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Volume Author/Editor: David M. Blank and George J. Stigler

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Chapter Author: David M. Blank, George J. Stigler

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# THE DEMAND AND SUPPLY
# OF SCIENTIFIC PERSONNEL

# CHAPTER I

# A GENERAL VIEW OF THE TECHNOLOGICAL PROFESSIONS

THE technological professions may be defined broadly as the professions whose subject matter is natural science and its applications. Much the largest of these is engineering, and much the second largest consists of the chemists. The rest—such as physicists, mathematicians, biologists, and geologists (but excluding the medical professions)—are even collectively slightly smaller in number than the chemists.

Our central purpose in this study is to investigate the methods by which one can explain—or predict, for explanation and prediction are equivalent—the supply and demand for technological and professional workers. But methods cannot be examined apart from the materials on which the methods are to be used—the world and the scholar are both so complex that it is easy to overlook real difficulties or to invent spurious ones. We shall examine techniques in the light of experience, and we begin with a broad survey of the technological professions. We trace first their growth, and in the process examine the boundaries of these groups; thereafter we summarize the growth of organized research—a development of considerable importance for our study.

## 1. *The Growth of the Technological Professions*

Two hundred years ago many of the technological professions did not exist, and none was large enough to be worthy of discussion as an element in an economy's labor force. The most famous and best established was mathematics, but one may conjecture that even the queen of the sciences was served full time by only a hundred or so men in the entire world. This is not to depreciate the progress of the sciences at the time, or to imply that a Newton can be replaced by 10,000 mediocre men. But the practitioners of the sciences did not constitute professions—they were small collections of gifted men.

Historians of engineering instruction differ as to when this largest of our technological professions began to be taught systematically and formally, rather than by the traditional methods of apprenticeship. Some set the beginnings in 1766, with the technical mining school at Freiberg; some set the beginnings in 1775, with the French Ecole des Ponts et Chaussées; and some set the date in 1794, when the great Ecole Polytechnique was founded.[1] But it is not disputed that the nineteenth century saw the international development of instruction in applied sciences on a large scale, nor that the pure scientists first began in that century to be slightly more than infinitesimal in number. The heroic age of the industrial revolution was presided over by the untutored entrepreneur, not the engineer or scientist.

Growth took place at an enormous rate in all branches of higher education in the nineteenth century, and nowhere more rapidly than in the United States. West Point and Rensselaer Polytechnic Institute were the only engineering schools before 1847; in the decade of the 1870's alone some 68 colleges of agricultural and mechanical arts were established. It has been estimated that 866 engineers were graduated in the United States before 1870, 2,259 in the next decade, and on average the number doubled in each of the next three decades.[2] But by this time we may turn to comprehensive data in the population censuses.

The record of the chemists and the engineers in the population census begins in 1870 (Table 1). It is apparent from what we have just said of the number of engineering graduates that the vast majority were not graduates of engineering schools in the period before the first World War. Since there is no clean line that divides skilled workers from academically trained technicians, the early figures are especially subject to qualification—in particular the decline in the number of engineers from 1870 to 1880 may well represent only a lifting of the census standards for an engineer. In fact there appears to have been a steady tendency up to the present time to raise the qualifications for an engineer in the census (we discuss this below). If one could define an engineer or chemist precisely for the entire period, which one cannot do because the level of competence was steadily rising, there is little doubt that a growth even more rapid than that displayed in Table 1 would be found.

Even with the downward bias, however, the growth has been

[1] See W. E. Wickenden, *A Comparative Study of Engineering Education in the United States and in Europe*, Society for the Promotion of Engineering Education, 1929; Thomas T. Read, "The Beginnings of Engineering Education," *Journal of Engineering Education*, December 1939, pp. 348–353.

[2] C. R. Mann, *A Study of Engineering Education*, The Carnegie Foundation for the Advancement of Teaching, 1918.

immense, and retardation has been relatively slight in recent decades for the engineers. Over the eight decades the number of chemists and engineers grew 17 times as fast as the labor force. It is not unusual for a new occupation to grow at a very rapid rate, but it is unusual for the rate of growth to be sustained at so high a level when the numbers involved approach 1 per cent of the entire labor force.

TABLE 1

The Growth of Engineering and Chemical Professions, 1870–1950

| | | | PERCENTAGE GROWTH IN DECADE | |
|---|---|---|---|---|
| | CHEMISTS | ENGINEERS | *Chemists* | *Engineers* |
| 1870 | 774 | 7,094 | | |
| 1880 | 1,969 | 7,061 | 154.4 | —0.5 |
| 1890 | 4,503 | 28,239 | 128.7 | 299.9 |
| 1900 | 8,847 | 43,239 | 96.5 | 53.1 |
| 1910 | 16,273 | 88,755 | 83.9 | 105.3 |
| 1920 | 32,941 | 136,121 | 102.4 | 53.4 |
| 1930 [a] | 47,538 | 227,590 | 44.3 | 67.2 |
| 1940 | 60,005 | 277,872 | 26.2 | 22.1 |
| 1940 [b] | 56,825 | 291,465 | | |
| 1950 [b] | 75,747 [c] | 534,424 [c] | 33.3 | 83.4 |

[a] Average of figures comparable to earlier and later years with respect to occupational classification.

[b] Chemists excluding metallurgists; engineers including metallurgists but excluding surveyors (who were 16,444 in 1940 and 26,229 in 1950). These data are based on the 1950 census in which definitions of chemists and engineers are slightly different from those used in the 1940 census. For details, see Appendix B.

[c] Plus about 6,300 professors and instructors of chemistry and about 8,300 professors and instructors in engineering who were not classified in the published census materials as chemists or engineers (special experimental tabulation for the National Science Foundation).

Source: Alba M. Edwards, *Comparative Occupation Statistics for the United States, 1870 to 1940,* Bureau of the Census, 1943, pp. 49, 111; *Census of Population, 1940,* Series P-14, No. 13; *Census of Population, 1950,* Vol. II, Part 1, Tables 124, 125.

The beginning of instruction in the natural sciences naturally varies widely among disciplines. Mathematics, for example, has been a traditional subject of university instruction and research for centuries; chemistry began to be taught in universities about the same time as engineering; and some disciplines like statistics entered the curriculum only after the Civil War. We have already noted that none of these disciplines was of appreciable size in terms of personnel, and this is especially true in the United States, where interest in pure science lagged considerably behind that of France and Germany in the nineteenth century.

It is not surprising, therefore, that information on the number of persons trained in pure science is very limited: the occupational census, for example, distinguishes this group for the first time in 1950. Some notion of the growth of their numbers, however, may be derived from the estimates of the number of baccalaureate degrees conferred, which have been prepared by the Commission on Human Resources (see Table 2). These estimates are based chiefly upon the departmental composition of the faculties of a small sample of schools, and probably have a large margin of error, but their general pattern is plausible.

TABLE 2

Bachelor's and First Professional Degrees in Natural Sciences since 1901 (in thousands)

| | *Chemistry* | *Physical Science* | *Earth Science* | *Biological Science* | *Total* | *Percentage Growth per Decade* |
|---|---|---|---|---|---|---|
| 1901–1905 | 5.5 | 5.5 | 1.7 | 7.2 | 19.9 | |
| 1906–1910 | 7.5 | 7.1 | 2.5 | 7.4 | 24.5 | |
| 1911–1915 | 9.7 | 8.6 | 3.4 | 7.9 | 29.6 | 48.7 |
| 1916–1920 | 10.4 | 8.6 | 3.6 | 7.5 | 30.1 | |
| 1921–1925 | 14.7 | 13.2 | 5.2 | 12.5 | 45.5 | 53.7 |
| 1926–1930 | 18.8 | 20.1 | 7.0 | 21.8 | 67.7 | |
| 1931–1935 | 19.5 | 20.7 | 7.1 | 24.1 | 71.4 | 56.9 |
| 1936–1940 | 25.3 | 23.4 | 8.5 | 28.8 | 86.1 | |
| 1941–1945 | 25.5 | 22.5 | 8.3 | 28.9 | 85.2 | 19.3 |
| 1946–1950 | 39.5 | 36.3 | 11.1 | 63.3 | 150.1 | |
| 1951–1955 | 33.2 | 36.9 | 14.0 | 69.0 | 153.1 | 79.7 |

Source: Dael Wolfle, *America's Resources of Specialized Talent,* Harper, 1954, Table B-2; *Earned Degrees Conferred by Higher Educational Institutions,* Office of Education, Circulars 418 and 461, December 1954 and 1955.

The increase in number has been about sevenfold in each of the natural sciences except biology, and about ninefold in this field, between 1901–1905 and 1946–1950. Large as these increases have been, however, they are less than the increase in the total number of bachelor's and first professional degrees; in the former period the natural sciences were 13.3 per cent of the total, and in the recent period 10.7 per cent of the total.

Nor do these holders of degrees in natural science constitute an occupation in the same sense that engineers do. Only one-fifth, it has been estimated, were active in natural sciences as a professional calling in 1953,[3] a quarter more were in health fields, and another quarter were still students (for advanced degrees) or outside of the labor force.

Moreover, the level of full professional preparation in these fields is commonly set at the level of the Ph.D., not the bachelor's degree. In some disciplines and lines of employment the goal is seldom reached: for example, only a small fraction of statisticians (classified as mathematicians) in industry or government have a doctorate; and only 20.8 per cent of the chemists surveyed by the Bureau of Labor Statistics in 1954 had doctor's degrees, although another 24.1 per cent had master's degrees.[4] On the other hand, most of the mathematicians and physicists of professorial rank—and universities have been the chief line of employment for these scientists—possess the Ph.D.

TABLE 3

Doctoral Degrees in Natural Sciences and Engineering since 1901

| | *Chemistry* | *Physical Science* | *Earth Science* | *Biological Sciences* | *Other* | *Engineering* | *Total* |
|---|---|---|---|---|---|---|---|
| 1901–1905 | | | | | | | 636 |
| 1906–1910 | | | | | | | 841 |
| 1911–1915 | 360 | 260 | 120 | 350 | | 10 | 1,100 |
| 1916–1920 | 420 | 280 | 130 | 390 | | 20 | 1,240 |
| 1921–1925 | 760 | 440 | 200 | 680 | | 60 | 2,140 |
| 1926–1930 | 1,470 | 770 | 350 | 1,280 | | 150 | 4,020 |
| 1931–1935 | 2,400 | 1,130 | 420 | 2,130 | | 340 | 6,420 |
| 1936–1940 | 2,560 | 1,300 | 430 | 2,810 | | 320 | 7,410 |
| 1941–1945 | 2,890 | 1,010 | 340 | 2,710 | | 230 | 7,170 |
| 1946–1950 | 3,190 | 1,790 | 540 | 2,470 | 80 | 1,180 | 9,240 |
| 1951–1955 | 5,098 | 3,716 | 997 | 4,921 | 74 | 2,763 | 17,569 |

Source: Before 1911: D. E. Scates, B. C. Murdoch, and A. V. Yeomans, *The Production of Doctorates in the Sciences, 1936–1948*, American Council on Education, 1951, p. 25; 1911–1950: Dael Wolfle, *America's Resources of Specialized Talent*, Harper, 1954, p. 300; 1951–1955: *Earned Degrees Conferred by Higher Educational Institutions*, Office of Education, Circulars 418 and 461, December 1954 and 1955.

The growth of the number of doctorates in natural science has been even more rapid than that of first degrees (see Table 3). Again, however, the growth has not outstripped that of all doctorates: the

[3] Based upon a small sample of graduates in 1930, 1940, and 1951 (see Dael Wolfle, *America's Resources of Specialized Talent*, Harper, 1954, p. 302).

[4] *Factors Affecting Earnings in Chemistry and Chemical Engineering*, Bureau of Labor Statistics, Bull. 881, 1946, p. 5.

natural scientists formed 44.2 per cent of the total in 1901–1905 and 38.3 per cent in 1946–1950.[5]

The 1950 census reports that aside from the chemists—whose numbers have already been given in Table 1—the natural scientists numbered about 72,000, distributed as follows:

| | | |
|---|---|---|
| Physical sciences | | 37,812 |
| Mathematics | 7,259 | |
| Physics | 11,120 | |
| Statistics | 19,433 | |
| Earth sciences | | 11,810 |
| Biological sciences | | 18,547 |
| Other | | 3,945 |

Since the total number of living doctorates in these fields was only about 25,000, and not all of these were professionally active, it is apparent that at most one scientist in three had the degree and that the average academic preparation was probably closer to a master's degree.

## 2. *What is an Engineer?*

A scientist or an engineer is a person with extensive knowledge of some area of technological science—knowledge which is at least somewhat formal and abstract, if we are to separate him from workers with purely empirical knowledge. How extensive this knowledge need be is obviously a matter of arbitrary decision, and if the decision is not to be absurd as well as arbitrary, it will vary with time and perhaps in space. The requirement of formal training, however, is essential: so long as one can acquire the necessary training wholly by experience, it is apparent that no sharp line can be drawn between professional and nonprofessional workers.

The problem of definition is acute especially in the case of engineers, for this profession is only a little over half way through the long transition from training through experience to training through formal education. The varying definitions of an engineer have been a source of major differences of opinion concerning the number of professional workers and their prospective number. Thus, the Bureau of Labor Statistics and the professional engineering societies estimate that the number of engineers in 1950 was about

[5] If the doctorates in engineering are added, the percentage is remarkably stable (at about 45 per cent) throughout the entire period.

400,000;[6] and the census reports 540,000. Before we turn to the differences in definition of an engineer, it will be instructive to examine the census data more closely.

The census data on engineers and chemists for 1940 and 1950 provide important clues on the sources and characteristics of new engineers. If we compare the number of engineers and chemists of (say) age 30 in 1940 with the number of age 40 in 1950, we would expect the latter number to be smaller if all new entrants came from graduating classes of engineering schools. Some engineers would have died during the decade (and in older age groups some

TABLE 4

Comparison of Numbers of Male Engineers and Chemists of Given Age in 1940 and 1950

| *Age Group in 1940* | *Number in 1940* | *Deaths and Retirements 1940 to 1950* [a] | *Predicted Number 1950* | *Actual Number in 1950* | *Predicted Number as Per Cent of Actual Number* |
|---|---|---|---|---|---|
| 25–34 | 86,685 | 4,265 | 82,420 | 160,487 | 51.4 |
| 35–44 | 94,009 | 10,830 | 83,179 | 108,862 | 76.4 |
| 45–54 | 63,648 | 17,497 | 46,131 | 58,550 | 78.8 |
| 55–64 | 29,010 | 20,176 | 8,834 | 15,892 [b] | 55.6 |
| Total | 273,352 | 52,768 | 220,584 | 343,791 | 64.1 |

[a] Estimated from *Tables of Working Life*, Bureau of Labor Statistics, Bull. 1001, 1950.
[b] 65 and over.
Source: *Census of Population, 1940,* Vol. III, *The Labor Force,* Part 1, Table 65, p. 98. *Census of Population, 1950,* Vol. II, Part 1, Table 127, p. 273.

would have retired), and some would have left engineering work. Of course some who had left engineering work before 1940 might return to this occupation during the decade—and no doubt a number did because of the increased employment opportunities. But as a rule this "re-entry" would be relatively small for an academically trained professional worker, simply because more could usually be earned even under depressed conditions in the field for which he was trained than in any other field. Such expectations are fully confirmed for a field like medicine, but not for engineers and chemists (Table 4).

We find, instead, at every age group for which a comparison can

[6] See *Effect of Defense Program on Employment Outlook in Engineering*, Bureau of Labor Statistics, Supplement to Bull. 968, 1951, p. 2; also Wolfle, *op. cit.*, pp. 95–96. We discuss the reconciliation of the 1950 census figures with those given for 1940 in Appendix E.

be made, that the expected number of 1940 survivors was only one-half to four-fifths of the actual number in 1950.[7] And this calculation makes no allowance for those who were engineers in 1940 but transferred to other occupations during the decade. Since relatively few of the men over 25 in 1940 would have acquired engineering degrees during the decade, we may infer that most of the new recruits were trained on the job rather than academically. These recruits were relatively most numerous in the younger age groups, but it is impressive that even in the age groups 55 to 65 (in 1950), at least one-fifth were new recruits. We may demonstrate our conclusion in another way. In the decade 1940–1950, the net increase in engineers was about 243,000 and the gross increase, about 333,000. The number of new graduates of engineering schools, however, was only 192,100, or 57.7 per cent of the gross increase. (We discuss the recruitment of new engineers in some detail in Chapter IV.)

In 1940, about 61 per cent of the engineers and chemists had attended college for 4 or more years,[8] and the percentage was almost the same in each of the major branches of specialization (see Table 5). We may estimate the total number of living graduates of engineering schools who were in the labor force in 1940 to be 226,000, and we find that they amounted to about 78 per cent of the number of engineers.[9] It appears, therefore, that a considerable number of engineering graduates leave the profession. Thus, if we may compare the 156,000 engineers with 4 or more years of college in 1940 (Table 5) with the 226,000 living graduates, we may say that three-tenths of the college-trained engineers had left the profession.[10]

The census definition of an engineer is less exacting than that of the professional engineering societies, but there is no evidence that

[7] Since the last 1950 group is 65 and over, rather than 65 to 75, it is a trifle too large for strict comparability, and the percentage of expected to actual numbers (55.6) is a trifle too small.

[8] Since the census does not distinguish types of college training, we cannot tell how many of these college-trained engineers studied in other fields. But we do know that about 15 per cent of those who were graduated by colleges in 1951 and entered engineering employment had specialized in nonengineering fields while in college (for details, see Chapter IV).

[9] We use Wolfle's series on graduates (*op. cit.*, pp. 294–295), and deduct deaths and retirements on the basis of *Tables of Working Life*, Bureau of Labor Statistics, Bull. 1001, 1950.

[10] Wolfle estimates the total number of persons living in 1953 with degrees in engineering to be 529,000; he estimates the number of college graduates employed in engineering in 1953 at 361,000 (Wolfle, *op. cit.*, p. 96).

it has become easier to qualify as an engineer in the successive censuses.[11] On the contrary, some categories which were once included have disappeared from the current enumerations, e.g., boat and steam shovel engineers (1910), foremen in radio stations (1920), mine experts (1920), factory experts, automobile factory (1930). One cannot doubt that the average level of skill of the engineers and chemists counted as such by the census has risen steadily.

TABLE 5

Educational Background of Employed Male Engineers and Chemists and Experienced Male Engineers and Chemists Seeking Work, 1940

| | *Total Number*[a] | *Number with 4 or More Years of College* | *Per Cent with 4 or More Years of College* |
|---|---|---|---|
| Chemists, Metallurgists | 55,420 | 32,620 | 58.9 |
| Civil Engineers | 85,920 | 51,000 | 59.4 |
| Electrical Engineers | 55,000 | 33,540 | 61.0 |
| Mechanical Engineers | 82,580 | 49,120 | 59.5 |
| Other Technical Engineers | 30,920 | 22,100 | 71.5 |
| Total | 309,840 | 188,380 | 60.8 |

[a] Excluding 1,260 who did not report their education.
Source: *Census of Population, 1940, The Labor Force, Occupational Characteristics,* pp. 59, 61.

The professional engineering societies vary somewhat in their requirements for membership, but currently they have either accepted in substance or are approaching the standards proposed by the Committee on Professional Recognition: [12]

1. Member

   Graduate of an approved engineering curriculum plus at least four years of "increasingly important engineering ex-

[11] There is a single exception to this generalization. In 1940 the Bureau of the Census did not count as an engineer anyone under 35 years of age who lacked four years of college training. In 1950, education information was collected only on a 20 per cent sample basis, and the census did not apply this criterion. Accordingly, the 1950 census volumes present data on the number of engineers in 1940 on a definitional basis comparable to 1950, i.e. including those engineers under 35 with less than four years of college. About 20,500 engineers were added to the original 1940 census total by this adjustment (letter from David L. Kaplan, Chief, Occupation and Industry Statistics Section, Population and Housing Division, Bureau of the Census, December 30, 1954). In general we use the 1950 census estimate of the number of engineers in 1940 throughout this study. For further details, see Appendixes B and E.

[12] *Seventeenth Annual Report,* Engineers Council for Professional Development, Sept. 30, 1949

perience," *or* at least ten years of increasingly important engineering experience.

2. Associate Member

   Graduate of an approved engineering curriculum, *or* at least six years of experience of suitable character.

These requirements are sufficiently higher than those required for census enumeration to permit a large difference in numbers.

One can use either the census definition or the stricter professional society definition so long as he is consistent, and for some purposes no doubt the latter definition is superior. For the study of supply and demand conditions, however, there are several reasons for preferring the census definition. Most data, including the reports from employers, will be based upon a definition close to the census practice, and it is therefore possible to bring much more empirical material to bear on the problem. Moreover, the definitions of the professional societies imply that a considerable number of nonengineers do not differ appreciably from engineers: for example, the able graduate of a leading engineering school with three years of experience is no doubt a better engineer than the mediocre graduate of a second class school who has five years' experience, yet the former would be ineligible for full membership in a society. The proportion of society members to all engineers in an industry would presumably be subject to varying influences which would further complicate our analysis.

The difficulties in defining a scientist are less in one direction: only the merest handful of people enter this group except through formal instruction at a college level. There still remains the ambiguity as to the level of academic preparation. We noticed above that only one-third of the scientists reported in the 1950 census could have possessed a doctor's degree. We shall argue for setting a high level of education—the doctorate—because at lower levels there is so much interdisciplinary mobility as to make it unnecessary to examine supply or demand for any one field.

### 3. *The Growth of Organized Research*

One modern development has left its imprint on many aspects of the technological professions: it is the growth of organized research. The explanation of employment in research of the technological professions is of special interest and difficulty, we shall find, because of two characteristics. The first is that research is not closely geared to current activity, whether governmental or business or academic: the army or the chemical company or the university can exist for a time even if research is abolished. The second characteristic is that the federal government plays a dominant role in the determination of the level and directions of this research.

Before we set forth the general facts on the growth of separately organized research, we must enter a warning against reading the statistics too literally. Research is now fashionable in a way it never was before, and it is now easier to get funds for research, in competition with other activities, than it ever was in the past. There is therefore a strong temptation to bring under this heading activities which were once, and not always improperly, classified as some form of nonresearch activity. The growth of organized research has been so vast that it cannot possibly be treated as a statistical illusion, but one should be at least moderately skeptical of some of the details of this growth.

Presumably after a long but gradual rise, expenditures on research in the United States reached an estimated $166 million in 1930, of which federal funds accounted for about $25 million, universities and other nonprofit institutions accounted for about the same amount, and industry accounted for about $116 million.[13] By 1941, total expenditures on research had risen to $900 million of which the government contributed about four-tenths, industry almost six-tenths and nonprofit institutions only several per cent (Tables 6 and 7). By this time the current practice of governmental financing of a considerable portion of research carried on by nongovernmental institutions had appeared on a large scale. Thus the government actually spent only $200 million on its own research activities, while granting $170 million for research carried on elsewhere; industry spent $660 million on research, of which $510 million came from its own funds; and nonprofit institutions spent $40 million on research, of which only $20 million came from their own funds.

Total expenditures on research rose rapidly through World War II, stabilized for several years thereafter, and rose again after the outbreak of the Korean War, reaching a level of $3,750 million in 1952. The government's share in support rose during World

[13] *Science and Public Policy*, President's Scientific Research Board, 1947, Vol. I, Table I; *The Organization of Applied Research in Europe, the United States, and Canada*, Organization for European Economic Cooperation, 1954, Vol. III, pp. 15–17

TABLE 6

Source of Research and Development Funds, 1941–1952
(in millions of dollars)

| | TOTAL | FUNDS RAISED BY Govern-ment | Indus-try | Nonprofit Institu-tions | PERCENTAGE DISTRIBUTION Govern-ment | Indus-try | Nonprofit Institu-tions |
|---|---|---|---|---|---|---|---|
| 1941 | $900 | $370 | $510 | $20 | 41 | 57 | 2 |
| 1942 | 1,070 | 490 | 560 | 20 | 46 | 52 | 2 |
| 1943 | 1,210 | 780 | 410 | 20 | 64 | 34 | 2 |
| 1944 | 1,380 | 940 | 420 | 20 | 68 | 30 | 2 |
| 1945 | 1,520 | 1,070 | 430 | 20 | 70 | 28 | 2 |
| 1946 | 1,780 | 910 | 840 | 30 | 51 | 47 | 2 |
| 1947 | 2,260 | 1,160 | 1,050 | 50 | 51 | 47 | 2 |
| 1948 | 2,610 | 1,390 | 1,150 | 70 | 53 | 44 | 3 |
| 1949 | 2,610 | 1,550 | 990 | 70 | 59 | 38 | 3 |
| 1950 | 2,870 | 1,610 | 1,180 | 80 | 56 | 41 | 3 |
| 1951 | 3,360 | 1,980 | 1,300 | 80 | 59 | 39 | 2 |
| 1952 | 3,750 | 2,240 | 1,430 | 80 | 60 | 38 | 2 |

Source: *The Growth of Scientific Research and Development,* Dept. of Defense, 1953, p. 10.

TABLE 7

Performance of Research and Development, Measured by Expenditures, 1941–1952
(in millions of dollars)

| | TOTAL | PERFORMANCE BY Govern-ment | Indus-try | Nonprofit Institu-tions | PERCENTAGE DISTRIBUTION Govern-ment | Indus-try | Nonprofit Institu-tions |
|---|---|---|---|---|---|---|---|
| 1941 | $900 | $200 | $600 | $40 | 22 | 73 | 5 |
| 1942 | 1,070 | 240 | 780 | 50 | 22 | 73 | 5 |
| 1943 | 1,210 | 300 | 850 | 60 | 25 | 70 | 5 |
| 1944 | 1,380 | 390 | 910 | 80 | 28 | 66 | 6 |
| 1945 | 1,520 | 430 | 990 | 100 | 28 | 65 | 7 |
| 1946 | 1,780 | 470 | 1,190 | 120 | 26 | 67 | 7 |
| 1947 | 2,260 | 520 | 1,570 | 170 | 23 | 69 | 8 |
| 1948 | 2,610 | 570 | 1,820 | 220 | 22 | 70 | 8 |
| 1949 | 2,610 | 550 | 1,790 | 270 | 21 | 69 | 10 |
| 1950 | 2,870 | 570 | 1,980 | 320 | 20 | 69 | 11 |
| 1951 | 3,360 | 700 | 2,300 | 360 | 21 | 68 | 11 |
| 1952 | 3,750 | 800 | 2,530 | 420 | 21 | 68 | 11 |

Source: *The Growth of Scientific Research and Development,* Dept. of Defense, 1953, p. 11.

War II to 70 per cent in 1945, dropped after the war to 51 per cent and then rose again in recent years; the government's share of research performance has continued to decline slightly since the early postwar years. Industry's share of both expenditures and performance moved inversely to the government's share over this period.[14] Nonprofit institutions have accounted for a rising share of actual expenditures, reaching 11 per cent in the early 1950's, but have contributed only about 2 or 3 per cent of total funds over the entire period.

TABLE 8

Number and Percentage Distribution of Research Engineers and Scientists, 1941–1952

| | | NUMBER (in thousands) | | | PERCENTAGE DISTRIBUTION | | |
|---|---|---|---|---|---|---|---|
| | TOTAL | *Government* | *Industry* | *Nonprofit Institutions* | *Government* | *Industry* | *Nonprofit Institutions* |
| 1941 | 87 | 17 | 62 | 8 | 20 | 71 | 9 |
| 1942 | 90 | 18 | 64 | 8 | 20 | 71 | 9 |
| 1943 | 97 | 21 | 67 | 9 | 22 | 69 | 9 |
| 1944 | 111 | 27 | 72 | 12 | 24 | 65 | 11 |
| 1945 | 119 | 29 | 76 | 14 | 24 | 64 | 12 |
| 1946 | 122 | 28 | 80 | 14 | 23 | 66 | 12 |
| 1947 | 125 | 25 | 84 | 16 | 20 | 67 | 13 |
| 1948 | 133 | 25 | 90 | 18 | 19 | 68 | 14 |
| 1949 | 144 | 26 | 94 | 24 | 18 | 65 | 17 |
| 1950 | 151 | 25 | 100 | 26 | 17 | 66 | 17 |
| 1951 | 158 | 28 | 104 | 26 | 18 | 66 | 17 |
| 1952 | 180 | 33 | 118 | 29 | 18 | 66 | 16 |

Source: *The Growth of Scientific Research and Development,* Dept. of Defense, 1953, p. 12.

The estimated number of research scientists and engineers roughly doubled between 1941 and the early 1950's, rising from almost 90,000 to 180,000 in 1952 (Table 8). (The much smaller rise in personnel than in dollar expenditures reminds us that a considerable part of

[14] The aircraft and electrical machinery industries receive the bulk of federal grants for research and development. According to BLS estimates, the aircraft industry engaged in $350 million of government-financed research in 1951, and the electrical machinery industry $250 million. About $50 million of research in the professional and scientific instruments industry was similarly paid for by the federal government. The remaining $200 million of federally financed industrial research was carried on by the remaining manufacturing and nonmanufacturing industries. *Scientific Research and Development in American Industry,* Bureau of Labor Statistics, Bull. 1148, 1953, p. 22.

the expenditure increase was due to rising prices.) There were an estimated 151,000 research scientists and engineers in 1950; professional research personnel thus represented between a fifth and a fourth of all engineers and natural scientists in that year. About two-thirds of the research scientists and engineers worked for industry in the early 1950's, and about one-sixth each for the government and nonprofit institutions.

TABLE 9

Federal Government Expenditures for Research and Development (in millions of dollars)

| *Fiscal Year* | *Expenditures for Conduct of Research and Development* | *Expenditures for Increase in Research and Development Plant* | *Total* |
|---|---|---|---|
| 1948 | 803 | 62 | 865 |
| 1949 | 981 | 116 | 1,097 |
| 1950 | 994 | 150 | 1,143 |
| 1951 | 1,126 | 216 | 1,342 |
| 1952 | 1,571 | 268 | 1,839 |
| 1953 | 1,846 | 262 | 2,108 |
| 1954 | 1,845 | 250 | 2,095 |
| 1955 [a] | 1,829 | 242 | 2,071 |
| 1956 [a] | 1,966 | 251 | 2,218 |

[a] Estimated.

Source: Raymond H. Ewell, "Estimated Volume of Research and Development Expenditures by Federal Government in 1955," *Papers of the Fourth Conference on Scientific Manpower,* National Science Foundation, December 1954, p. 24.

Other data on federal expenditures for the support of research carried on both within and without the government are available for more recent years and are presented in Table 9. These data overlap in time those discussed above and differ somewhat in coverage. The data in Tables 6 and 7 were prepared by the Department of Defense and include estimates of research and development costs included in procurement contracts,[15] as well as compensation for uniformed personnel assigned to research installations. Currently, government estimates of federal expenditures on research and development are prepared by the National Science Foundation and the latter's definitions exclude procurement costs and uniformed personnel compensation, but include capital ex-

[15] Such research and development costs have been estimated at about a half billion dollars in recent years.

penditures for research. In terms of the National Science Foundation definitions, federal expenditures rose about $700 million between fiscal years 1950 and 1952, of which almost $600 million was for current research operations, and almost $300 million more in fiscal 1953, all of which was for current operations. Federal expenditures stabilized at slightly more than $2.0 billion in 1954 and 1955, and increased again in 1956 to about $2.2 billion.[16]

The bulk of federal research funds (72 per cent in fiscal 1955) are spent by the Department of Defense. The agency with the next largest research budget is the Atomic Energy Commission, which accounted for 13 per cent of the total in 1955. The remaining 15 per cent of federal research funds are scattered widely over other government agencies.[17]

Of an estimated 60,000 engineers, physical scientists and mathematicians employed by the federal government in 1954, about 28,000 were engaged in research activities.[18] Engineers were almost one-half of the research personnel and about two-thirds of all federally employed technological professional workers. The second largest group in government employment were the 5,400 physicists, of whom almost nine-tenths were in research. The third largest group consisted of 4,900 chemists (of whom three-quarters were in research).

Employment in organized industrial research, i.e., that portion of industrial research carried on in separately organized private research laboratories, grew from less than 10,000 in 1920 to 70,000 in 1940 and to 165,000 in 1950, according to surveys by the National Research Council.[19] Total professional personnel in such laboratories

[16] Of the total federal obligations for research in 1955, the physical sciences accounted for about 86 per cent, the biological sciences, about 4 per cent, the medical sciences, 5 per cent, the agricultural sciences about 2 per cent and the social sciences about 2 per cent. *Federal Funds for Science,* National Science Foundation, *III. Federal Research and Development Budget, Fiscal Years 1953, 1954, and 1955,* not dated, p. 7.

[17] *Ibid.,* p. 21.

[18] Raymond H. Ewell, "Estimated Volume of Research and Development Expenditures by Federal Government in 1955," in *Papers of the Fourth Conference on Scientific Manpower,* National Science Foundation, December 1954, p. 27. These totals do not include all research scientists who were federally employed; for example, they exclude those in the life sciences, as well as those physical scientists and engineers who were holding jobs whose civil service titles did not clearly indicate that they should be included.

[19] *Research—A National Resource,* National Resources Planning Board, 1940, Vol. II, pp. 174–176; *Research in Development Personnel in Industrial Laboratories, 1950,* Office of Education, 1952, p. 9. A portion of this apparent growth represents fuller coverage.

rose from 37,000 in 1940 to 71,000 in 1950. The major occupations represented in 1950 were engineers (including metallurgists) who accounted for 54.2 per cent of all professional laboratory personnel, chemists, 32.8 per cent, and physicists, 4.2 per cent. The only important changes since 1940 in the relative importance of the several scientific disciplines were the growth of engineers (who represented 46.6 per cent of the laboratory professionals in 1940) and the decline of chemists (who accounted for 42.9 per cent of all professions in 1940).

TABLE 10

Industrial Research Activities, 1952–1955

| | PERFORMANCE OF RESEARCH (in millions) | SUPPORT OF INDUSTRIAL RESEARCH (in millions) | | *Number of Industrial Research Scientists and Engineers* |
|---|---|---|---|---|
| | | *Government* | *Industry* | |
| 1952 [a] | $2,030 | $600 | $1,430 | 95,000 |
| 1953 | 2,450 | 850 | 1,600 | 114,000 |
| 1954 | 2,580 | 850 | 1,730 | 120,000 |
| 1955 | 2,700 | 850 | 1,850 | 126,000 |

[a] On the earlier Department of Defense definitions, performance of research by industry and government support of such research were about $500 million higher, and the number of research scientists and engineers was 33,000 higher.

Source: A. L. Lyman, "Estimated Volume of Research and Development Expenditures by Industry in 1955," *Papers of the Fourth Conference on Scientific Manpower,* National Science Foundation, December 1954, pp. 32–34.

Estimates of the total number of research scientists and engineers in industrial employment since 1952 are presented in Table 10.[20] The volume of industrial research expenditures continued to rise in this period and the number of research scientists and engineers increased by 6,000 per year between 1953 and 1955.[21]

[20] A. L. Lyman, "Estimated Volume of Research and Development Expenditures by Industry in 1955," in *ibid.* The expenditure estimates were derived by means of a survey of a sample of large companies in those industries which account for the bulk of private research expenditures. Percentage changes since 1952 for each industry were weighted by the proportion of industrial research expenditures accounted for by each industry in 1952. The personnel figures were derived by assuming that the same volume of research expenditures per scientist was incurred in 1953–1955 as in 1952 under the Department of Defense definitions.

[21] Since these data are based upon National Science Foundation definitions, they exclude research carried on and personnel employed under procurement contracts.