2. ORGANIZATION OF RESEARCH

ORGANIZATION OF THE RESEARCH ENTERPRISE

Kotaro SHIMO

(Unless otherwise stated, the source of figures is the Survey of R&D, Statistics Burearu, Prime Minister's Office, 1979)

I. Facts and Figures

1. R&D expenditure

The total R&D expenditure in Japan in 1978 is 4,045.9 billion yen, of which 88.2% is for natural science and 11.8% is for social science and humanities. (Table 1)

The ratio of the scientific R&D expenditure (3,570 billion yen) as against GNP (209,248 billion yen) is 1.71%.

2. Distribution by sector

Of the R&D expenditure (henceforth for the scientific), 64.2% is expended by industry, 20.0% by universities and colleges, and 15.8% by research institutions.

3. Sources of funds

71.9% of the R&D expenditure is borne by private sector, 28.0% by government sector and the rest from abroad.

4. Government R&D expenditure

The total government expenditure related to science and technology amounts to 1,150,841 million yen. (Table 2, White Paper on Science and Technology 1979)

This accounts 2.98% of the government budget.

Its distribution by purpose is, 17.7% for nuclear technology, 9.7% for space, 2.2% for defence, 1.7% for ocean and 68.7% for other civilian purposes.

5. Types of R&D

In industry, 4.6% of R&D expenditure is for basic research, 18.2% for applied research and 77.1% for development.

In universities and colleges, 57.3% is for basic research, 37.3% for applied research and 5.4% for development.

In research institutions, the ratio is 17.6%, 38.7% and 43.7% respectively.

6. Components and man-power of the research system (as of April 1, 1979)

The number of R&D executing entities is, 14,757 companies, 618 universities and colleges, 894 research institutions.

The number of persons engaged in R&D in each sector is, 310,120 for companies, 137,377 for universities and colleges, 65,279 for research institutions.

The number of researchers in each sector is, 157,279 (companies), 96,724 (universities and colleges) and 27,917 (research institutions) people.

7. R&D in industry

The industries having preponderant R&D expenditure are, electrical machinery 25.3% of the total, transportation equipment 17.6%, chemical products 17.6%, machinery except electrical 7.0% and iron and steel 4.7%. (Table 3)

The industries having higher R&D expenditure as percentage of sales are, drugs and medicines 5.0%, electrical machinery 3.74% precision machinery 3.15%, and motor vehicles 2.6%. (Table 4)

8. R&D in universities and colleges

The number of natural science faculties in *national* universities and colleges accounts 349, that of *public* universities and colleges 42, that of *private* ones 227.

The number of researchers are, 52,019, 7,124, 32,365 people respectively.

The R&D expenditure is, 399,275 million yen, 35,676 M.¥, 277,667 M.¥ respectively. (Table 5)

II. Analysis and Critical Comments

1. Organization and autonomy

Fig. 1 shows the organization of Japan's scientific and technological administration.

Recent conspicuous organizational evolution and commencement of new programs are, Atomic Energy Safety Commission (1979), Agency of Natural Resources and Energy (1973), National Inter-University Research Institutes (1971), Sunshine Project (new energy R&D, 1974) Moonlight project (energy conservation R&D, 1978), etc.

As regards national research institutes, selection of R&D themes and budget allocation are made each year according to the policy orientation of the controlling ministries and agencies. In making the general orientation of policies, government agencies take into account opinions of the attached advisory councils.

Generally speaking, advisory councils make reports and recommendations every few years in response to the enquiry made by the government agencies, while each government agency has strong autonomy in policy making.

2. Cooperation between government institutes, academia and private sector

In Japan, both cooperation between the three sectors and mobility of R&D personnel across sectors are very insufficient.

According to the recent survey made by the Science and Technology Agency, there are four major obstacles for the cooperation; government single year budget principle, attribution of research results, confidentiality and publication of research results and lack of fora for cooperation.

Obstacles for mobility lie in the traditional life employment system and public service regulations.

Attempts have been undertaken to establish a better cooperation between three sectors in Tsukuba Science City. This scientific complex is the outcome of a government plan to develop comprehensively education and research activities by bringing together universities, research institutes and industrial laboratories into a national science centre. The 43 government research institutes and educational institutions have moved in the newly constructed city by March, 1980.

Some private industrial laboratories have been established to take advantage of collaboration with these national research establishments. Tsukuba Science City is located 60km north-east of Tokyo and extends 2,700 hectares (6,672 acres). More than ten years and 1,132 billion yen have been spent for its construction.

3. Internationalization

It seems that the Japanese R&D community does not have sufficient international collaboration and exchange of personnel. While the Japanese scientists and engineers extend their activities abroad, foreign counterparts have much difficulty to stay and execute research in Japan.

There are two major obstacles to be overcome; the language problem and the restrictive regulations related to the Public Service Law.

III. Recommendation for Improvement

1. Increase of R&D expenditure

The Council of Science and Technology recommends 3% of national income as a long term objective of R&D expenditure. The recently published "Vision for the 80s" by the MITI proposes the increase of R&D expenditure up to 2.5% of GNP by the mid-80s, up to 3% by the end of 80s. It also recommends that the government spending should be increased to 40% of the total R&D expenditure. These figures can compare with the present US and European efforts.

2. Measures for improvement of cooperation and mobility of personnel between three sectors.

Efforts should be made to resolve the problems mentioned above. In particular, restrictive measures imposed on the government sector (research institutes and universities) should be abated. Engineering faculties of national universities now suffer declension of heraldic role because of dwindling collaboration with industries.

3. Cultivation of creative scientists and international cooperation

The introduction of new common entrance examination for the national universities since 1979 seems to have substantial impact on the selection of capable students. It is expected that such reform with induce further improvement of educational system for the young people having special abilities. The post-war educational system has been effective to democratize higher education and to cultivate general ability of the young generation. There now needs variety of creative abilities in different disciplines for Japan's future.

There needs also substantial and prompt improvement related to the public service qualification in order to internationalize staff composition in the national universities.

Table 1. R&D Expenditure

(billion yen)

Year	Total	Natural science	Social science and humanities
70	1,355.5	1,195.3	160.2
71	1,532.4	1,345.9	186.5
72	1,791.9	1,586.7	205.2
73	2,215.8	1,980.9	234.9
74	2,716.0	2,421.4	294.7
75	2,974.6	2,621.8	352.7
76	3,320.7	2,941.4	379.3
77	3,651.3	3,233.5	417.8
78	4,045.9	3,570.0	475.9

Table 2. Government Expenditure for Science and Technology

(million yen)

	Government expenditure for science & technology (A)	Government budget (B)	A/B (%)
1975	677,321	21,288,800	3.18
1976	771,959	24,296,001	3.18
1977	870,605	28,514,270	3.05
1978	990,489	34,295,011	2.89
1979	1,150,841	38,600,143	2.98

White Paper on Science & Technology, 1979.

Table 3. Industrial R&D Expenditure

	Industry	Expenditure on R&D (million yen)					
		1973	1974	1975	1976	1977	1978
1	All industries	1,301,927	1,589,053	1,684,847	1,882,231	2,109,500	2,291,002
2	Agriculture, forestry and fisheries	1,256	3,799	3,672	2,883	4,959	9,040
3	Mining	8,050	10,559	10,898	12,203	7,886	7,605
4	Construction	34,779	41,807	53,041	50,998	61,531	51,212
5	Manufacturing	1,193,515	1,459,385	1,536,514	1,727,415	1,923,105	2,098,741
6	Food	35,261	38,626	46,133	50,925	57,924	61,515
7	Textile mill products	21,193	20,904	22,599	20,917	18,869	24,277
8	Pulp and paper products	21,967	13,576	13,591	12,030	12,464	13,572
9	Publishing and printing	3,465	4,530	5,612	5,660	7,361	6,086
10	Chemical products	238,189	304,235	322,099	351,886	385,952	404,208
11	Industrial chemicals	118,890	156,001	153,451	159,646	164,790	164,513
12	Oils and paints	26,169	34,079	36,642	37,870	47,652	49,724
13	Drugs and medicines	64,406	79,157	95,191	109,537	120,537	134,714
14	Other chemicals	28,724	34,998	36,816	44,834	52,974	55,257
15	Petroleum and coal products	12,817	15,559	17,095	18,069	27,047	24,886
16	Rubber products	19,179	25,395	28,557	30,994	40,367	42,991
17	Ceramics	27,760	38,102	41,745	52,137	52,828	58,415
18	Iron and steel	59,595	80,424	89,211	99,835	103,681	107,921
19	Non-ferrous metals and products	20,180	26,876	25,995	28,631	30,897	34,415
20	Fabricated metal products	20,655	23,264	29,428	40,470	38,577	39,948
21	Machinery, except electrical	86,925	146,208	115,524	138,624	171,252	160,535
22	Electrical machinery	341,492	397,388	400,495	491,667	501,291	580,521
23	Electrical machinery, equipment and supplies	146,905	159,563	166,656	206,359	229,145	266,975
24	Communication and electronic equipment	194,587	237,825	233,839	285,308	272,147	313,546
25	Transportation equipment	215,088	242,250	289,465	286,635	357,724	404,155
26	Motor vehicles	160,245	184,128	195,930	219,344	269,499	332,966
27	Other transportation equipment	54,842	58,122	93,535	67,291	88,224	71,189
28	Precision machinery	30,876	34,641	35,908	43,224	57,218	69,195
29	Other manufacturing	38,872	47,408	53,055	55,712	59,653	66,100
30	Transport, communication and public utilities	64,328	73,502	80,722	88,731	112,019	124,403

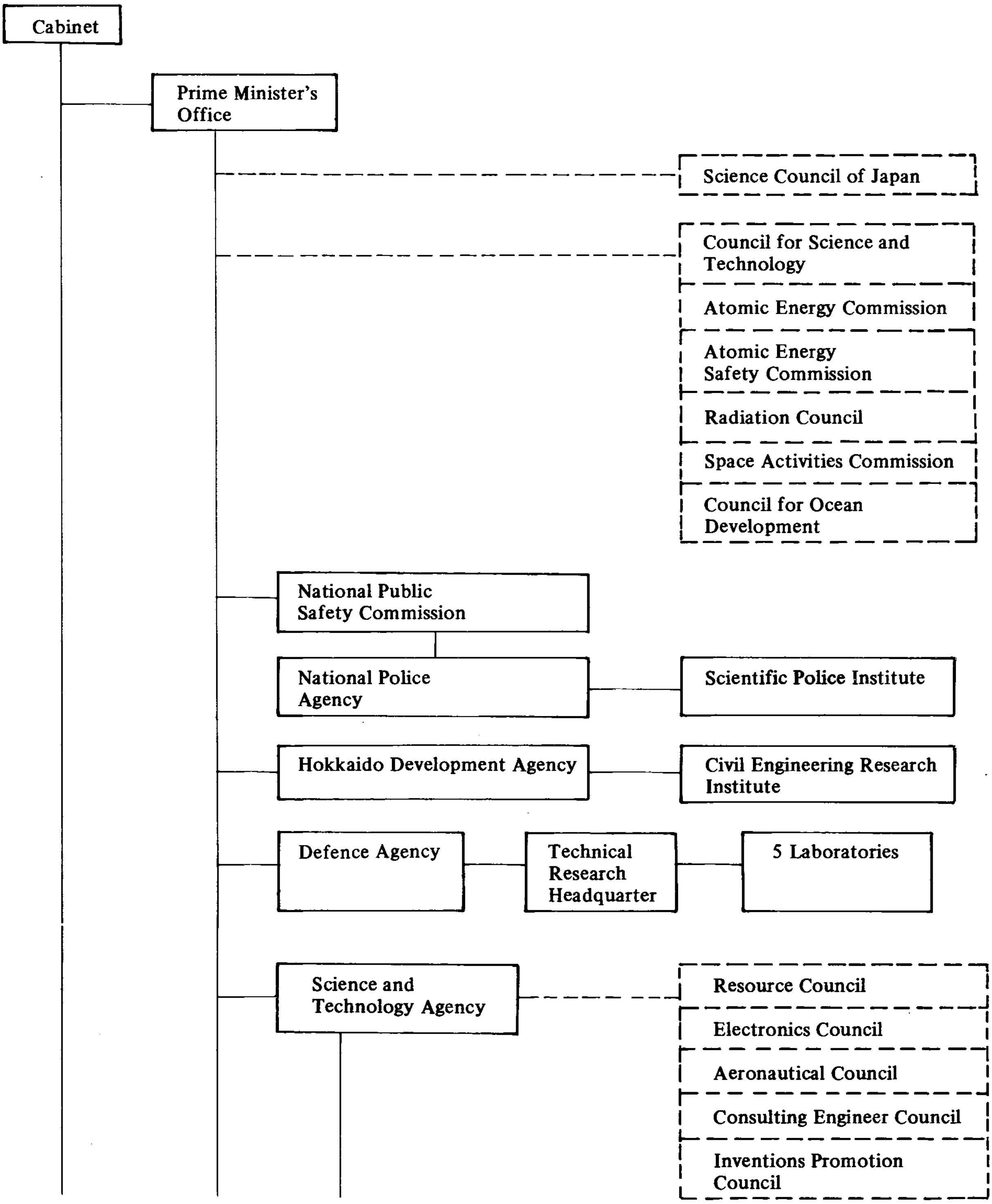
Table 4. Industrial R&D Expenditure as Percentage of Sales

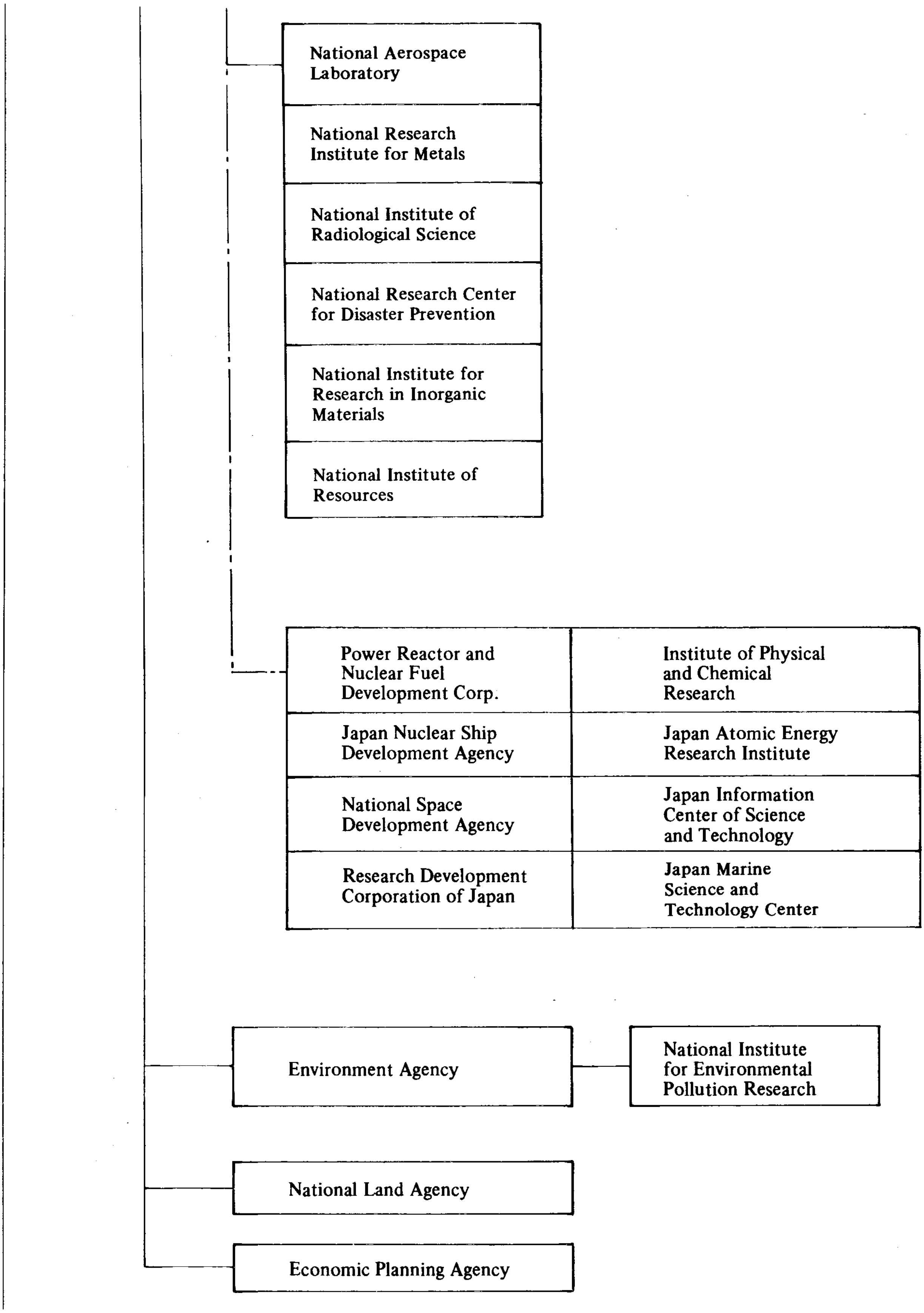
	Industry	Expenditure on R&D (%)					
		1973	1974	1975	1976	1977	1978
1	All industries	1.42	1.42	1.39	1.42	1.48	1.57
2	Agriculture, forestry and fisheries	0.15	0.41	0.32	0.24	0.31	0.60
3	Mining	0.51	0.58	0.58	0.57	0.50	0.54
4	Construction	0.33	0.38	0.49	0.48	0.53	0.42
5	Manufacturing	1.65	1.65	1.61	1.64	1.70	1.82
6	Food	0.54	0.50	0.49	0.49	0.50	0.51
7	Textile mill products	0.73	0.78	0.71	0.66	0.56	0.77
8	Pulp and paper products	1.00	0.54	0.49	0.47	0.46	0.49
9	Publishing and printing	0.39	0.42	0.43	0.46	0.41	0.36
10	Chemical products	2.35	2.33	2.46	2.39	2.62	2.71
11	Industrial chemicals	1.86	1.83	1.84	1.69	1.87	1.92
12	Oils and paints	2.19	2.38	2.40	2.40	2.71	2.73
13	Drugs and medicines	4.11	4.37	4.91	5.05	4.84	5.00
14	Other chemicals	2.94	2.78	2.76	2.88	3.12	3.03
15	Petroleum and coal products	0.28	0.18	0.18	0.18	0.23	0.27
16	Rubber products	1.79	1.85	2.20	2.25	1.96	2.60
17	Ceramics	1.05	1.10	1.25	1.40	1.22	1.29
18	Iron and steel	0.84	1.01	1.05	1.02	1.11	1.08
19	Non-ferrous metals and products	0.87	1.07	1.01	0.96	1.01	1.00
20	Fabricated metal products	0.95	1.01	1.10	1.00	1.18	1.08
21	Machinery, except electrical	1.55	1.93	1.74	1.79	2.01	1.93
22	Electrical machinery	3.64	3.72	3.75	3.66	3.61	3.74
23	Electrical machinery, equipment and supplies	3.22	3.10	3.29	3.49	3.49	3.59
24	Communication and electronic equipment	4.04	4.28	4.17	3.80	3.71	3.89
25	Transportation equipment	2.18	2.14	1.95	2.08	2.27	2.44
26	Motor vehicles	2.51	2.38	1.77	2.20	2.32	2.60
27	Other transportation equipment	1.57	1.61	2.48	1.76	2.12	1.90
28	Precision machinery	2.68	2.66	2.74	2.37	2.91	3.15
29	Other manufacturing	0.98	1.17	1.17	1.24	1.15	1.16
30	Transport, communication and public utilities	0.27	0.24	0.27	0.27	0.33	0.35

Table 5. R&D Personnel and Expenditure in Universities and Colleges

Kind of Univ.	1974		1975		1976		1977		1978	
	Researchers (persons)	R&D expenditure (million yen)	Researchers (persons)	R&D expenditure (million yen)	Researchers (persons)	R&D expenditure (million yen)	Researchers (persons)	R&D expenditure million yen)	Researchers (persons)	R&D expenditure (million yen)
National	43,362	245,135	46,771	284,293	50,795	317,986	53,110	351,945	52,019	399,275
Public	6,605	27,052	6,148	29,574	7,120	31,877	7,559	35,745	7,124	35,676
Private	26,232	173,054	28,489	202,414	30,209	237,790	32,110	242,007	32,365	277,667

Fig. 1 Organization Chart of Japan's Scientific and Technological Administration

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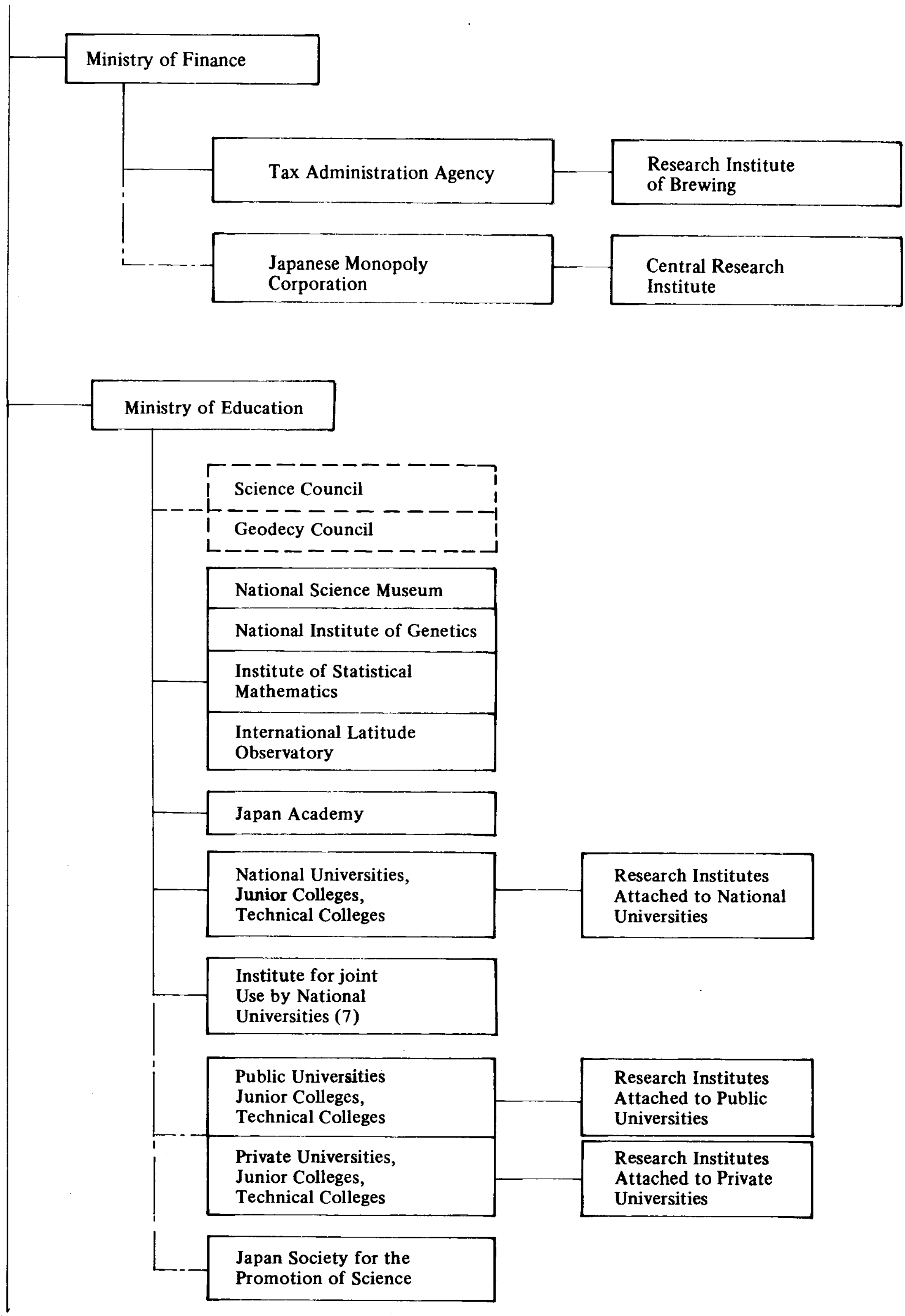
National Research Institute for Metals
National Institute of Radiological Science
National Research Center for Disaster Prevention
National Institute for Research in Inorganic Materials
National Institute of Resources
Power Reactor and Nuclear Fuel Development Corp.
Institute of Physical and Chemical Research
Japan Nuclear Ship Development Agency
Japan Atomic Energy Research Institute
National Space Development Agency
Japan Information Center of Science and Technology
Research Development Corporation of Japan
Japan Marine Science and Technology Center
Environment Agency
National Institute for Environmental Pollution Research
National Land Agency
Economic Planning Agency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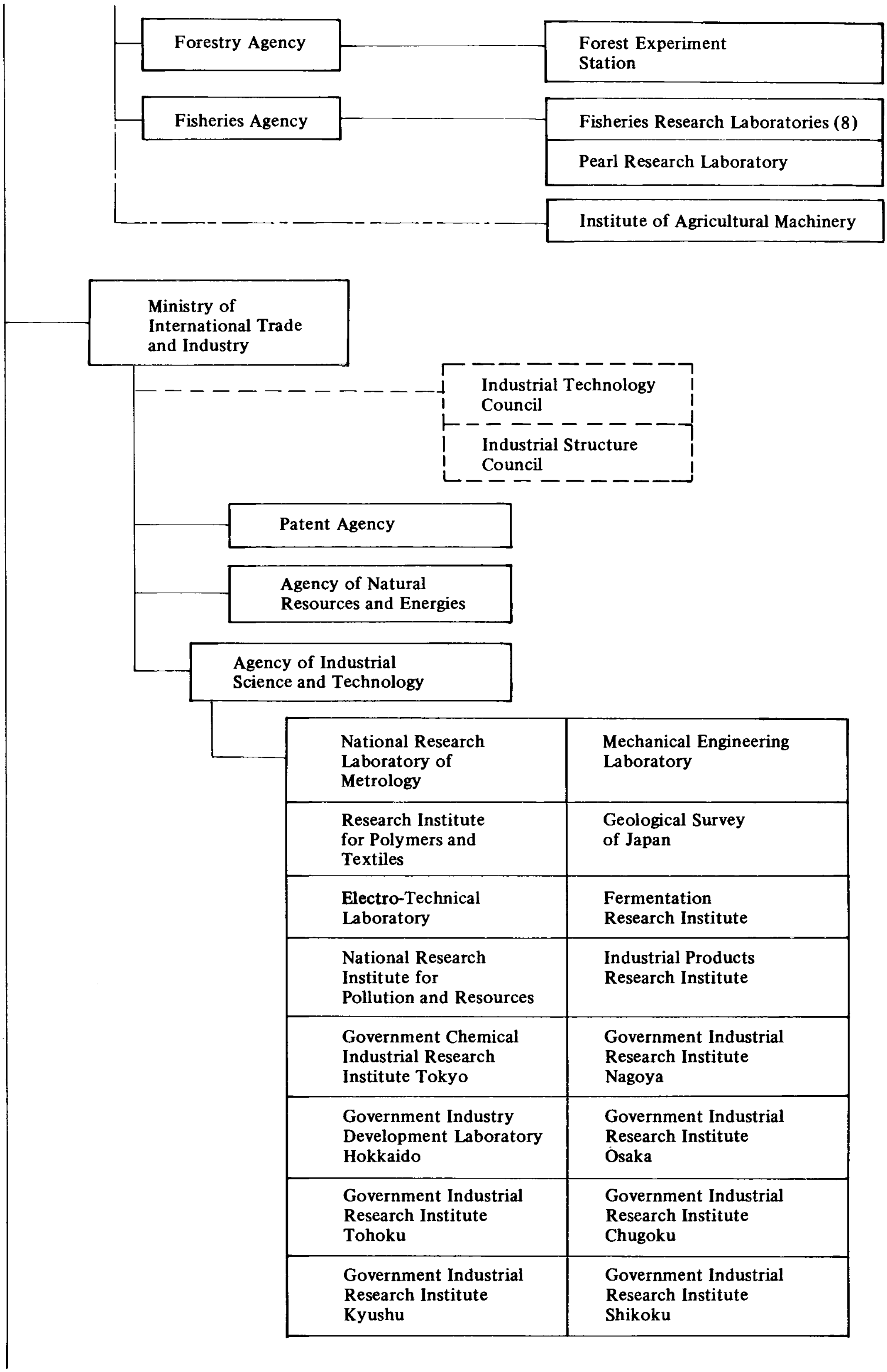
Tax Administration Agency
Research Institute of Brewing
Japanese Monopoly Corporation
Central Research Institute
Ministry of Education
Science Council
Geodecy Council
National Science Museum
National Institute of Genetics
Institute of Statistical Mathematics
International Latitude Observatory
Japan Academy
National Universities, Junior Colleges, Technical Colleges
Research Institutes Attached to National Universities
Institute for joint Use by National Universities (7)
Public Universities Junior Colleges, Technical Colleges
Research Institutes Attached to Public Universities
Private Universities, Junior Colleges, Technical Colleges
Research Institutes Attached to Private Universities
Japan Society for the Promotion of Science

- Ministry of Health and Welfare
  - Institute of Public Health
  - National Institute of Hygienic Science
  - National Institute of Nutrition
  - Institute of Popullation Problems
  - National Institute for Leprosy Research
  - National Institute of Mental Health
  - National Cancer Center
  - National Institute of Health
  - Institute of Hospital Administration
- Ministry of Agriculture and Forestry
  - Agriculture, Forestry and Fisheries Research Council
  - National Institute of Agricultural Science
  - Central Agricultural Experiment Station
  - National Research Institute of Agricultural Economics
  - Sericultural Experiment Station
  - National Institute of Animal Industry
  - Fruit Tree Research Station
  - National Institute of Animal Health
  - National Grassland Research Station
  - Vegetable Research Station
  - National Research Institute of Tea
  - National Foodstuffs Research Institute
  - National Research Institute of Agricultural Engineering
  - Agricultural Experiment Stations (6)
  - Institute for Plant Virus Research
  - Tropical Agricultural Research Centre


Forestry Agency
Forest Experiment Station
Fisheries Agency
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Pearl Research Laboratory
Institute of Agricultural Machinery
Ministry of International Trade and Industry
Industrial Technology Council
Industrial Structure Council
Patent Agency
Agency of Natural Resources and Energies
Agency of Industrial Science and Technology
National Research Laboratory of Metrology
Mechanical Engineering Laboratory
Research Institute for Polymers and Textiles
Geological Survey of Japan
Electro-Technical Laboratory
Fermentation Research Institute
National Research Institute for Pollution and Resources
Industrial Products Research Institute
Government Chemical Industrial Research Institute Tokyo
Government Industrial Research Institute Nagoya
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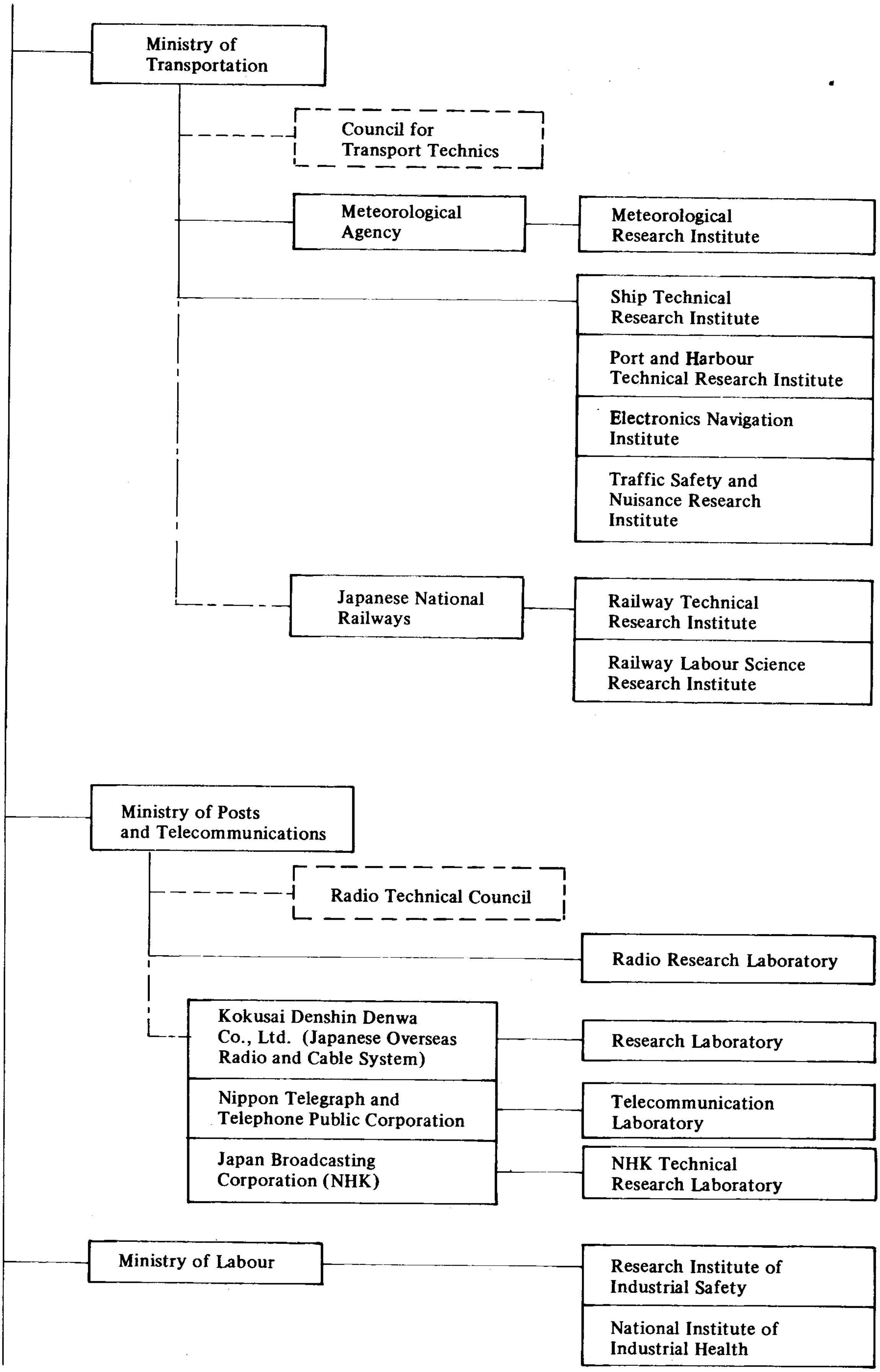
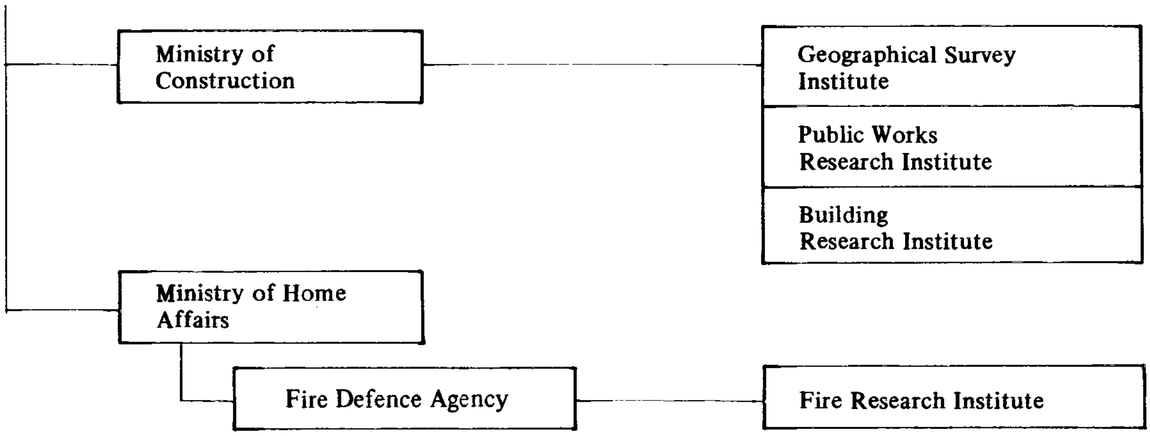

Ministry of Transportation
Council for Transport Technics
Meteorological Agency
Meteorological Research Institute
Ship Technical Research Institute
Port and Harbour Technical Research Institute
Electronics Navigation Institute
Traffic Safety and Nuisance Research Institute
Japanese National Railways
Railway Technical Research Institute
Railway Labour Science Research Institute
Ministry of Posts and Telecommunications
Radio Technical Council
Radio Research Laboratory
Kokusai Denshin Denwa Co., Ltd. (Japanese Overseas Radio and Cable System)
Research Laboratory
Nippon Telegraph and Telephone Public Corporation
Telecommunication Laboratory
Japan Broadcasting Corporation (NHK)
NHK Technical Research Laboratory
Ministry of Labour
Research Institute of Industrial Safety
National Institute of Industrial Health


Ministry of Construction
Geographical Survey Institute
Public Works Research Institute
Building Research Institute
Ministry of Home Affairs
Fire Defence Agency
Fire Research Institute

ORGANIZATION OF RESEARCH IN THE UNITED STATES

Dael WOLFLE

The research system of the United States is pluralistic in nature and decentralized in management. Government agencies, universities, industrial firms, and research institutes have traditionally engaged in such research as their interests and resources have determined, and any that has enough money to pay the costs is still free to decide what research it will conduct. However, many of the institutions are unable to pay for all the research they wish to conduct, and must therefore seek financial support from other sources, sometimes from industry or private foundations, but usually from the Federal Government.

Understandably, the agencies that pay the costs wish to exercise some control over the selection of research topics and the planning of research methods. Because the amount of money transferred from the supporters of research studies to the conductors of those studies is substantial, there is also a substantial amount of dual control, with both the agency providing the funds and the institution providing the scientific talent and resources involved in deciding what work will be done. Because most of the money devoted to research is provided by agencies of the Federal Government, forces tending toward centralization have developed that oppose the traditional decentralization of reponsibility. Coordination of research activities used to be largely informal, brought about by the collective judgement of scientists and engineers as to what research appeared most interesting and most likely to be useful. The judgement of the research community is still important, but so also are the national budget, formal policy statements by public and private bodies, and the plans and priorities of federal agencies.

Both the coordinating processes and the tensions between the traditional customs of decentralization and the growing pressures for more centralized planning and control constitute important topics of science and technology policy, and will therefore, be discussed in other papers as well as this one. The principal purpose of this paper is to describe the components of the nation's research system, the ways in which those components divide reponsibility for achieving the nation's research goals, the processes used to determine what research will be conducted, the scientists and engineers who are engaged in research, and some of the current problems of the nation's research system.

Most of the description will pertain to research, both basic and applied research, but not including development. Some of the tables will present figures for research (basic and applied) and also for the totality of research and development, but unless otherwise clearly indicated, the discussion will deal with research activities rather than with research and development:

Principal Performers of Research

The Federal Government

The Federal Government pays for about 55 percent of all research conducted in the United States, but Federal Government agencies conduct only about 17 percent of all research. Neither in conducting research internally nor in supporting external research does the Federal Government act as a unit. Instead, each agency plans and manages its own activities. There is a considerable amount of coordination and joint planning, yet in the main the National Science Foundation, the National Institutes of Health, the National Oceanic and Atmospheric Administration, the Department of Agriculture, and all the other departments and agencies involved are responsible for determining what research they will conduct and what external research they will support. Table 1 shows the estimated 1980 expenditures for research, and also for research and development, of each federal agency that has a large research program. Expenditures are shown separately for intramural and extramural programs.

Industry

Industry conducts over 40 percent of all research in the United States. Government funds pay for about one quarter of industrial research, and industry uses its own funds to pay for the other three quarters.

The amount of research is quite uneven among firms. There is much more in some industries than in others, and within the same industry some firms are much more heavily involved than are some others. As one would expect, most industrial research is conducted in the chemical, electrical, electronic, aviation, and other high-technology industries. Table 2 shows the distribution among major industrial groups.

Small research programs are found in some 15,000 firms, but most industrial research is concentrated in a few large firms. In fact, 60 percent of the total is conducted by about one percent of all of the firms, large firms that have 10,000 or more employees each and that, because of their size and products, have greater incentives to engage in research.

Table 1. Federal Funds for Research, and for Research and Development, Used Intramurally and Extramurally by Selected Agencies, 1980 (Dollars in millions)

Agency	Research		R&D	
	Intramurally	Extramurally	Intramurally	Extramurally
Total, all agencies	3,714	7,879	7,747	22,986
Department of Agriculture	414	222	437	227
Department of Commerce	178	80	217	105
Department of Defense	866	1,547	3,763	10,117
Department of Energy	52	1,216	326	4,332
Department of Health, Education and Welfare	725	2,493	792	2,934
(National Institutes of Health)	(505)	(2,062)	(557)	(2,405)
Department of Interior	247	122	261	156
Environmental Protection Agency	122	192	162	274
National Aeronautics and Space Administration	756	881	1,275	3,265
National Science Foundation	98	803	99	812
Others	256	353	415	764

Source: National Science Foundation, *Federal Funds for Research and Developement: Fiscal Years 1978, 1979, and 1980.* NSF 79–318, 1979.

Table 2. Research Expenditures, by Industry (Dollars in millions)

Industry	Federal Funds	Company Funds	Total Funds	Total Percent
Totals	$1,321	$3,792	$5,113	100%
Chemicals & allied products	136	1,169	1,307	26%
Electrical equipment & communication	362	699	1,059	21%
(Communications equipment and communications)	(154)	(415)	(568)	(11%)
Aircraft and missiles	413	276	689	13%
Petroleum refining & extraction			360	7%
Machinery			354	7%
All others				26%

Source: NSF, *Research and Development in Industry, 1975,* NSF 77-324, 1977 Tables B-45 *and* B-46

Universities and Colleges

Universities and colleges conduct about one third of the nation's research, far more than they are able to pay for from their own resources. Nearly three quarters of the financial support comes from the Federal Government; about 18 percent from university and college funds; and the rest from industry and private foundations.

As is true in industry, there is great variability among colleges and universities in their research activities. Most of the 3,000 and more colleges and universities in the United States do little or no research. In contrast, 50 of the largest universities are responsible for more than 60 percent of all academic research, and the top 100 universities are responsible for about 85 percent of the total.

Other Nonprofit Organizations

Also involved are a number of nonprofit organizations: independent research institutes, museums, zoos, hospitals, scientific societies, and private foundations. Some of these organizations conduct research; some make grants to universities or other institutions to support research; and some conduct their own research and also support research conducted by others.

In dollar terms, this is the smallest sector in the research enterprise. Nonprofit organizations (other than universities and colleges) conduct about 7 percent and support about 4 percent of all research. However, the importance of private foundations and research institutes has been far greater than their dollar contribution, for they have pioneered fields of research, types of research organization, and methods of providing financial support that have later been adopted on a much larger scale by the Federal Government. Widely known examples include the Carnegie Institution of Washington, the Woods Hole Oceanographic Institution, the graduate and postdoctoral fellowships of the Rockefeller and Guggenheim Foundations, and the world-wide public health programs of the Rockefeller Foundation.

Table 3 shows, for the year 1980, the estimated amount of research money contributed by each of the four sectors, the amount expended by each, and the transfers of funds among the four sectors.

Only the Federal Government pays for all of its own research activities. Each of the other sectors receives much money from other sectors; industry 23 percent; nonprofit organizations other than universities and colleges, 74 percent; and universities and colleges (including associated Federally Funded Research and Development Centers) 82 percent. Moreover, each sector includes numerous independent organizations. Clearly, this is a decentralized and pluralistic system.

Research Goals: Division of Responsibility

The United States is one of the few nations that in recent times has attempted to maintain a comprehensive program covering all fields of basic and applied science. An effort of such breadth requires much division of labor. Much of that division of labor comes naturally and easily, for government laboratories, industrial firms, universities, and the other institutions involved have somewhat different goals and objectives.

Basic and Applied Research

Given the nature of their responsibilities, both the Federal agencies and industrial firms emphasize applied research. In fact, most firms do no basic research at all. However, some of the larger ones, such as the Bell Telephone Company and the General Electric Company, have conducted a considerable amount of basic research and have made notable contributions to scientific knowledge. Indeed, research scientists employed by those companies have won Nobel Prizes for their work in surface chemistry, solid-state physics, and astrophysics. Table 4 shows the distribution of basic and applied research by performing sectors.

Universities have a different emphasis. Universities are responsible for about 60 percent of the basic research conducted in the United States, but only about 15 percent of the applied research. Basic research is conducted in all fields of science, and applied research also covers a broad spectrum, but universities have traditionally given considerable emphasis to agricultural and medical research.

In addition to universities, government laboratories, and industrial firms there is a wide variety of specialized research institutes and organizations. Some concentrate on basic research, while others emphasize applied research.

There is also a special group of research institutes called Federally Funded Research and Development Centers. Some of these research centers are operated by industry, some by universities, and a few by other nonprofit organizations. All are financed by the Federal Government to work in designated areas such as space research, military research, high energy physics, or astronomy. In table 3 these Federally Funded Research and Development Centers are included with industry, universities, or nonprofit organizations, depending upon the organization that operates each.

Table 3. Transfer of Funds for Conduct of Research in the United States, 1980 estimated (Dollars in millions)

Sources of funds	Research Conducted by: Federal gov't	Industry	Nonprofit organizations	Universities	Total Dollars	Total Percent
Federal Government	3,730	2,150	1,000	5,150	12,030	55%
Industry		7,300	160	200	7,660	35%
Nonprofits			415	405	820	4%
Universities				1,225	1,225	6%
Total	3,730	9,450	1,575	6,980	21,735	
Percent	17%	43%	7%	32%		100%

Source: National Science Foundation, *National Patterns of Science and Technology Resources 1980,* NSF 80–308, 1980.

Table 4. Performance of Basic and Applied Research, by Sector, 1980 (Dollars in millions)

Performer	Basic amount	Research percent	Applied amount	Research percent	Basic as percent of total
Federal Government	1,210	15%	2,520	19%	32%
Industry	1,325	16%	8,125	60%	14%
Universities	4,925	59%	2,055	15%	71%
Nonprofits	770	9%	805	6%	49%
Total	8,239		13,505		38%

Source: National Science Foundation, *National Patterns of Science and Technology Resources 1980,* NSF 80–308, 1980.

The National Science Foundation

The National Science Foundation (NSF) has a special role in the support of research. When that agency was established in 1950, Congress instructed it not to develop any laboratories of its own, but required it instead to support research conducted by others. Unlike most agencies of the Federal Government, NSF has no operating mission; its purpose is to support research broadly to advance scientific knowledge. Thus its research funds go to universities and other research institutes to support the research that scientists and engineers in those institutions wish to perform.

Other Federal Agencies

The National Institutes of Health and some of the other federal agencies also use part of their funds as grants or contracts to support research, usually in fields of science related to their operating responsibilities. For example, the National Institutes of Health support much research on problems of health, and the Department of Energy supports research in high energy physics. One result of this system is that several agencies support research in the same field of science, for example, biology or mathematics, with each agency deciding individually how its funds will be divided among the field to which it gives support. The National Science Foundation is, therefore, sometimes expected to serve as a balancing agency. For example, if NSF staff members and advisors believe the total amount of support for research in chemistry should be increased, NSF can shift some of its funds from other fields into chemistry in order to increase the total amount available for chemical research.

Processes Determining What Research Will be Conducted

Institutions that are spending their own money have developed internal mechanisms for deciding how those funds will be used. In an industrial firm, alternative research ideas may be evaluated in terms of their probability of success, how well the new product or process would fit into the general nature or the overall plans of the firm, and the expected dollar value of the new product or process if the study turns out to be successful.

In the Federal Government, large-scale decisions are made by Congress, the President, and the Office of Management and Budget -- all as influenced by changing emphasis on national goals and by economic, international, and social trends. Thus special emphasis may be placed on cancer research, on energy self sufficiency, on space exploration, on national defense, or on improving science education. Each of these and other topics has at one time or another been given special attention in the federal research budget.

After the large-scale decisions have been made and the research budgets of individual agencies and parts of agencies have been determined, it becomes necessary to decide which specific research opportunities and projects will be supported and which will not. It has long been agreed that the people best able to make these decisions are the scientists and engineers who are most knowledgeable in the particular field involved. Sometimes that means members of the staff of the sponsoring agency. Often, however, external advisors are asked to help select those proposals that are considered most likely to be scientifically valuable. This is the well known "peer review" system of deciding which research studies are most worthy of support. The system has sometimes been criticized as tending to favor well established scientists at the expense of younger ones, or as favoring the friends of the advisors. Most of these charges are without foundation. Inevitably there are sometimes differing judgements about individual projects, yet every objective study of the operation of the peer review system has demonstrated that the judgements are generally objective and that the scientific merit of the competing proposals is the primary basis for deciding which will be supported and which will not.*

Functional Fields

Table 5 shows the 1980 distribution of federal funds for research, and also the federal funds for research and development, by functional field. When funds for developmental activities are included, military R&D accounts for half of the total, and dwarfs all other functions.

When only research funds are considered, health is the largest category; accounting for a little over one fourth of all of the federal money devoted to research. Military or defense research comes in second place. And, in third place comes basic research that is intended to add to scientific knowledge rather than to contribute directly to some practical purpose.

The percentages in Table 5 cannot be interpreted directly as measures of relative importance, for some fields, such as space research, are inherently more expensive than others, such as agriculture. However, changes in funding over time can be used as indicators of changing priorities. Over the past 10 years, the relative emphasis given to military and space research has declined, while emphasis on health and energy has risen.

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* *Review Processes: Assessing the Quality of Research Proposals,* Washington, D.C.: National Commission for Research, 1980

Table 5. Federal Funds for Research, and For Research and Development, by Function, 1980

Function	1980 Funds for Research	1980 Funds for Res. & Dev.
Total, all functions	$11,562	$30,629
Health	3,035	3,444
Nationalddefense	2,628	15,117
General science and basic research	1,239	1,248
Space research and technology	1,172	4,051
Energy	981	3,429
Natural resources and environment	851	1,054
Transportation	560	862
Agriculture	536	559
Education, training, employment, and social services	175	351
Other functions	384	517

Source: National Science Foundation, *Federal R&D Funding by Budget Function: Fiscal Years 1978–80, 1979, Appendix A.*

Scientists Primarily Engaged in Research

In 1978 there were 2,473,000 scientists and engineers employed in the United States. Nearly 90 percent were primarily engaged in teaching, administration, development, technical production, or other non-research activities, although many spent some time in research. The other 11 percent, or 278,000, reported research to be their primary activity. About one third of those primarily engaged in research had earned Ph.D. degrees. Table 6 shows the distribution by fields of science of the scientists and engineers who were primarily engaged in research.

The nation's research staff has grown rapidly over the past several decades. Because additions have greatly outnumbered retirements, the median age is comparatively young, about 40 years of age. However, the growth rate has started to slow down so the average age is beginning to increase. The size of the successive age groups, the numbers of students graduating from college with degrees in science and engineering, and the numbers receiving doctoral degrees in science and engineering all indicate that the total scientific population will continue to grow over the next decade or two, but at a slower rate than that of the past two decades, and that as a result the average age will continue to rise.

Table 6. Scientists and Engineers Primarily Engaged in Research, by Field, 1978

	Basic research	Applied research	All research
Total	132,400	145,600	278,000
Physical Scientists	32,500	33,900	66,400
Mathematical Scientists	7,300	5,400	12,700
Computer Scientists	1,000	4,700	5,700
Environmentl Scientists	7,500	13,100	26,000
Engineers	8,500	41,800	50,300
Biologists	48,100	9,900	58,000
Agricultural Scientists	4,000	16,000	20,000
Medical Scientists	7,400	4,000	11,400
Psychologists	4,000	7,400	11,400
Social Scientists	12,100	9,400	21,500

Source: *National Science Foundation, U.S. Scientists and Engineers 1978,* NSF 80–304, 1980.

Current trends also indicate that there will be an adequate supply of scientists available for appointment to research positions, except, perhaps, in computer science and some branches of engineering.

Relations Among the Major Sectors

The American research system took its form in the years shortly after World War II. Scientists and engineers had contributed so effectively to the development of radar, sonar, and other new weapons, and to penicillin and other new medicines, that it was widely believed that further research would bring new benefits to human health and to the economic welfare of the nation. Accordingly, the country embarked on what became a 20-year period of rapid expansion of its whole research endeavor. The National Institutes of Health were expanded. The Atomic Engergy Commission and the National Science Foundation were established. Congress steadily increased the amount of money available for research in universities and other research institutions. As a result, solid-state physics, molecular biology, space science, geophysics, medicine, and other fields of research flourished.

The economy grew rapidly: industrial innovations were frequent; and economic studies indicated that research and development was a major contributor to the nation's economic growth.

Although the research system that has been given much credit for these achievements took its form in the years following World War II, some of the characteristics of that system have much deeper roots. The practice of providing federal support for research conducted outside of government has a long history. Tr * ~rangement was used effectively for a large amount of research conducted during World War II, especially that sponsored by the temporary wartime Office of Scientific Research and Development. After the war, the decision to rely heavily on industrial, university, and other non-governmental institutions was formally debated and adopted. Since then, this policy has several times been reviewed by Presidential request, and each time has been confirmed as the most effective method of attaining national research objectives. The policy has not been a completely one-sided one, however, as the excellent research record of the National Institutes of Health exemplifies. Nevertheless, it has been public policy to rely heavily on scientists and engineers outside of government to accomplish much of the nation's research work.

This policy was founded on a basis of mutual trust. Scientists and engineers were considered to be the best judges of which research ideas seemed most promising, and of which methods seemed most appropriate. In turn, scientists and engineers were expected to use prudently the public monies entrusted to them and were often expected to decide for themselves how those monies could be used most effectively.

This "golden age" came to an end a dozen years ago. Measured in terms of constant dollars, to take account of inflation and rising costs, research funds grew steadily and rapidly up through 1968. From 1968 through 1975, however, there was no growth; in some years the amount went up a bit and in other years it went down. The high costs of a war in South-east Asia and a shift in national priorities toward social problems brought an end to the rapid growth of funds for research. Later, a sagging rate of industrial growth brought into question the role of research in the nation's economy. Scientists no longer enjoyed as high prestige as they had earlier, and Congress and the Executive Branch of the Federal Government no longer gave scientists as free a hand in deciding what research should be conducted.

As a result of these changes, the decade of the 1970's has seen a good deal of reassessment of the role of research in the nation's affairs, and of how the research system can best operate. There is still much research of high quality, but there are also some disagreements about objectives, funding, and relationships among the agencies that support and those that conduct research. The reassessment is not complete, and will surely continue in the 1980's and perhaps longer. It is impossible to know just where it will lead, but for the time being relations among the major components of the research system have become somewhat strained.

Government-Industry Relationships

As mentioned earlier, Federal funds pay for about 25 percent of the research conducted in industry. This percentage has been declining; 20 years ago the Federal Government paid nearly 40 percent of the cost of industrial research. The decline in the government percentage came about for several reasons, including a decline in government spending for space research and a rise in indutrial expenditures for research in the pharmaceutical and electronic industries. These changes mean that industrial research is somewhat less dependent on government financing than it used to be.

Nevertheless, industry and government are dependent upon each other in many ways, and their working relationships must be cooperative, at least in part. Yet the relationship is also often an adversarial one. Some government officials charge industry with working against the public interest. Industrial leaders respond that taxation and patent policies and regulatory procedures are short-sighted, unnecessarily restrictive of industrial freedom and flexibility, and are working against the nation's need for economic growth and technological innovation.

Yet at the same time these arguments go on, many representatives of the Federal Government have become greatly concerned over the fact that industrial productivity has not been growing as rapidly as it did in earlier years or as rapidly as it is in some of our trading partners such as Japan and West Germany. As a consequence, government policy studies and some operating programs are being directed toward the stimulation of productivity and industrial innovation. It is too early to assess the effect of these programs, but together with frequent adversarial encounters they indicate that the relationships between government and industry are complicated and uneasy.

Industry-University Relationships

Prior to World War II there were some fairly close relationships between industry and university faculty members, especially engineers and chemists who served as consultants to industry. After World War II, as Federal funds for university research expanded rapidly, the ties between universities and industry grew weaker. Now there are several efforts to renew those ties and to encourage more cooperation between universities and industry.

The National Science Foundation has provided some funds to encourage such cooperation. The Department of Commerce, concerned about lagging growth of industrial productivity and innovation, appointed an Advisory Committee on Industrial Innovation. Among its recommendations, this committee proposed more university research on topics of interest to industry and matching grants to stimulate industry-university cooperation. Also proposed was the creation of a number of research centers to be established at universities or other research institutions to work on different kinds of generic technology--technology that can be broadly used in industry as distinct from the proprietary secrets of particular firms. Each center would be partially supported by government, and partially by industry, with the government support gradually declining and the industrial support increasing if the result justified continuation of the center.*

Independently of government action, some new cooperative relationships have been arranged between individual firms and universities. Joseph E. Seagram & Sons recently made a grant of $5.3 million to the Harvard University Medical School to study why some people are more susceptible to alcoholism than are others. This is said to be the largest grant for basic research ever made by an industrial firm. As another example, the Westinghouse Corporation has agreed to provide a million dollars a year to the Carnegie-Mellon University to help support a new Robotics Institute to work on the problems of designing robots for industrial use, a field in which Japan is now credited with being the international leader. Additional funding from other firms is expected.

Government-University Relationships

Since World War II the Federal Government has been the chief patron of university research. It still is, but from 1969 through 1976 the growth rate of research funds did not keep up with inflation. By 1975, the resulting problems were recognized by President Ford's advisors and by the Office of Management and Budget. They concluded that the nation was investing too little in basic research, and too little in research conducted in universities. Accordingly, the federal budget was increased to provide for slightly faster growth in the amounts available for university research. The present administration has supported this policy and although the growth rate of funds for university research cannot be expected to return to the high level of 20 years ago, it has for the past few years run a little ahead of inflation and of the increases in other research and development expenditures.

During the years when funds for university research failed to increase or increased only slightly, university enrollments and hence university faculties continued to increase, and so did the requests for research support. In an effort to spread available funds as far as possible, instrumentation needs received inadequate attention; as a consequence, much scientific instrumentation in university laboratories is becoming worn out and obsolete.**

While these changes have been going on, a trend has developed toward tighter government control over university research funded by government agencies. In many fields there has long been a substantial amount of govern-

* Advisory Committee on Industrial Innovation, *Final Report*, U.S. Department of Commerce, September 1979.

** Bruce L.R. Smith and Joseph Karlesky, *The State of Academic Science: The Universities in the Nation's Research Efforts*, Volumes I and II, New Rochelle, New York: Change Magazine Press, 1977 and 1978.

ment control. Government agencies conduct some research in their own laboratories, and contract for other research they want done. Moreover, a number of the federal agencies restrict their grants to those fields of research that are related to their operating missions.

At the same time, however, several agencies, including the Department of Defense, the National Institute of Health, and the National Science Foundation, have supported much research, in many fields of science, that was planned by scientists in universities or private research institutes.

Both types of research support continue, but there appears to be more centrally planned programs than there used to be. Congress has also been calling for more central planning of the nation's research activities. An Act adopted by Congress in 1976 asked the President's Office of Science and Technology Policy to submit each year a Five-Year Outlook that identifies those scientific and technological opportunities that warrant particular support and attention over the next five years, and the national problems to which science and technology can make significant contributions during those years. Responsibility for preparing this report has been shifted to the National Science Foundation. That agency had considerable difficulty in developing the first Five-Year Outlook, which was published earlier this year and is not very satisfactory from the standpoint of advising Congress about priorities for the next five years. Nevertheless, the congressional request for such advice is evidence of growing interest in more centralized planning of the nation's research activities.

How far this movement will go is far from clear, for although there is pressure for central planning there is also a substantial amount of skepticism about the value of central planning for science and technology. Many people doubt that government staff members can do as good a job of identifying needs and opportunities as can scientists and engineers working in industry, universities, and research institutes.

Thus planning on the large scale may encounter some serious difficulties, Details, however, have come to be increasingly under the control of government agencies. For one reason or another, neither scientists nor universities are trusted as much as they used to be to use grant funds prudently and efficiently. Thus many new regulations have been adopted by government agencies, regulations controlling the use of human subjects, the care of animals, the avoidance of hazards in the laboratory, the selection of faculty and staff members, the nature of research procedures, the number and variety of reports that must be submitted to the granting agency, and much more. Most of these new regulations have been adopted for quite commendable reasons, but they have led to widespread frustration at the added work required, and widespread feeling that the government has gone too far in trying to control the details of how research is carried out.*

From the 1940's through the 1960's when there was much less central planning and control, science flourished, and scientists were happy in their relationships with the Federal Government. It is too soon to know whether a larger amount of central planning and control will be equally or more effective in leading to scientific progress, or how much the new regulations will hinder scientific progress. One of the current problems that is receiving much attention from special study commissions, some government personnel, and many scientists is that of achieving a better balance between the government's need to be assured that the research it supports is properly conducted and the scientist's freedom to use his own best judgement as to how his research should be conducted.**

Clearly, the relationships linking government, industry, and universities in a research partnership are not altogether satisfactory from the standpoint of any of the three partners. We can expect the same partners to continue to be involved and to continue to be productive of new scientific understanding and technological developments. But if some of the current problems can be worked out and some of the tensions eased, there will be less cause for argument, and more time for research.

* *Accountability: Restoring the Quality of the Partnership.* Washington, D.C.: National Commission for Research, 1980.
** *ibid.*