "Research Expenditures and Growth Accounting", in *Science and Technology in Economic Growth,* B. R. William (ed.), (New York: J. Wiley, 1973).
23. Mansfield, E., et al., *Social and Private Rates of Return from Industrial Innovations.* An unpublished paper presented before the Eastern Economic Association, October 26, 1974.
24. Terleckyj, N. E., *Effects of R&D on the Productivity Growth of Industries: An Exploratory Study* (Washington, D.C.: National Planning Association, 1974).
25. Arrow, K., "The Comment", in *The Rate and Direction of Inventive Activity,* R.R. Nelson (ed.), National Bureau of Economic Research (Princeton: Princeton University Press, 1962).
26. Nelson, R. R., "The Simple Economics of Basic Scientific Research: A Theoretical Analysis", *Journal of Political Economy,* Vol. 67 (June 1959).
27. *Economic Report of the President and The Annual Report of the Council of Economic Advisors, 1972,* p. 126.
28. Nelson, R. R., *Science, The Economy, and Public Policy* (Santa Monica: The Rand Corporation, 1964).

Virtually all major fields of science contribute to technological innovation, but certain fields are particularly significant, as indicated in the table above. The physical sciences (especially chemistry and physics) are of general importance across the entire spectrum of industrial innovation. The significance of the biological sciences and medicine has increased considerably in the last decade, both in their direct and indirect contributions to innovation.

RETURNS FROM R&D AND INNOVATION

The contribution of R&D and innovation to the economy and society is presently understood in broad and general terms only. Existing knowledge of the subject is fragmented and tenuous, to an extent which prohibits the development of indicators of the kind presented elsewhere in this report. Several studies, however, have been conducted in the area, particularly in the last decade. Some of the major findings of these studies are summarized below in the form of tentative conclusions based upon the collective results of these investigations.

The findings from the various studies, including estimated rate of returns from investment in R&D and innovation, are not strictly comparable. The studies employ different concepts, assumptions, and methodologies; each has limitations regarding the specification of inputs, the level of aggregation and the availability of data, and the method and degree of attribution of calculated outputs. They, in addition, have one major limitation in common—the inability of conventional measures (such as the Gross National Product and output per man-hour) to capture the full impact of technological innovation on the economy and on society. For these and other reasons of a methodological nature, findings regarding the contributions and returns from R&D and innovation appear to be underestimated in general **(1)**.[57]

*The contribution of R&D to economic growth and productivity is "positive, significant, and high"***(2)**. This contribution occurs through technological innovation consisting of enhanced production processes and new and improved products and services. These may expand economic output, increase productivity, or reduce unit costs. Such innovation is regarded as an important—possibly the most important—factor in the economic growth of the United States in this century **(3-5)**.

Investment in R&D and innovation yields a rate of return as high—and often higher—than the return from other investments. This applies to investments for specific innovations by both the public and private sectors and to R&D investments by individual industries. Rates of return from specific innovations are estimated, conservatively, to average between 10 and 50 percent per year **(6-11)**, while returns to innovating industries in the form of productivity growth range from 30 to 50 percent **(12-21)**.

The benefits to industries which purchase new and improved products from innovating firms may equal or exceed the direct returns to the innovating firms themselves. These benefits occur particularly in the form of reduced costs or prices per unit of output in the industries which purchase and use the innovations. The rate of return to these industries is estimated to range from 20 to 80 percent per year **(22-24)**.

Industry may underinvest in R&D and innovation with respect to the probable returns to the firm and the benefits to society **(25-27)**. Firms may invest less than the average returns to them would warrant because of the uncertainty and risk associated with specific innovation efforts, as well as the lengthy time before returns can be expected, and the scale of investment which is often involved in innovation. Although the potential benefits to society may often exceed the cost of innovation, a firm may not be able to translate enough of these benefits into profits to justify the necessary investment. "This is particularly true of basic research, where the output frequently occurs. . . not as a marketable product but rather as an advance in basic knowledge that can subsequently be used in applied research and development by a wide and often unforeseeable range of firms" **(27)**.

Standard indices of economic performance reflect only part of the contribution which R&D and innovation make to the economy and society **(28)**. Technological innovation sometimes results in new products (e.g., antibiotics and the airplane) which satisfy material needs and wants not satisfied previously. The value of such innovations may far exceed the price paid for the products, although only the latter is counted in standard economic measures. In addition, the effects of qualitative improvements in products and services (e.g.,

[57] These numbers refer to the references provided at the end of this chapter.

suggests. First, much of the transferred technology itself is based on prior research. But even more important is the contribution from the total body of knowledge gained from centuries of scientific research—knowledge upon which innovation in general draws.

The research directly underlying the innovations was reported by the firms to have been performed primarily by the innovating companies themselves. This was particularly true for applied research, but significantly less so for basic research. In some 96 percent of the cases, applied research was performed within the innovating firm, compared with 73 percent for basic research. Although no attempt was made to determine where the external portion of the basic research was performed, it may be presumed to have been performed largely in the university sector. As indicated in the "Basic Research" chapter of this report, industrial innovation (as represented by major patented technological advances) depends heavily upon basic research performed in universities—a dependency which has increased over the years.

Research figures prominently in the sampled innovations of all industries, the least R&D-intensive as well as the most intensive (figure 4-23). Applied research was involved in some 70 percent of the innovations in each of the three groups of industries (Groups I, II, and III) which vary from high to low in their R&D intensiveness. Basic research, on the other hand, was more frequently associated with the innovations of Group I industries than with those of Groups II and III—44 percent versus 32 and 28 percent, respectively.[56]

A similar pattern of dependency was found between research and the "radicalness" of innovations (figure 4-24). Applied research was reported with nearly equal frequency for innovations representing radical breakthroughs, major technological advances, and improvements in existing technologies. Basic research, however, was more often involved in innovations characterized as radical breakthroughs than it was in the other two categories. Such research was reported as a source of innovation in 68 percent of the new products and processes regarded as radical innovations, compared with less than 50 percent in the case of other innovations.

[56] The percentages reported in this section are based on the innovations within each group of R&D-intensive industries.

Figure 4-23
Research underlying major U.S. innovations, by groups of R&D intensive industries, 1953-73

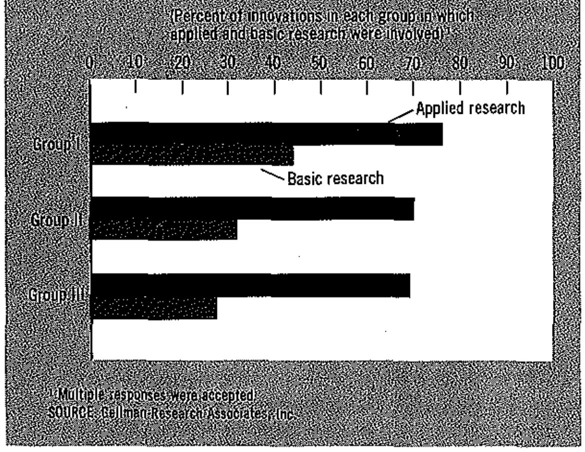
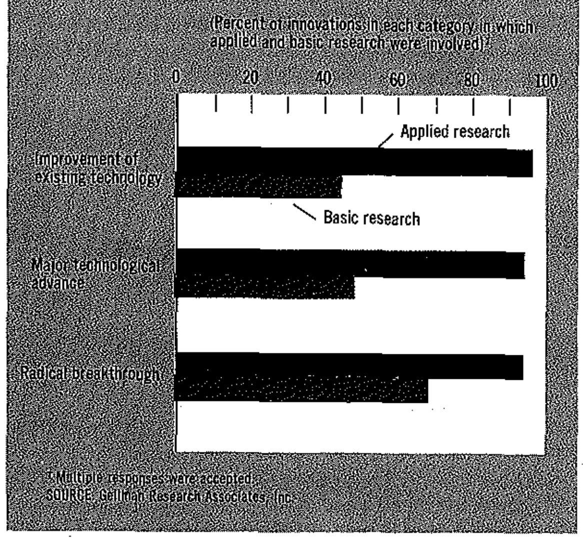


Figure 4-24
Research underlying major U.S. innovations and "radicalness" of innovations, 1953-73



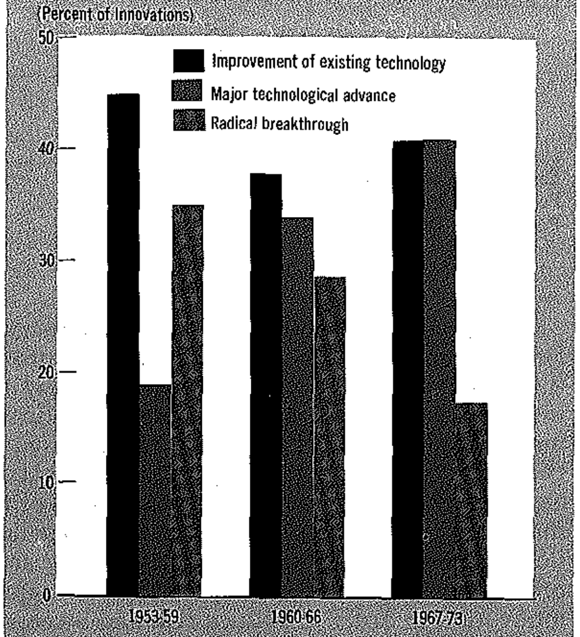
The U.S. innovations included in the study conducted by Gellman Research Associates, Inc., were examined to identify the more specific fields of science which had contributed in a major way to the realization of these innovations. These fields are listed below, along with the principal industries and product areas to which the fields contributed most directly. Associated with each field is a sample of the innovations in which the specific field played a significant role.

"Radicalness" of the innovations. Innovations may range from imitations of existing technologies to developments of radically new technologies and products. At one end of the spectrum, little or no new knowledge may be involved in an innovation, while at the other end, new and fundamental advances in knowledge may constitute the basis for the innovation. The distribution of innovations along this spectrum was estimated by obtaining ratings of the "radicalness" of the innovations. These ratings were made by the innovating organizations themselves. Although inherently subjective, such ratings may provide some valid insights regarding trends in industrial innovation.

Each innovation was assigned to one of five categories which together form the "radicalness" continuum: "no new knowledge required", "imitation of existing technology", "improvement of existing technology", "major technological advance", and "radical breakthrough".[54] Of the 225 innovations for which ratings were obtained, only 17 were rated in the first two categories; these innovations were omitted in subsequent analyses. Included among the innovations rated as radical were integrated circuits, permanent magnetic alloys, and L-Dopa, which is used in the treatment of Parkinson's disease. Innovations regarded as representing major technological advances included hand-held solid state calculators, Ketalor (an anesthetic), and an ultrasonic process for the joining of synthetic fibers. Improvement of existing technology was represented by such innovations as a high-speed phototypesetting machine, resin catalysts, and Pyroceram, a hard, light-weight, and heat-resistant material.

Innovations involving the improvement of existing technology were most prevalent, followed in order by those which constitute a major technological advance and the set which represents radical breakthroughs (figure 4-20). Over the 1953-73 period as a whole, 41 percent of the 208 innovations included in the analysis were rated as improvements in existing technology, compared with 32 percent in the category of major technological advance and 27 percent in the radical class. The most significant change in this distribution during the period

Figure 4-20
"Radicalness" of major U.S. innovations, 1953-73



SOURCE: Gellman Research Associates, Inc.

centered on the latter two categories. The number of innovations rated as radical breakthroughs declined nearly 50 percent between 1953-59 and 1967-73, while the number representing major technological advances doubled during the same period. As a result of these changes, radical innovations accounted for 18 percent of the innovations in the 1967-73 period, down from 35 percent in 1953-59.

The overall decline in radical innovations (and the corresponding increase in innovations representing a major technological advance) is due primarily to reductions in the number of such innovations from the most R&D-intensive industries (figure 4-21). Radical innovations in these industries decreased from 23 percent of the innovations in 1953-62 to 14 percent in 1963-73, whereas the proportion involving major technological advances rose from 20 percent to 30 percent over the same periods.

Research and innovation. The technology embodied in an industrial innovation may be

[54] The "radicalness" of innovations, it may be noted, does not determine their economic or social significance. Innovations which represent improvements or even imitations of existing technologies may have greater economic returns or social consequences than more radical innovations.

novations in product fields associated with chemicals appear to have declined somewhat since the 1950's.

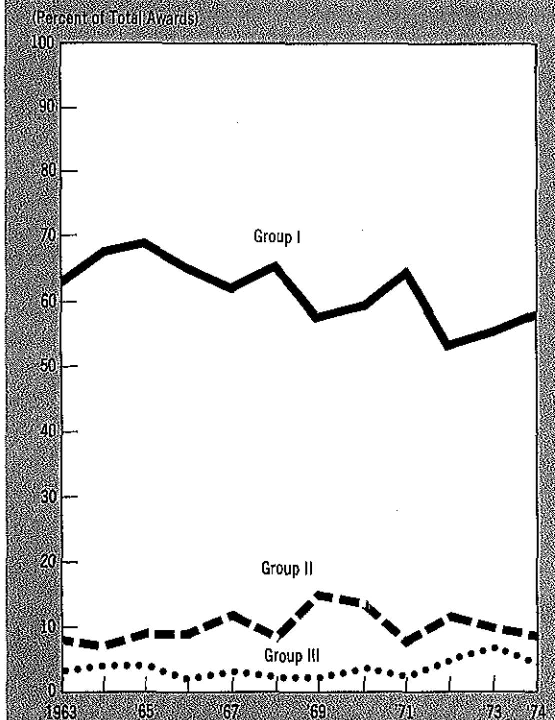
Another set of technological innovations was used in developing an additional indicator for this report.[48] This set consisted of "IR-100" award winners, one hundred of which are selected annually by the Editorial Advisory Board of *Industrial Research* magazine. The awards, begun in 1963, identify significant technological advances and recognize innovators and organizations responsible for such developments. The innovations are selected on the basis of their importance, uniqueness, and usefulness from a technical standpoint. They are chosen, in general, from advances in technology which have particular interest for the industrial research community; for this reason, the innovations tend to concentrate in areas such as scientific instruments, electronic apparatus, and new industrial materials. The innovations, therefore, represent a somewhat limited segment of the total U.S. innovation activity, and do not reflect market success nor economic impact.

Each of the more than 1,200 "IR-100" award-winning innovations chosen over the 1963-74 period was classified according to the SIC designation of the industry of origin and grouped in terms of its industry's R&D intensity. Over 75 percent of the innovations were found to originate in industries included in the three groups of R&D-intensive industries. (The remainder originated primarily in nonmanufacturing industries, academic institutions, or U.S. Government agencies.) As shown in figure 4-18, the most R&D-intensive industries (those of Group I) were responsible for the largest share of innovations over the twelve year period, accounting for about 62 percent of all the "IR-100" awards. Industries in Group II claimed approximately 10 percent and Group III industries some 4 percent of the total innovations. The preponderance of innovations in Group I results primarily from the large number of innovations originating in the electrical equipment and communications industry and the professional and scientific instruments industry. Together, these two industries accounted for over 45 percent of all the "IR-100" awards given over the twelve year period.

[48] *Indicators of the Output of New Technological Products from Industry*, Battelle Columbus Laboratories, 1975. (A study commissioned specifically for this report).

Figure 4-18

"IR-100" award-winning innovations[1], by groups of R&D-intensive industries, 1963-74

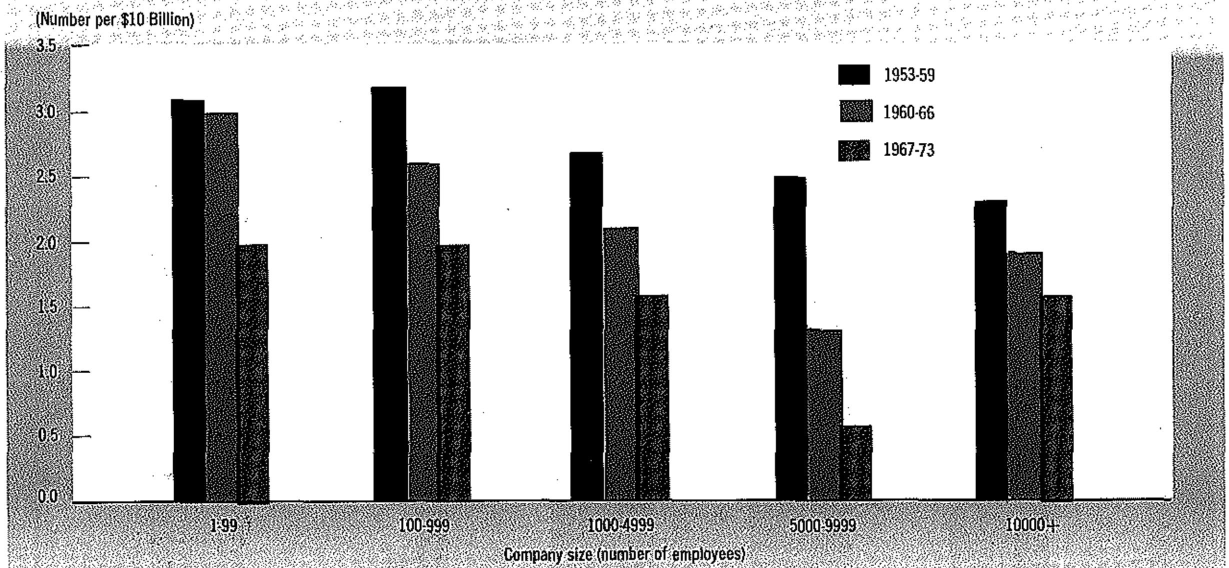


[1] *Industrial Research* magazine's annual awards for the 100 "most significant new technological products of the year."

SOURCE: Battelle Columbus Laboratories.

Time between invention and innovation. The innovation process—extending from the "first conception" of the innovation to "first realization"—may cover a long period of time. This interval may be necessary, among other things, to conduct research, determine the technical feasibility of the potential innovation, design and test engineering prototypes, develop the required manufacturing capability, and perform market analyses. The period is difficult to define precisely, since invention and innovation usually occur as stages in the process, rather than as discrete events. Roughly, invention occurs when initial determination of the technical feasibility of a new idea is made, while innovation corresponds to the actual commercial development and marketing of the new product or process. The invention-innovation intervals are approximate, and are usually not strictly comparable from one study to the next.

Figure 4-15
Major U.S. innovations per $10 billion in sales, by size of company, 1953-73



SOURCE: Gellman Research Associates, Inc., and Department of Commerce.

Innovation and R&D intensity. The most R&D-intensive industries (Group I industries) produced the largest fraction of the major U.S. innovations in the manufacturing sector—182 of the 277 innovations included in this analysis—during the 1953-73 period, followed by innovations from industries in Groups II and III (figure 4-16). Innovations by Group I industries comprised 66 percent of the total, compared with 24 percent in Group II and 10 percent in Group III industries.

Group I industries accounted for 80 percent of the total industrial R&D expenditures over roughly the same period (1956-73), compared to 16 percent from Group II, and 4 percent from Group III. Over the 1953-73 period as a whole, the number of innovations from the most R&D-intensive industries increased to a greater extent than those from the other two industrial groups. After the 1965-68 period, however, the number of innovations in Group I industries declined in relative terms.

Within these industry groups, the largest number of innovations—171—are in four of the most R&D-intensive industries: electrical equipment and communication; chemicals and allied products; machinery; and professional and scientific instruments (figure 4-17).[46] It should be noted that innovations in the defense and space areas are not included unless they were introduced into the commercial market; this may account, at least in part, for the relatively small number of innovations from the fifth Group I industry—aircraft and missiles.

Innovations in the manufacturing sector were examined to identify the major areas of innovative activity and the shifts among these areas during the 1953-73 period. For this purpose, innovations were classified in terms of their product fields through use of the Standard Industrial Classification (SIC). The product fields with the largest number of innovations are listed below for each of three time periods. The fields are described briefly in terms of their corresponding three-digit SIC designations, and ranked in approximate order of the number of associated innovations.

[46] See Appendix table 4-17 for the number of major innovations in each of the 15 manufacturing industries.

industries; these goods may enable the purchasing industries to increase their productivity, improve the quality of their products, or develop new and improved products and services for their own markets. The computer is one of the most obvious examples of an innovation from the first group of industries which is used extensively by other industries.

In addition to its importance at the firm and industry levels, technological innovation is acknowledged as a prime source of the Nation's economic progress, contributing to productivity and economic growth.[38] The capability for such innovation, moreover, is regarded as a major comparative advantage which the United States has in international relations—political, military, and economic.[39]

The present indicators focus on major technological innovations. The vast majority of innovation efforts, however, seek or attain modest improvements in products and processes, rather than major advances. The results of these efforts are not captured by present measures even though the cumulative impact of the more numerous minor advances may often exceed that of major innovations.[40] Furthermore, no indicators are provided of the extent to which the innovations replace or represent advances over existing products and processes. In addition to these limitations, the indicators do not specify the economic and social benefits—and costs—associated with the innovations.

Indicators of trends in innovation presented in this section are based, for the most part, on a study conducted specifically for this report. The study provides information on 500 major product innovations which were introduced into the market during the 1953-73 period by leading industrialized nations.[41] The innovations were selected by an international panel of experts as representing the most significant new industrial products and processes, in terms of their technological importance and economic and social impact.[42] Information on a subset of these innovations—a total of the 319 produced by U.S. industries—was used to develop the measures of innovation presented below. The innovations on which the indicators are based span a wide range of technologies and all major manufacturing and nonmanufacturing industries. The diversity is suggested by the following innovations which were among those included in the study.

- Integrated circuits
- Lasers
- Microwave transmission
- Cortisone synthesis
- Permanent magnetic alloys
- Weather satellites
- Double-knit synthetics
- Computer time-sharing
- Light-emitting diodes
- Textured granular protein

Innovation and company size. A topic of enduring concern is the relationship between size of firm and technological innovation.[43] This topic was examined through the use of the major innovations described above. The results are shown in figure 4-14, in terms of the percentage of innovations produced by companies in each of five size categories. These data, which are based on a total of 277 innovations,[44] show that large manufacturing companies (those with 10,000 or more employees) produced the greatest proportion of major innovations, followed by firms in the two smallest size categories. Companies of intermediate size (1,000-4,999 and 5,000-9,999 employees) accounted for the fewest innovations. The data also show that the number of innovations from large companies has increased over time, in both absolute and relative terms.

Small firms, however, are sometimes regarded as those with less than 1,000 employees. By this

[38] These aspects are discussed later in this chapter in the section entitled, "Returns from R&D and Innovation."

[39] See the chapter "International Indicators of Science and Technology" in this report for indicators of the role of technology in international trade.

[40] Jacob Schmookler, *Patents, Invention, and Economic Change,* (Cambridge: Harvard University Press, 1972).

[41] This information was used in devising indicators of the relative innovativeness of the United States and other major developed nations; these indicators are presented in an earlier chapter of this report, entitled "International Indicators of Science and Technology."

[42] For details of the methodology employed in the study, see *Indicators of International Trends in Technological Innovation,* Gellman Research Associates, Inc., 1975. (A study commissioned specifically for this report).

[43] For a discussion of factors related to firm size which may influence innovation, see Sumner Myers and Donald G. Marquis, *Successful Industrial Innovations, A Study of Factors Underlying Innovation in Selected Firms,* National Science Foundation (NSF 69-17).

[44] Here, and elsewhere, the number of innovations used for analysis may be less than the total 319 innovations mentioned earlier because of the unavailability of specific data on all the innovations, or the consideration of only those originating from manufacturing industries.

actual number of patents assigned to U.S. corporations increased 73 percent between 1960 and 1973. "Assignment," however, cannot be equated completely with the actual source of the invention. Some patents granted to individuals may be assigned subsequently to corporations, and some patents assigned to the Federal Government have their origins in federally funded R&D performed in industry. Nevertheless, it is clear that industry is the major producer of patented inventions in the U.S.

Patent output by product field. In addition to the sources of patents, information was obtained on the product fields in which the patents were most likely to be applied. Through a concordance developed between the patent classification system of the U.S. Patent Office and the Standard Industrial Classification (SIC)[29] system, it was possible to categorize U.S. patents granted between 1963 and 1973 into 30 SIC-based product fields,[30] with respect to the fields in which the patents were most likely to be applied. These product fields encompass most of the manufacturing sector of industry, and include 96 percent of all U.S. patents granted during the period.

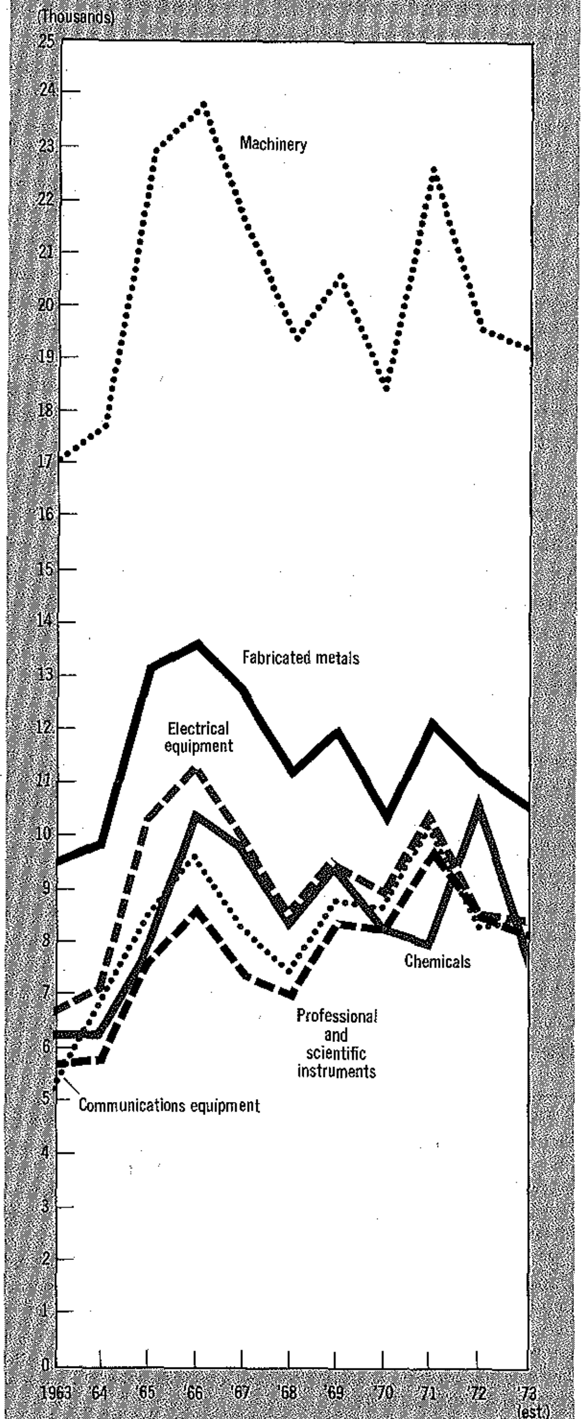
All patents granted to U.S. citizens, corporations, and the Federal Government were assigned to these product fields on the basis of the area of their probable use.[31] The six product fields with the highest patent activity are shown in figure 4-12. The greatest number of patents during the 1963-73 period were applicable to the machinery product field, and within this field to the construction, mining and materials handling machinery subfield. Following machinery in the number of patents were fabricated metals, chemicals (particularly basic industrial chemicals), electrical equipment, communication equipment, and professional and scientific instruments. These fields include many of the areas with a high output of major innovations. (See the later section of this chapter entitled "Technological innovation".)

[29] *Standard Industrial Classification Manual*, Executive Office of the President, Office of Management and Budget, 1972.

[30] *Indicators of the Patent Output of U.S. Industry*, Office of Technology Assessment and Forecast, U.S. Patent Office, 1974. (A study commissioned specifically for this report).

[31] Because of the possible utilization of the technology represented by a given patent in more than one product field, many patents were counted more than once. For this reason, product field totals do not correspond with the patent totals presented in the previous section.

Figure 4-12
U.S. patents granted for inventions,[1] by selected major product field, 1963-73



[1] Patents originating in the United States.
SOURCE: Office of Technology Assessment and Forecast, U.S. Patent Office.

processes and on developing new ones. Some R&D in the form of basic research is performed to gain new insights into areas of company interest, and the results from these efforts may be incorporated eventually into new or improved products. In this way, R&D assists companies to maintain existing markets or to expand into new ones, to reduce production costs, and to increase profits.

The importance of improving and developing new products and processes, and the associated levels of R&D, vary among industries. In addition, the emphasis placed on new developments versus improvements differs—over time and among individual companies and industries. Some indication of the relative emphasis of the R&D programs of manufacturing industries during 1974 is indicated below.[22]

Objectives of industrial R&D programs, 1974

Objective	Percent of R&D expenditures
Improving existing products	50
Developing new products	36
Developing new processes	14

As shown in the table, one-half of the R&D expenditures are aimed at improving existing products. Only three industries—electrical equipment and communication, professional and scientific instruments, and food and kindred products—reported new product development as the principal objective of their R&D programs. Petroleum refining and extraction and the nonferrous metals industries were the only two in which new process developments received the largest share of R&D funds. All other manufacturing industries in 1974 emphasized the improvement of existing products in their R&D programs. Product improvements were also the predominant type of innovations found in a sample of major innovations reported later in this chapter under "Technological innovation."

Some industries depend upon R&D more than others. This dependency might be expected to be greatest among those industries relying most heavily on sales from new products, rather than on the improvement of existing ones. Although data are lacking on actual sales from new products, information is available on the sales expected from such products. These estimates, expressed as a percentage of total expected sales, are summarized in the table below.[23] As indicated, the most R&D-intensive industries have expected a higher proportion of their sales to be in new products than the two groups of less R&D-intensive industries.

Expected sales from new products[24] as a percent of future sales

R&D intensity	Mean percent		
	1969-70	1971-72	1973-74
Group I	27	26	24
Group II	15	15	20
Group III	11	15	11

The three industries reporting the highest proportion of R&D expenditures for new product development (electrical equipment and communications, machinery, and professional and scientific instruments) are among the five industries expecting the largest proportion of sales from new products during the 1969-74 period.

The expected level of new product sales appears to have declined slightly for Group I industries overall, and increased for Group II industries since 1969-70. This decline in Group I industries may result from a longer term shift away from the development of new products toward innovations representing improvements in existing technologies. (See the later section in this chapter entitled "Radicalness of the innovations.")

Patented inventions

Patented inventions are one of the more direct outputs of industrial R&D. They often represent actual or potential advances in technology, and thus indicate, to some extent, the level, direc-

[22] *Business' Plans for R&D Expenditures, 1975-78*, McGraw-Hill Publications Co., May, 1975. (Strictly comparable data are not available for earlier years.)

[23] The data presented in the table are based on an analysis, commissioned especially for this report, of information from *Business' Plans for R&D Expenditures*, McGraw-Hill Publications Co., Economics Department, annual surveys, 1966-74.

[24] "New products" were defined as those expected to be introduced into the market within three years following the time of the survey. What constitutes a "new product" and the extent to which it differs from previously existing products may vary among industries and/or companies.

placed into one of three groups according to its relative level of R&D intensity over the 1961-72 period. These groups, each consisting of five industries, are shown in the table below along with their R&D intensity indices, with Group I industries being the most R&D-intensive and Group III the least.

As the table shows, the level of R&D intensiveness among industries within each group is within a relatively close range regardless of the specific index chosen. Furthermore, the R&D intensity of each group is separated from the next by approximately a factor of three.

The R&D intensity of manufacturing industries overall has declined steadily since 1964. As shown in figure 4-10, the declines occurred almost exclusively in the most R&D-intensive industries (Group I), and were caused primarily by reductions in the level of Federal support for industrial R&D after the mid-1960's. Aside from the changes produced by declining Federal support, the R&D intensity of each group of industries has changed little since 1961.

The assignment into three major groups of industries exhibiting approximately the same level of R&D activity provides a convenient and direct method for relating R&D to the outputs and returns from such effort, as shown in the next section of this chapter.

OUTPUTS FROM R&D AND INNOVATION

Earlier sections of this chapter dealt largely with the resources employed in industrial R&D and structural aspects of the system. This section attempts to provide indicators of some of the outputs and returns from R&D—aspects which are considerably more difficult to measure than inputs.

The principal indicators in this section deal with trends in technological invention and innovation. Measures of invention are in terms of patents and include indicators of the areas and magnitude of inventive output, sources of invention, product areas involved, and relationships with R&D intensity. Indicators of innovation are based upon new industrial products embodying major advances in technology and include characteristics of innovating organizations, innovativeness of different industries, relationship to investment in R&D, time between invention and innovation, and the role of research.

The measures of output presented here represent only a step toward the array of indicators needed for the industrial sector. Present measures are small in number, broad in scope, and restricted generally to relatively direct outcomes of R&D. Lacking are indicators such as reduced costs, gains in an industry's productivity or increases in sales which result from R&D. The measures, in addition, do not encompass the qualitative improvements in industrial products and processes which often constitute the major form of return from R&D investment.

The present indicators, furthermore, do not specify the separate and distinct contribution of R&D to invention and innovation. As noted earlier, invention and innovation result from a complex of interacting factors—economic, social, and technical. Analytical efforts to date have not been successful in determining the precise contribution of the individual factors, including that of R&D. Thus, indicators presented here should be regarded as approximate measures of the relationship between this factor and invention or innovation.

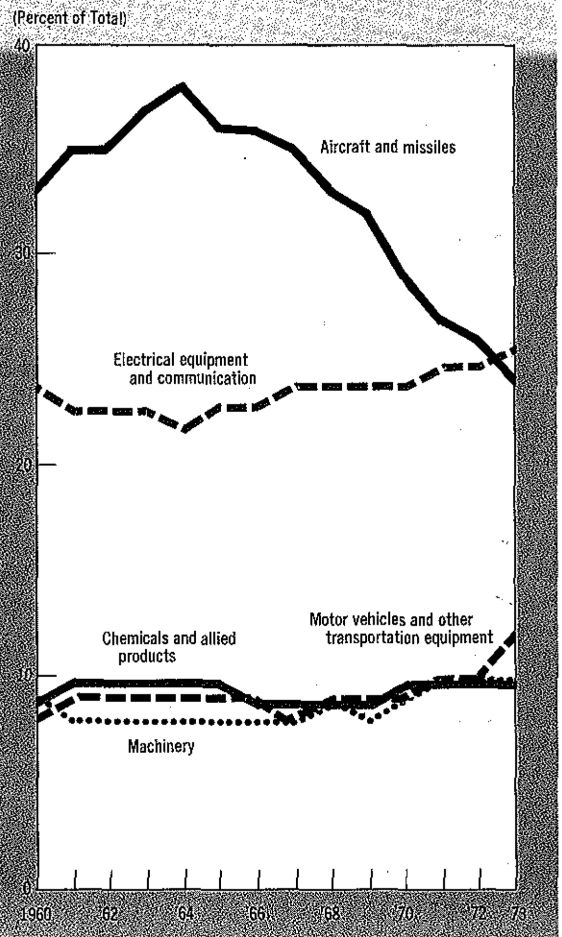
The impact of technological innovation on productivity and economic growth is, in turn, understood only in general terms. Present knowledge of the causal connection between innovation and economic returns is not sufficient for developing quantitative indicators of the relationship. In lieu of such indicators, the major conclusions derived from studies in this area are summarized.

Finally, the indicators in this chapter do not include measures of the negative impacts and side-effects of technological innovation. These costs may be extensive in human and social terms, ranging from the loss of jobs to the pollution of our environment. The determination of these costs and their assessment relative to benefits, is necessary for the wise management of innovation. Valid indicators of these costs, however, are exceedingly difficult to develop; it is for this reason, rather than a lack of recognition of their need, that such indicators are not provided in this report.

Objectives of industrial R&D

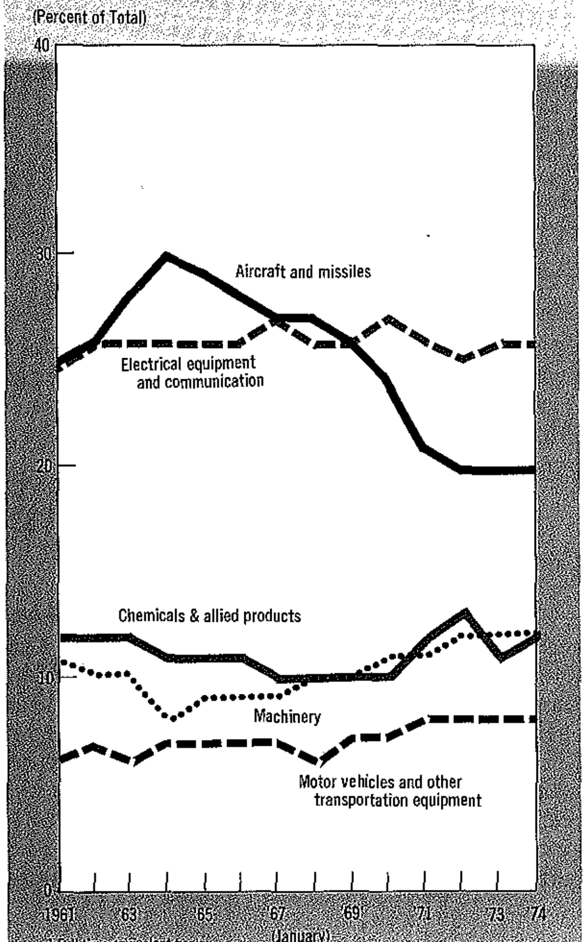
In general, industry views R&D as a means to remain competitive and profitable. Most industrial R&D is an attempt to focus science and technology on improving existing products and

Figure 4-8
Distribution of industrial R&D expenditures among selected industries, 1960-73



SOURCE: National Science Foundation.

Figure 4-9
Distribution of scientists and engineers[1] engaged in industrial R&D among selected industries, 1961-74



[1] Full-time equivalent basis.
SOURCE: National Science Foundation.

federally supported R&D scientists and engineers in industry as of January, 1974, representing almost 30 percent of all R&D scientists and engineers employed by industry.

Most of the R&D activity in industry is further concentrated within a small number of large companies.[19] Of a total of over 11,000 R&D-performing companies in 1973, the 300 companies with over 10,000 employees accounted for more than 80 percent of all industrial R&D expenditures. Thirty-one of these companies reported R&D programs costing more than $100 million, for a total of almost $12 billion, or more than 60 percent of all R&D expenditures by industry. Thus, even small percentage changes in the level of R&D activity in a few large companies can have a substantial effect on the overall U.S. industrial R&D effort.

When viewed against the totality of companies which comprise industry, or even the manufac-

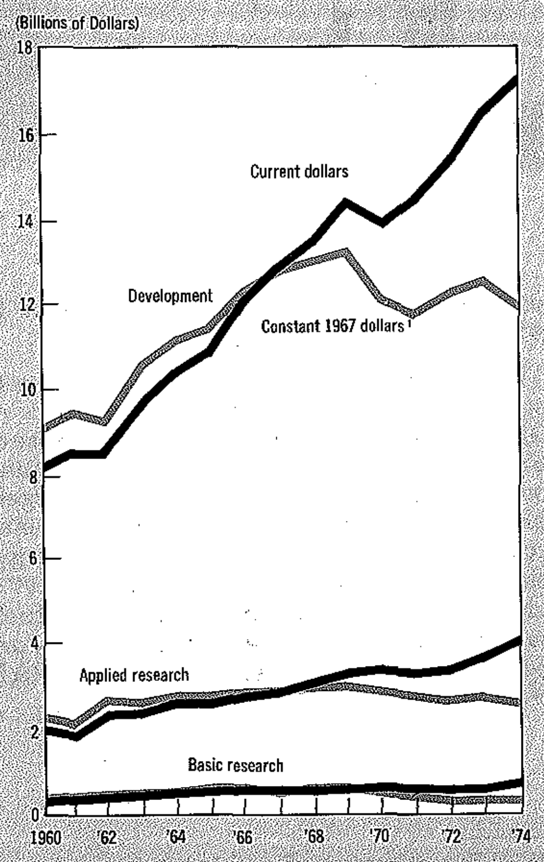
[19] The words "company" and "firm" are used interchangeably in this report, even though they may have slightly different meanings in other contexts. Each term denotes a business organization consisting of one or more establishments under common ownership or control.

R&D expenditures by character of work

Development activities receive by far the largest portion of total expenditures for industrial R&D, followed by applied and basic research. The proportion going for development efforts has ranged between 75 and 80 percent of total expenditures during the 1960-74 period, compared with nearly 20 percent for applied research and some 3 to 4 percent for basic research (figure 4-7).

The emphasis on development efforts reflects the general nature of industrial R&D, which is usually focused on specific product lines and relatively short-range goals in terms of the time between R&D and expected returns from the investment. These tendencies are strengthened by the usually large proportion of total corporate R&D resources—funds and personnel—which are controlled by divisional managers of firms whose major focus is often on existing product lines and processes.

Figure 4-7
Industrial R&D expenditures for basic research, applied research, and development, 1960-74



¹ GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

Expenditures in current dollars for applied research and development generally increased each year between 1960 and 1974, whereas funding of basic research has remained at a relatively fixed level of some $600 million since 1965. Constant dollar expenditures, on the other hand, declined after 1969 for development efforts, due primarily to reductions in Federal funds, whereas those for applied research have changed little since 1964. Funding of basic research in constant dollars has fallen since the mid-1960's, reaching a level in 1974 which is approximately equal to that of 1961.

The distribution of funds among these categories of R&D differs according to the sources of funds, with industry providing most of the funds for basic and applied research and a lesser, but still the largest, share of development funds. In 1974, for example, industry funded 78 percent of its own basic research and 75 percent of its applied research, compared to 59 percent of its development.[14]

Applied R&D in product fields

Over the last two decades there has been a rapid expansion and diversification of firms into new product lines, markets, and technical fields. Thus, R&D data reported by a firm may include expenditures in several product fields, in addition to the single, major field which determines the broad industrial category to which the firm is assigned. Therefore, R&D expenditures in terms of product areas, rather than industries, are more indicative of the actual composition and focus of the national effort in industrial R&D.

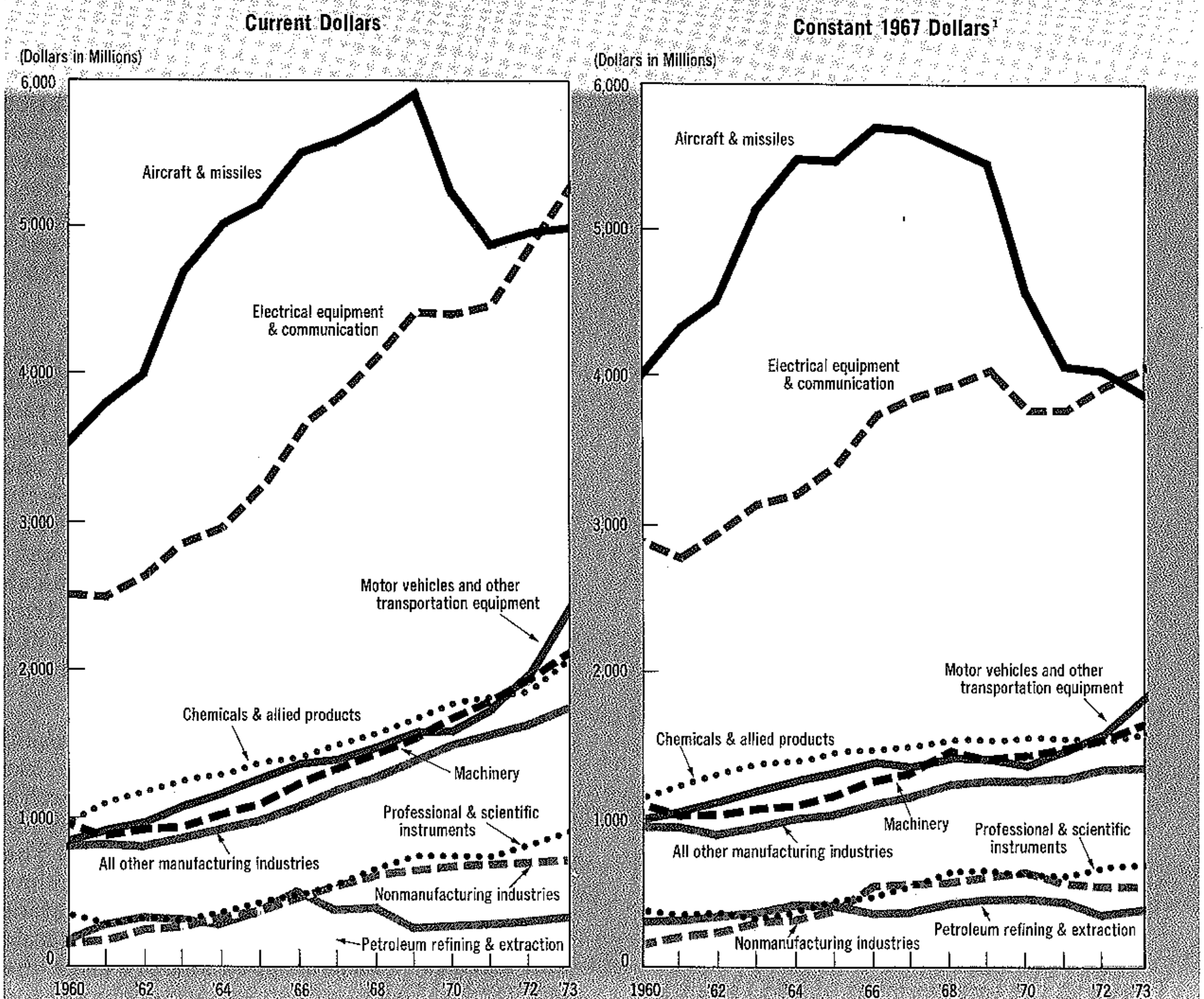
Expenditures for applied research and development[15] are concentrated in 6 of the 15 broad product fields used for classification purposes.[16] These 6 fields, and the percentage of

[14] *National Patterns of R&D Resources, 1953-75,* National Science Foundation (NSF 75-307).

[15] Expenditures for basic research are excluded since such research, by definition, is not directed toward specific products.

[16] See Appendix table 4-12 for a listing of these product fields.

Figure 4-5
R&D expenditures, by selected industries 1960-73



[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

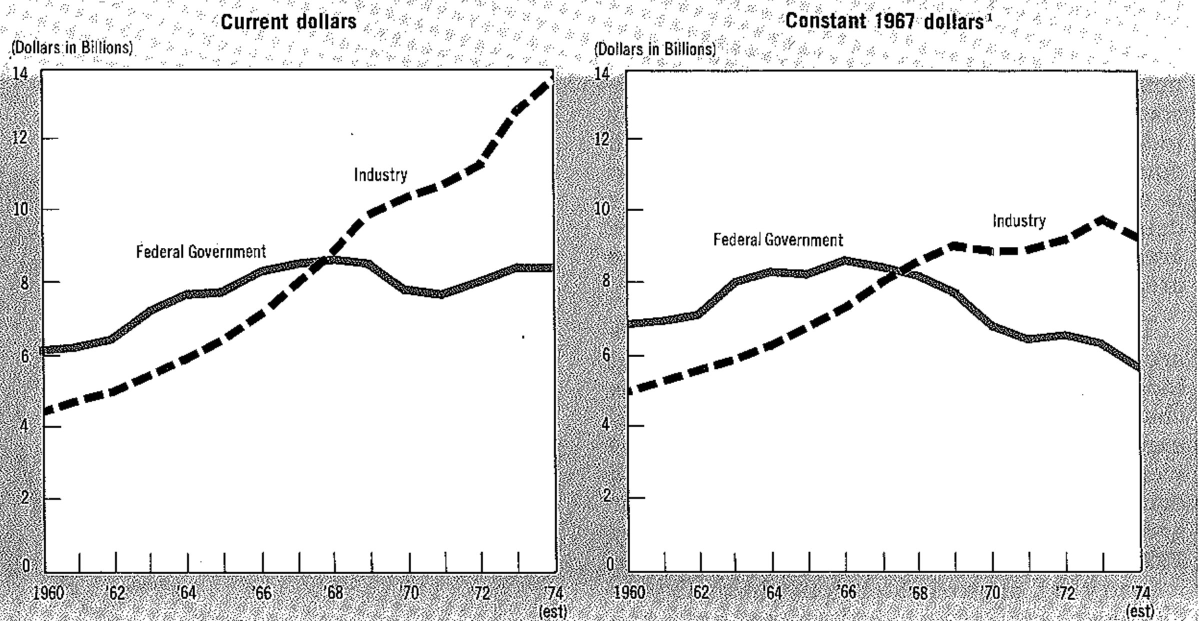
Expenditures for R&D in nonmanufacturing industries changed little after 1970.[10]

Industries differ substantially in the size of recent changes in their R&D expenditures. Industries with the largest relative growth in R&D spending between 1971 and 1973 are shown in figure 4-6.

[10] R&D expenditures for all industries are presented in Appendix table 4-5.

The overall pattern of R&D funding shown in figures 4-5 and 4-6 as well as elsewhere in this chapter, indicates a general shift in the Nation's industrial R&D effort. One aspect of the shift is that industry itself, rather than the Federal Government, has become the prime source of funds for industrial R&D. A second and related aspect is that the R&D is directed increasingly to "civilian" areas, i.e., to areas other than defense and space such as the development of new sources of energy, conservation of resources,

Figure 4-3
Expenditures for industrial R&D, by source of funds, 1960-74



[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

another, as shown in the table below.[5]

Federal funds as a percentage of total industrial R&D expenditures, by industry, 1973

Industry	Percent
Aircraft and missiles	78
Electrical equipment & communication	50
Professional & scientific instruments	20
Motor vehicles and other transportation equipment	17
Machinery	16
Rubber products	12
Chemicals and allied products	10
Fabricated metal products	5
Primary metals	4
Petroleum refining and extraction	3
Stone, clay, and glass products	2
Textiles and apparel	2
Food and kindred products	1
Paper and allied products	1

[5] Federal support for nonmanufacturing industries amounted to 56 percent of their total R&D expenditures in 1973.

Industrial R&D personnel

Another indicator of the magnitude of industrial R&D is the number of scientists and engineers engaged in such activities. Trends in this measure are shown in figure 4-4, for the total of such personnel as well as for those who are supported by industry itself and those by R&D funds from the Federal Government. The total number of these personnel rose to a high of some 387,000 in 1969, declined 10 percent over the next three years, and rose slightly in both 1973 and 1974.

The decline in 1970-72 was concentrated among those scientists and engineers, principally the latter, supported by Federal R&D funds. The reductions, corresponding to the pattern of declines in Federal funding of industrial R&D described above, were primarily in the aircraft and missiles industry and secondarily in the electrical and communication, machinery, and chemicals industries. Some 70 percent of the reduction in numbers of federally supported R&D scientists and engineers was in these four industries.

magnitude of the effort. Expenditures for R&D are presented initially for the total industrial R&D effort, followed by information on the source of funds and expenditures by specific industries. Trends in the number of scientists and engineers engaged in R&D are presented in terms of the Nation's overall effort in industrial R&D. These are followed by indicators of the division of R&D resources among the categories of basic research, applied research, and development, as well as the product fields on which the effort focuses. Data are presented also on certain institutional characteristics of industrial R&D—the distribution of R&D expenditures among companies of different size and among specific industries. The section concludes with trends in the R&D intensity of U.S. industries.

Financial and human resources for R&D represent only a small part of the total investment which industry makes for technological innovation, the principal aim of its R&D. Although little empirical data are available regarding total expenditures for innovation, estimates have been made of the typical distribution of costs among the several steps in the innovation process.[2] These estimates, which apply to successful innovations only, are shown in the table below.

Typical distribution of costs in successful product innovations

Activity	Percent
Research (advanced development-basic invention)	5-10
Engineering and designing the product	10-20
Tooling (manufacturing engineering)	40-60
Manufacturing start-up expenses	5-15
Marketing start-up expenses	10-25

Although R&D (which encompasses all of the first step and most of the second) is estimated to account, on the average, for no more than 15-30 percent of the total costs of innovation, it is especially significant in that R&D often initiates and provides the basis for the subsequent steps in the innovation process.

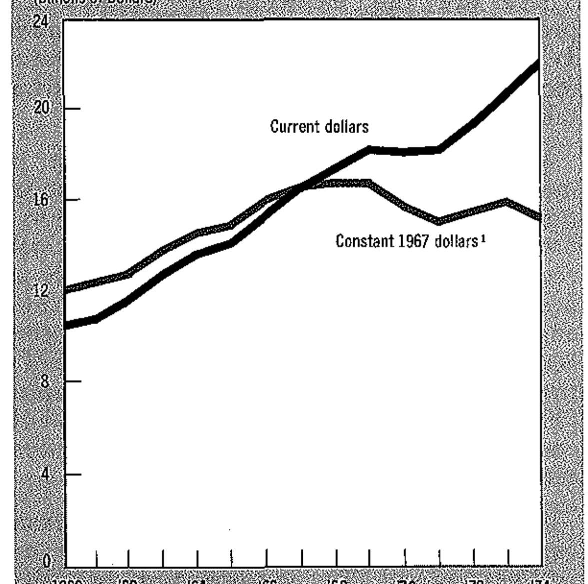
[2] *Technological Innovation: Its Environment and Management,* Department of Commerce, 1967. For a discussion of other estimates of the distribution of costs associated with innovation, see Edwin Mansfield, et. al., *Research and Innovation in the Modern Corporation,* (New York: W. W. Norton, 1971).

Expenditures for industrial R&D

The total national expenditures for industrial R&D[3] are comprised of funds from both the Federal Government and private industry. The combined funding is shown in figure 4-1, in current and constant dollars. Total expenditures in current dollars more than doubled between 1960 and 1974, with one-third of the growth occurring after 1971. The average annual increase of just over $1.0 billion during that latter time was greater in absolute terms than in any other three-year interval between 1960 and 1974, and came almost entirely from an increase in funding by industry.

Total expenditures in current dollars for industrial R&D were over $22 billion in 1974. The growth in current dollar funding, however, was less than increases in inflation in recent

Figure 4-1
Industrial R&D expenditures, 1960-74



¹ GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

[3] Industrial R&D expenditures presented in this report include all costs incurred in support of R&D (i.e., salaries, laboratory equipment, overhead, etc.), but do not include associated capital expenditures. See *Research and Development in Industry, 1973,* National Science Foundation (NSF 75-315) p. 81, for further information on the scope of these costs.

Industrial R&D and Innovation

INDICATOR HIGHLIGHTS

- Total expenditures for industrial R&D more than doubled between 1960-74, with one-third of the growth occurring after 1971; the large increases in recent years came almost entirely from industry's own funds, raising the total expenditures for industrial R&D to more than $22 billion in current dollars in 1974.
- Adjusted for inflation, total expenditures in 1967 constant dollars for industrial R&D were $15.2 billion in 1974, which was 11 percent lower than in 1968-69, the years of highest funding, and approximately equivalent to the funding level of 1965; in 1974, development activities accounted for 79 percent of total industrial R&D expenditures, compared with 18 percent for applied research and 3 percent for basic research.
- The total number of scientists and engineers engaged in industrial R&D increased in 1973 and 1974 to 360,600, following a decline from a peak employment level in 1969 of 387,000; such personnel supported by industry's own funds increased throughout the 1960-74 period, while the number supported by the Federal Government declined to pre-1960 levels.
- Expenditures for applied research and development in industry are focused on six product areas: communications equipment and electronic components, aircraft and parts, guided missiles and spacecraft, machinery, motor vehicles and other transportation equipment, and chemicals; these areas comprised nearly 70 percent of all such expenditures in 1973.
- Industrial R&D is concentrated in a few manufacturing industries and in a relatively small number of large companies within those industries; five industries accounted for some 80 percent of all industrial R&D expenditures in 1973 and a similar proportion of all R&D personnel, while the 100 companies with the largest R&D programs spent nearly 80 percent of all industrial R&D funds.
- Improvement of existing products was the reported goal of one-half of all industrial R&D in 1974, compared with approximately 35 percent for developing new products, and 15 percent for new processes.
- The R&D intensity[1] of manufacturing industries declined steadily after 1964 as a result of reduced Federal support for industrial R&D (primarily in the aircraft and missiles industry); in terms of industry support alone, however, the level of R&D intensiveness has changed little since the early 1960's.
- The most R&D-intensive industries were the largest producers of patented inventions, accounting for over 67 percent of all patents granted during the 1963-73 period; the majority of patents were for inventions in six major product fields: machinery, fabricated metals, electrical equipment, chemicals, professional and scientific instruments, and communications equipment.
- The most R&D-intensive industries produced the majority of a sample of major technological innovations during the 1953-73 period; these industries accounted for 66 percent of the innovations, followed by intermediate level industries with 24 percent, and the least R&D-intensive industries with 10 percent.
- Large companies (those with 10,000 or more employees) produced a greater number of the sample of innovations between 1953-73 than companies with less than 100 employees, but a smaller number than firms

[1] The proportion of net sales devoted to R&D and the number of R&D scientists and engineers relative to total company employment.