PRACTICES IN UNITED STATES GOVERNMENT SUPPORT FOR BASIC RESEARCH

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I. INTRODUCTION

In the first Science Policy Seminar under the U. S.-Japan Cooperative Science Program, D. Wolfe gave an overview of the organization of research in the United States and R. M. Konkel described research allocation processes in the U. S. Administration and Congress (1). This paper describes the trends in United States Government support for basic research, the roles of the different agencies, the management of basic research support, and the coordination within the government (2,3).

A brief reference to history may be useful to provide an impression of the forces which have shaped the present United States research system. The Constitution of the United States did not

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provide a specific authority to Congress for the support of research and no funds were appropriated for such activities in the early years of the Republic. It was not until 1807 that the first continuing scientific activity, the Coast Survey, was authorized by Congress. At the beginning of the 20th Century the activities and the number of scientific agencies had significantly increased and included: the Bureau of Standards, the Geological Survey, the Bureau of Mines, several research-related bureaus in the Department of Agriculture and, of course, the National Academy of Sciences (chartered by Congress in 1863).

The early pattern of establishing research institutions in response to perceived national needs, either as new and independent agencies or as additions to existing government departments, has continued to the present and has resulted in a highly decentralized, pluralistic research system. Although this system is, at times, cumbersome, difficult to coordinate and manage, and almost impossible (for foreigners and natives) to fully understand; its flexibility and adaptability allows immaginative and novel approaches and practices. The spectacular success of the National Aeronautics and Space Administration (NASA), for instance, might not have been possible within the framework of an established department or agency.

II. RECENT TRENDS IN GOVERNMENT SUPPORT FOR BASIC RESEARCH

In discussions on basic research issues one must be conscious of the difficulty in making a sharp distinction between basic and applied research as, quite often, research has basic as well as applied aspects. Statistical data must therefore be used carefully. In this paper use is made of data from the Division of Science Resources Studies of the National Science Foundation (NSF) which are internally consistent. These data provide a basis for analyzing the roles played by different government agencies and performers and how the support for the various fields of science has changed.

United States federal expenditures for basic research in the last decade have shown a steady increase rising from $2.441 billion in 1969 to an estimated $5.557 billion in 1980. However, this trend looks different if the expenditures are expressed in constant (1972) dollars taking inflation into account. With this adjustment the support for basic research actually dropped slowly but steadily from 1969 to 1975 by an annual average of 1.2 percent. After 1976, this trend reversed and expenditures increased between 4 percent and 7 percent annually until 1980 (see Table 1). During the same period federal expenditures for R & D as a percentage of gross national product declined from 2.74 to 2.30 (see Table 2). Also, it is worth noting that the federal portion of the support for basic research dropped during this time slightly but steadily from 70.9 percent to 68.3 percent (Table 1).

The majority of federal funding for basic research (about 95%) is provided by six agencies: The Department of Health and Human Resources (HHS), the National Science Foundation (NSF), the Department of Defense (DOD), the Department of Energy (DOE), the National Aeronautics and Space Administration (NASA), and the U.S. Department of Agriculture (USDA). The most pronounced change during the last decade is the increased share of funds for the Department of Health and Human Resources, which rose from about 30 percent to more than 37 percent (see Table 3).

Trends in federal support for basic research by field of sciences are shown in Tables 4 and 5. Life Sciences is now the major recipient of federal funds; their share of the total has increased from 31.4 percent in 1970 to 35.3 percent in 1977.

TABLE I. National R & D Expenditures by Character of Work and Sources of Funds: 1969-81 (in millions of dollars)

Year	Federal		Non-Federal	
	Current	Constant[a]	Current	Constant[a]
	Basic Research			
1969	$ 2,441	$ 2,829	$ 1,000	$ 1,156
1970	2,436	2,675	1,060	1,162
1971	2,487	2,600	1,143	1,192
1972	2,592	2,592	1,196	1,196
1973	2,687	2,568	1,237	1,177
1974	2,880	2,564	1,327	1,168
1975	3,106	2,518	1,469	1,182
1976	3,388	2,573	1,540	1,167
1977	3,778	2,689	1,707	1,217
1978	4,382	2,921	1,936	1,290
1979	4,937	3,032	2,227	1,368
1980 (est.)	5,557	3,144	2,575	1,455
1981 (est.)	5,922	3,046	2,850	1,464
	Applied Research			
1969	$ 2,785	$ 3,221	$ 2,531	$ 2,918
1970	3,086	3,383	2,640	2,888
1971	3,057	3,192	2,731	2,844
1972	3,098	3,098	2,880	2,880
1973	3,385	3,227	3,203	3,035
1974	3,517	3,112	3,694	3,221
1975	3,948	3,185	3,923	3,131
1976	4,486	3,403	4,511	3,416
1977	4,811	3,430	4,973	3,555
1978	5,250	3,501	5,588	3,725
1979	5,830	3,581	6,367	3,911

TABLE I. National R & D Expenditures by Character of Work and Sources of Funds: 1969-81 (continued) (in millions of dollars)

Year	Federal		Non-Federal	
	Current	Constant[a]	Current	Constant[a]
	Applied Research			
1980 (est.)	$ 6,421	$ 3,629	$ 7,305	$ 4,120
1981 (est.)	6,950	3,572	8,340	4,279
	Development			
1969	$ 9,669	$11,159	$ 7,205	$ 8,303
1970	9,308	10,190	7,542	8,247
1971	9,397	9,799	7,838	8,163
1972	10,070	10,070	8,593	8,593
1973	10,274	9,756	9,879	9,349
1974	10,403	9,122	10,993	9,568
1975	11,011	8,823	11,712	9,330
1976	11,959	9,062	13,051	9,878
1977	13,085	9,345	14,569	10,418
1978	14,261	9,506	16,606	11,067
1979	15,789	9,699	19,065	11,713
1980 (est.)	17,324	9,778	21,945	12,373
1981 (est.)	19,793	10,163	25,210	12,933

[a] 1972 dollars based on GNP implicit price deflator.

(Source: Division of Science Resources Studies/STIA, April, 1981.)

TABLE II. National R & D Expenditures as a Percent of GNP: 1960-79 (in billions of dollars[a])

Year	*Total*	*Federal*	*Other*	*Basic and Applied Research*
1960	*2.67*	*1.72*	*0.95*	*0.83*
1961	*2.73*	*1.76*	*0.97*	*0.85*
1962	*2.73*	*1.76*	*0.98*	*0.95*
1963	*2.88*	*1.88*	*0.99*	*0.96*
1964	*2.97*	*1.97*	*0.99*	*1.01*
1965	*2.91*	*1.89*	*1.02*	*1.00*
1966	*2.90*	*1.86*	*1.05*	*0.99*
1967	*2.90*	*1.81*	*1.11*	*0.98*
1968	*2.83*	*1.72*	*1.12*	*0.97*
1969	*2.74*	*1.59*	*1.14*	*0.94*
1970	*2.64*	*1.50*	*1.14*	*0.94*
1971	*2.50*	*1.40*	*1.10*	*0.88*
1972	*2.43*	*1.35*	*1.08*	*0.84*
1973	*2.34*	*1.25*	*1.09*	*0.81*
1974	*2.31*	*1.19*	*1.13*	*0.81*
1975	*2.30*	*1.19*	*1.11*	*0.82*
1976	*2.28*	*1.15*	*1.13*	*0.82*
1977 (prelim.)	*2.27*	*1.14*	*1.13*	*0.81*
1978 (est.)	*2.25*	*1.13*	*1.12*	*0.80*
1979 (est.)	*2.21*	*1.11*	*1.11*	*0.80*

[a] *GNP implicit price deflators to convert current dollars to constant 1972 dollars.*

note: Percents are calcualted from unrounded figures. Detail may not add to total due to rounding.

Source: National Science Foundation, Division of Science Resources Studies/STIA.

TABLE III. Federal Obligations for Basic Research by Agency: FY 1972-82 (in millions of dollars)

Fiscal Year	Totals	HHS[a]	NSF	DOD[b]	DOE[c]	NASA	USDA	All Others
1972	$2,216	$ 662	$368	$321	$268	$332	$137	$128
1973	2,233	656	392	298	275	350	143	119
1974	2,392	845	415	297	270	306	146	113
1975	2,599	902	486	299	313	309	154	136
1976	2,773	981	524	321	346	293	171	137
1977	3,262	1,108	625	366	389	414	204	156
1978	3,704	1,274	678	404	441	480	243	184
1979	4,199	1,576	733	465	463	513	256	193
1980	4,682	1,758	819	540	523	559	275	208
1981 (est.)	5,038	1,871	877	613	594	541	319	223
1982 (est.)	5,545	2,009	950	722	680	592	361	231

[a] Prior to 1979 HEW data were used minus the Office of Education, the National Institute of Education, and the Assistant Secretary for Education (HEW).

[b] Data for 1972-79 for DOD are estimated and preliminary, pending later revision.

[c] Prior to 1974 AEC data were used; in 1974-76 ERDA data were used.

Sources: National Science Foundation, Division of Science Resources Studies/STIA and the Office of Management and Budget (April, 1981).

TABLE IV. *Federal Obligations for Basic Research by Field of Science: 1963-79*

(in millions of dollars)

Field	1963	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978 est.	1979 est.
All Fields	1152	1728	1721	1779	1762	1779	1974	2001	2076	2279	2425	2894	3292	3637
Life Sciences	372	573	579	539	554	574	668	669	737	797	878	1021	1167	1229
Env. Sciences	164	209	199	235	256	280	291	299	320	339	355	456	512	567
Physical Sciences	404	605	599	662	589	582	625	618	640	702	722	874	978	1068
Psychology	35	60	55	53	56	44	54	46	49	60	44	54	64	74
Math & Computer Sci.	40	65	67	56	58	51	63	57	49	59	70	79	89	101
Engineering	110	156	156	151	180	169	185	204	190	234	240	303	346	374
Social Sciences	25	57	61	71	64	70	80	78	73	73	85	95	117	128
Other Sciences	2	4	4	11	4	9	9	28	16	15	33	12	20	25

Source: National Science Foundation, Division of Science Resources Studies/STIA

TABLE V. Federal Obligations for Basic Research by Field of Science (in percentage of total support from Table IV)

Field of Science	*1970*	*1974*	*1977*
Life Sciences	*31.4*	*35.5*	*35.3*
Physical Sciences	*32.3*	*30.8*	*30.2*
Environmental Sciences	*14.5*	*15.4*	*15.8*
Engineering	*10.2*	*9.2*	*10.5*
Social Science	*3.6*	*3.5*	*3.3*

III. FEDERAL SUPPORT OF BASIC RESEARCH IN UNIVERSITIES AND COLLEGES

Research, particularly basic research, is part of the normal activity of many university science faculty members. The combination of doing research and providing advanced education and training has become an essential part of the United States research system. Almost all basic research conducted in universities and colleges is performed in institutions which grant doctoral degrees.

This effort relies heavily on federal support. Over the last decade, about 70 percent of basic research funds in this sector were provided by the federal government (Table 6) and accounted for about one-half the federal obligations for basic research. The considerable stability in the proportion of federal funds over the last decade is also apparent in the distribution by field of science (Table 7). Differences, however, can be observed in the rate of growth for particular fields. Environmental sciences and engineering research have enjoyed the most rapid growth whereas social sciences have only moderate growth.

The major part of federal support for basic research at institutions of higher education are in the form of grants for in-

TABLE VI. R & D Expenditures at Universities and Colleges: FY 1968-80 (in millions of dollars)

Fisacal Year	*Total*		*Federally Financed*	
	Current	*Constant*[a]	*Current*	*Constant*[a]
1968	*$ 2,149*	*$ 2,611*	*$ 1,572*	*$ 1,911*
1970	*2,335*	*2,569*	*1,647*	*1,812*
1972	*2,630*	*2,630*	*1,795*	*1,795*
1973	*2,884*	*2,762*	*1,985*	*1,901*
1974	*3,023*	*2,702*	*2,032*	*1,816*
1975	*3,409*	*2,769*	*2,288*	*1,859*
1976	*3,727*	*2,830*	*2,512*	*1,907*
1977	*4,070*	*2,895*	*2,730*	*1,942*
1978[b]	*4,621*	*3,081*	*3,057*	*2,038*
1979	*5,354*	*3,289*	*3,594*	*2,208*
1980	*6,049*	*3,423*	*4,093*	*2,316*

[a] *1972 dollars based on GNP implicit price deflator.*

[b] *Estimates based on data collected from doctorate-granting institutions only.*

Source: National Science Foundation, Division of Science Resources Studies/STIA (October, 1981).

dividual projects. Typically, these grants are not intended to support the total research project but require cost-sharing by the universities. The arrangements for this cost-sharing differ with the agency and the university involved but often are related to salaries, equipment, and overhead costs. In the 1960s legislation was proposed and discussed to design a formula system for broad, institutional federal support for universities. However, the legislation was never passed.

The United States basic research system appears to be strong and healthy. However, there are several aspects which might sig-

TABLE VII. Federal Obligations for Basic Research in Universities and Colleges by Field of Science for Selected Agencies: 1973-77[a] (in millions of dollars)

Field	1973	1974	1975	1976	1977	average annual percent change 1973-75	average annual percent change 1975-77	average annual percent change 1973-77
Life Sciences	$366.3	$430.7	$451.5	$504.6	$566.5	11.0	12.0	11.5
Psychology	29.0	29.6	29.3	28.8	32.6	0.5	5.5	3.0
Physical Sciences	177.3	177.1	201.6	211.0	241.1	6.6	9.4	7.8
Environmental Sci.	80.5	89.2	102.6	106.7	144.1	12.9	18.5	15.7
Mathematics and Computer Sciences	40.9	36.3	41.6	45.7	54.9	0.9	14.9	7.6
Engineering	75.5	76.6	94.4	101.4	123.5	11.8	14.4	13.1
Social Sciences	45.7	41.8	40.1	44.4	51.9	- 6.4	13.8	3.2

[a] The agencies included here are the Department of Agriculture, Department of Defense, Department of Health, Education, and Welfare, Department of Energy and its predecessor agencies, and the National Science Foundation. The National Aeronautics and Space Administration is not included because data for all years are unavailable. The five agencies included represented approximately 93 percent of all agencies' obligations in 1977.

Source: National Science Foundation, Division of Science Resources Studies/STIA.

nificantly impact the future of the system:

decreasing U.S. share of the world's production of new scientific knowledge;

diminishing public confidence in science and technology;

deteriorating and aging instrumentation;

aging tenured faculty;

a shift from risk-taking to relatively "safe" and more predictable lines of inquiry; and

increased requirements for record keeping and reporting.

IV. FEDERAL SUPPORT OF BASIC RESEARCH IN AGENCY LABORATORIES AND FEDERAL FUNDED RESEARCH AND DEVELOPMENT CENTERS

Unlike most other scientifically-advanced nations, the United States has no elaborate system of national laboratories or research centers for conducting basic research. However, a considerable portion of federal basic research funds supports work at agency laboratories and some twenty Federally Funded Research and Development Centers (FFRDC) administered by universities; in 1976 29.6 and 11.7 percent, respectively (Table 8). In addition, there are about ten FFRDC operated by private contractors. Unfortunately, these are usually treated, for statistical purposes, as part of the contractor's operation although they are much like in-house laboratories of the sponsoring government agency.

As no common body administers these laboratories and FFRDC, there is great variation in the degree to which authority over basic research is delegated. There is a whole spectrum of laboratories, from those that are essentially autonomous to those that

TABLE VIII. *Federal Obligations for Basic Research, by performer (in millions of dollars)*

Performer	Actual			Estimates			
	1968	1976	1968-1976[a]	1977	1976-1977[a]	1978	1977-1978[a]
Totals	$1,721	$2,425	+4.4	$2,755	+13.6	$3,012	+9.3
Federal intramural[b]	410	719	+7.3	791	+10.0	851	+7.6
Industrial firms[b]	217	152	-4.4	201	+32.2	250	+24.4
Universities and colleges	745	1,137	+5.4	1,290	+13.5	1,399	+8.4
FFRDC administered by universities	225	284	+3.0	315	+10.9	347	+10.2
Other nonprofit institutions[b]	97	108	+1.4	125	+15.7	131	+4.8
Other performers	27	25	-1.0	33	+32.0	34	+3.0

[a] Average annual percent change

[b] Includes Federally Funded Research and Development Centers (FFRDC) administered by this sector.

Source: National Science Foundation, Division of Science Resources Studies/STIA are integral parts of their funding agency. The FFRDC, administered by universities, often provide facilities for the training and the support of related research in the universities.

The NSF is the largest supporter of basic research and, under existing law, is not permitted to operate laboratories. However, NSF is the major supporter of six FFRDC, all of which perform basic research:

> the National Center for Atmospheric Research, operated by a consortium of 45 universities called the University Corporation for Atmospheric Research;
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> the 1,000-foot radio telescope and radar at Arecibo, Puerto Rico, operated by Cornell University;
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> the National Radio Astronomy Observatory, operated by a consortium of universities called the Associated Universities, Incorporated; and
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> an array of optical telescopes at three facilities, operated by still another university consortium, the Association of Universities for Research in Astronomy.

V. FEDERAL SUPPORT FOR BASIC RESEARCH IN INDUSTRY

Basic research in industry is limited by the needs of private enterprise to demonstrate returns on their investments in a relatively short time. The federal government, on the other hand, primarily looks toward the educational and non-profit sector to fulfill perceived national needs for a strong fundamental research effort to contribute to future economic opportunities. Accordingly, less than ten percent of federal support for basic research is awarded to industrial firms which finance about twenty percent of the total industrial effort in this sector.

The amount of federal funding is even less if we consider that part of the federal support is for basic research at FFRCD. As mentioned earlier, these establishments are included in most statistics as part of the private sector although they more closely resemble in-house laboratories of the funding agencies. Chemistry and communications account for about two-thirds of federal funds for basic research in industry by field of science.

VI. MANAGEMENT OF BASIC RESEARCH IN THE AGENCIES

Generally, agencies derive their research programs from past plans, past proposals, reviewers commentaries, staff proposals, and studies by formal and informal advisory groups. Annual program changes are, for the most part, incremental. At NSF, for instance, where support of basic research is a primary mission of the agency, planning is initiated in accordance with policies set by the National Science Board. Program managers assess the needs and opportunities in their respective areas based on past experience and ideas received from professional societies, discussions with advisory and review panels, and contacts with the multitutde of scientists they meet. Most NSF program managers have been active scientists in their disciplines. The propositions of the program managers for emphasis of research areas or for new initiatives are reviewed and modified by the NSF management. This last process can be either highly structured or fairly informal depending on the management practices of each directorate. Usually the research community is informed of the NSF research programs through program announcements which encourage the submission of unsolicited proposals.

NASA, as an example of an agency supporting research as well as development, uses a management system for research called Research and Technology Objectives and Plans (RTOP). Here a statement of objectives and plans is developed by the agency which includes an estimate of the resources required. The next step is to select the best and most appropriate performers. For work to be performed in-house, the manpower requirements and the necessary funding are determined before the work is authorized. If the work is to be done by a contractor or a university, the plan is brought to the attention of potential performers by circulating a Request for Proposal and/or through personal contacts between agency research managers and interested researchers.

Most agencies use similar criteria in their decisions to support or not to support specific proposals. Among these criteria are: the qualifications and the competence of the investigators; the availability of appropriate facilities and instrumentation of the investigator; the technical soundness of the proposed research; the relative importance of the proposed work to the agency as compared to other proposals received; and the availability of funds.

Most agencies follow one of four mechanisms to arrive at decisions to fund specific proposals:

1. a review by a panel of experts, after which the program manager considers the panel's findings and recommends action;

2. a two-stage review in which more than one panel evaluates the proposal sequentially;

3. a mail review, in which the proposal is sent for review to experts in the particular field, after which the program manager considers these reviews and recommends action; and

4. a review by the program manager who has discretion for seeking outside advice but has total responsibility for

the final decision.

In special cases, where decisions are especially difficult to reach or are anticipated to be controversial, agencies may use a combination of the above methods. The decision to adopt one or another of the above mechanisms is often based on the customs in a particular field of science and on agency management practices. Agencies with mixed programs of basic research, applied research, and development use varying strategies to allocate funds for basic research. Some agencies, such as DOE or USDA, allocate a percentage of available funds for the support of basic research while other agencies do not indicate precise numbers in advance of their project decisions.

Most agencies that have a choice of using in-house laboratories or outside performers examine their own research capabilities before exploring outside capabilities. This practice, essentially giving preference to in-house laboratories, produces a stop-and-go funding phenomenon for outside performers when agency budgets fluctuate, resulting in an especially adverse impact on the conduct of basic research in universities.

A special United States mode of establishing and managing contract laboratories is the use of university consortia. This approach is used where program advice and planning are on a scale broader than one university can perform. Members of these consortia generally include several universities, each of which is an institutional member of the corporation with representatives on the governing board. The consortium assumes responsibility for management and operation of the laboratory. The individual universities provide guidance and supervision through their board representatives. The board hires a president with management responsibilities, selects the director of the laboratory, and oversees the program management in accordance with their contract with the government agency.

Because newly formed consortia generally have few, if any, fiscal resources, agencies negotiate a management fee, which covers the consortium's expenses and provides some funds to permit the accumulation of a fiscal reserve for unexpected expenses. Most consortia have established user panels to obtain program advice and to insure fair access to the laboratory facilities by staff and non-staff scientists.

VII. INTERAGENCY COORDINATION OF BASIC RESEARCH SUPPORT

Coordination of activities in the highly decentralized structure of basic research in the United States has for many years been of concern to members of the executive and legislative branches of the government as well as to the members of the scientific community. A surprisingly large number of coordination mechanisms, both formal and informal, have been developed over the years—the informal mechanisms being particularly important. Due to such a large number, an adequate description and discussion in this context is impossible. The following tabulations give an idea of the complexity of the system. Selected examples will be discussed later.

Some formal mechanisms:

Federal Coordinating Council for Science, Engineering, and Technology (FCCSET) and its committees and ad hoc committees;

Interagency groups, panels, committees, and boards;

Executive orders;

Legislative mandates;

Transfer of funds in support of programs of joint interest to two or more agencies; and

Cooperation agreements between agencies.

Some informal mechanisms:

Exchange of research proposals;

Requests to personnel of other agencies to review research proposals;

Liaison membership on review committees or panels;

Joint funding of research projects or conferences;

Joint participation in meetings of professional societies; and

Working level, informal contacts of program managers.

VIII. THE PRESIDENT'S SCIENCE ADVISOR

The most visible Executive Branch office involved in the coordination and guidance of the government's effort in basic research is headed by the Science Advisor to the president. Although earlier presidents had sought advice on critical scientific and technological questions from eminent scientists, President Eisenhower was the first president to appoint an official Science Advisor in 1957. One chief role of this office has been to help identify and clarify the government's choices for allocating resources for science and technology.

Very different individuals have served as Science Advisors, yet they have had a common denominator: the president's need for a full-time senior scientist to both provide him with advice, and to relay to him the views of the scientific community. Each president has chosen his advisor in his own distinct way.

Each advisor has developed his own personal relationship with the president he served which determined, to a large extent, the nature and character of the job. Dr. James Killian, the first presidential Science Advisor, was used extensively by President Eisenhower for advice on space research including military and civilian applications. Similarly, Dr. Jerome Wiesner, Science Advisor to President Kennedy, significantly influenced the space program, played an important role in the decision to proceed with a lunar landing program, and was involved in military missile and submarine questions.

IX. FEDERAL COORDINATING COUNCIL FOR SCIENCE, ENGINEERING, AND TECHNOLOGY (FCCSET) AND THE FEDERAL COUNCIL FOR SCIENCE AND TECHNOLOGY (FCST)

The present FCCSET was established by Executive Order 12039, dated February 24, 1978, under the chairmanship of the Director of the Office of Science and Technology Policy as the major coordinating body for science, engineering, and technology. Its predecessors were the Federal Council for Science and Technology (FCST), which existed from 1959 to 1976, and the first version of an FCCSET, which existed from 1976 to 1977. The history of FCST is described in detail in a report prepared by the Congressional Research Service of the Library of Congress (4).

The following sketch of FCCSET refers to its operation under Dr. Press, Science Advisor to President Carter (5). Under his leadership, FCCSET operated as a sub-cabinet group whose membership included the chief officials for R & D in various agencies. The Council met to consider major policy matters of concern to all R & D agencies. Examples of the issues addressed by the Council were:

Industrial innovation;

Health effects of ionizing radiation;

Obsolescence of scientific instrumentation and facilities;

Conflict of interest and ethics legislation;

Establishment of an Institute for Scientific and Technological Cooperation; and

Coordination of international science and technology programs in domestic agencies.

Interagency coordination on specific policy and program issues of continuing interest was achieved through topical committees of FCCSET made up of policy-level officials from the agencies. Special problems were handled by ad hoc groups. From 1978 to 1979 six Committees were chartered: the Committee on Atmosphere and Oceans; the Committee on Health and Medicine; the Committee on Food and Renewable Resources; the Committee on International Science, Engineering and Technology; the Committee on Ocean Pollution Research and Development and Monitoring; and the Committee on Intellectual Property and Information.

Ad hoc interagency committees dealt with problems such as: dam safety; automotive research and development; science and technical information policy; and the Institute for Scientific and Technological Cooperation.

X. THE OFFICE OF MANAGEMENT AND BUDGET (OMB)

Through the budget process of the Federal Government, the OMB exerts considerable influence in shaping government-supported research. The OMB can and does, during the annual budget cycle, assess programs regularly and coordinates them across different government agencies. As arbiter of the inclusion or exclusion of programs in the president's budget, OMB decisions deeply affect federal efforts in basic research.

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POLICIES AND PRACTICES OF GOVERNMENT SUPPORT FOR BASIC AND APPLIED SCIENCE

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I. A REVIEW OF RESEARCH SUPPORT POLICY

A. Structure

During the past century, since the Meiji Restoration, the Japanese government has taken the initiative to support basic and applied science. This indicated the recognition of the need for

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Japan to catch up with the industrialized and advanced nations with the greatest speed.

It is recognized, generally, that basic research has been carried out in universities, while development has been carried out in industry, and applied research has been carried out at various ministerial institutes. The Ministry of Education, Science, and Culture (MESC) has been responsible for the promotion of basic science research carried out in the universities. Applied research in such areas as mining, iron and steel, shipbuilding, railways, telecommunications, etc., has been promoted in laboratories under the jurisdiction of the appropriate ministries. The Ministry of International Trade and Industry (MITI) has been the key promoter of industrial technology. The Science and Technology Agency (STA), established in 1956 to meet the postwar development of new technology, such as nuclear and space science, sponsors the operation of the Japanese Atomic Energy Research Institute, the Power Reactor and Nuclear Fuel Development Corporation, the National Space Development Agency, and other institutions.

Developmental research in science and technology has been promoted and has reached a very high level in the private sector. Some people suggest that the government should concentrate its research and research support activities on high risk and high social needs areas.

Distinctions, however, seem to become blurred due to direct involvement of the government in the development of nuclear and space technologies and due to increasing interest of the industrial sector in basic research. In particular, a recent attempt by MITI and STA to start new areas of government R & D promotion seems to challenge the now obsolete demarcation of Japanese institutional roles in science and R & D. STA, under the Office of the Prime Minister, is jurisdictionally responsible for the coordination of expenditures, but in reality, STA has little power to do so because each ministry is strongly autonomous.

Government expenditures for science and technology is administered by different ministries and agencies with increasing co-operation across different ministries and agencies.

B. Research Manpower

As of April 1980, the total number of research workers in Japan was 367,000 compared to 118,100 in April of 1960; the strength of research manpower has grown threefold in twenty years. Analyses of the figures that follow reveal some of the trends in growth in the different sectors. Figure 1 shows the increase of qualified researchers by type of employer (universities, laboratories of government ministries, and private industrial companies; each type roughly corresponds, respectively, to basic, applied, and developmental activities).

In 1960, research workers employed by industrial companies numbered 42,000 and their ratio to the total number of researchers country-wide was 36.3 percent; in 1980, researchers numbered 173,200 and the ratio to the total number of researchers country-wide was 47.2 percent.

The number of research workers in universities also increased, but at a slower pace than in the industrial companies. The number grew from 59,800 in 1960 to 161,000 in 1980, but in terms of their share of the total number of research workers, the ratio decreased from 50.6 percent in 1960 to 44.1 percent in 1980.

The number of research workers at national and public research institutions grew from 15,800 in 1960 to 31,900 in 1980, but the ratio decreased from 13.4 percent in 1960 to 8.7 percent in 1980.

Thus the larger groups of scientific research workers in Japan are those of the universities and of the industrial companies. To date, the two groups have been roughly the same size. This balance, however, is starting to shift toward the industrial companies.

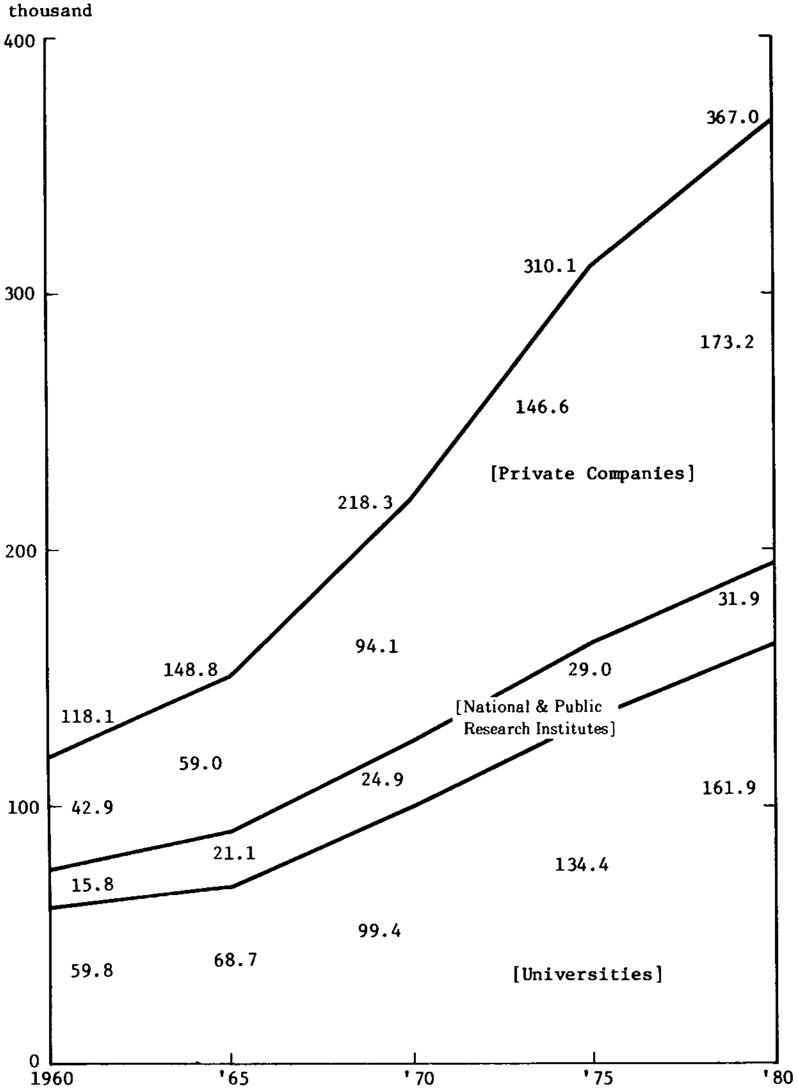


FIGURE 1. Qualified Researchers by Employer

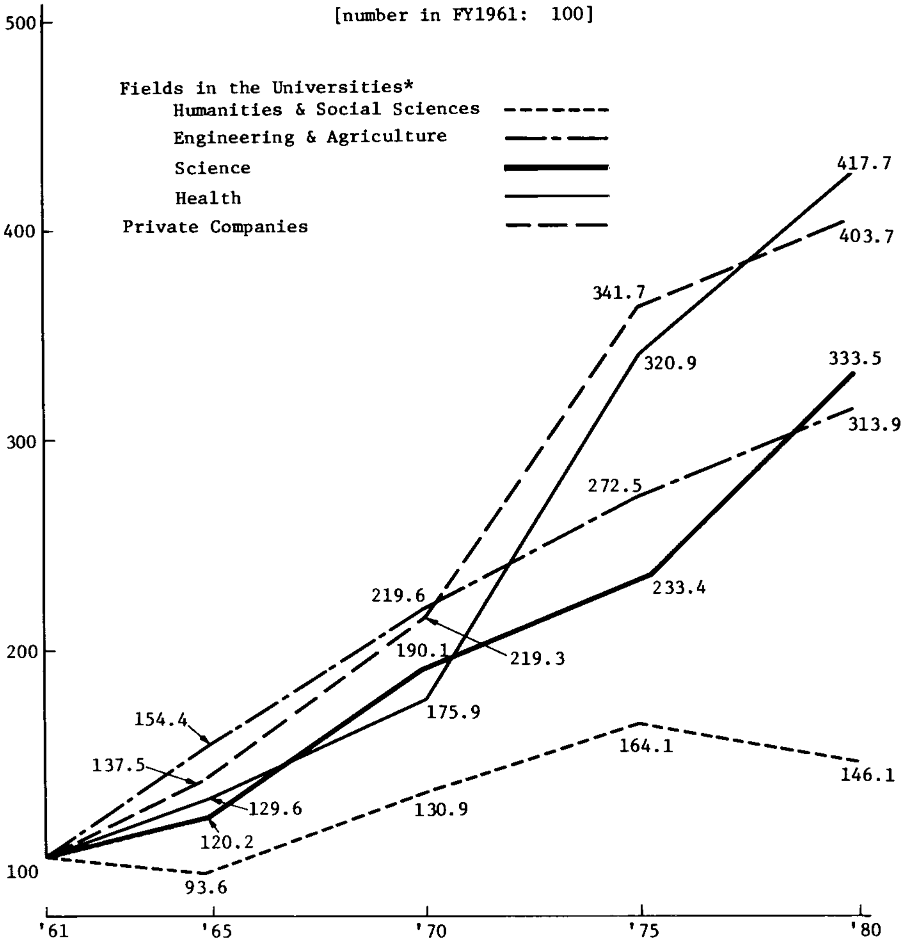
Source: *Sorifu Tokei Kyoku (Statistics Bureau, Office of the Prime Minister)* Kagaku Gijutsu Kenkyu Chosa Hokoku. *Report on the Survey of Research and Development, Showa 35 Nen (1960); Showa 40 Nen (1965); Showa 45 Nen (1970); Showa 50 Nen (1975); Showa 55 Nen (1980).*

A second consideration, looking specifically at university researchers (i.e., the trend of basic sciences) is the rapid growth in the number of faculty members in health sciences, the more moderate growth in engineering, agricultural science, and other sciences, and the decline in the humanities and social sciences. Figure 2 shows these trends as a percent of 1961 positions, as well as the trend of the industrial companies. Figure 3 shows this same information numerically.

The health field faculty members increased from 13,121 in 1961 to 54,812 in 1980, indicating a growth of 4.1 times in only 20 years. Humanities and social science faculty members remained relatively stagnant while engineering and agricultural faculty members increased steadily from 11,583 in 1961 to 36,355 in 1980, marking growth of 3.14 over 20 years. The increase in science faculty members, at the rate of 3.34 times, was quite comparable.

Furthermore, in view of the triple structure of Japanese universities (national, municipal, and private), the comparatively larger contribution of national universities in science is noteworthy (see Fig. 3). The policy of emphasizing national efforts to strengthen the science area is even more clearly discernible from Fig. 4.

National universities have 14.9 percent of science faculty members as opposed to 8.7 percent in all other universities. In the more "policy-oriented" research institutions of the national universities and the research institutes for joint use, the number is even higher: 29.2 percent and 60 percent respectively. These figures eloquently reveal the MESC policy to emphasize the support to research in science.



*Fields represented are on the basis of faculties in the universities. Science comprises mathematics, physics, chemistry, biology, etc.

FIGURE 2. Increasing Trend in Number of Faculty Members in Universities and Number of Researchers in Private Companies

Source: *Sorifu Tokei Kyoku (Statistics Bureau, Office of the Prime Minister)* Kagaku Gijutsu Kenkyu Chosa Hokoku. *Report on the Survey of Research and Development, Showa 35 Nen (1960); Showa 40 Nen (1965); Showa 45 Nen (1970); Showa 50 Nen (1975); Showa 55 Nen (1980).*

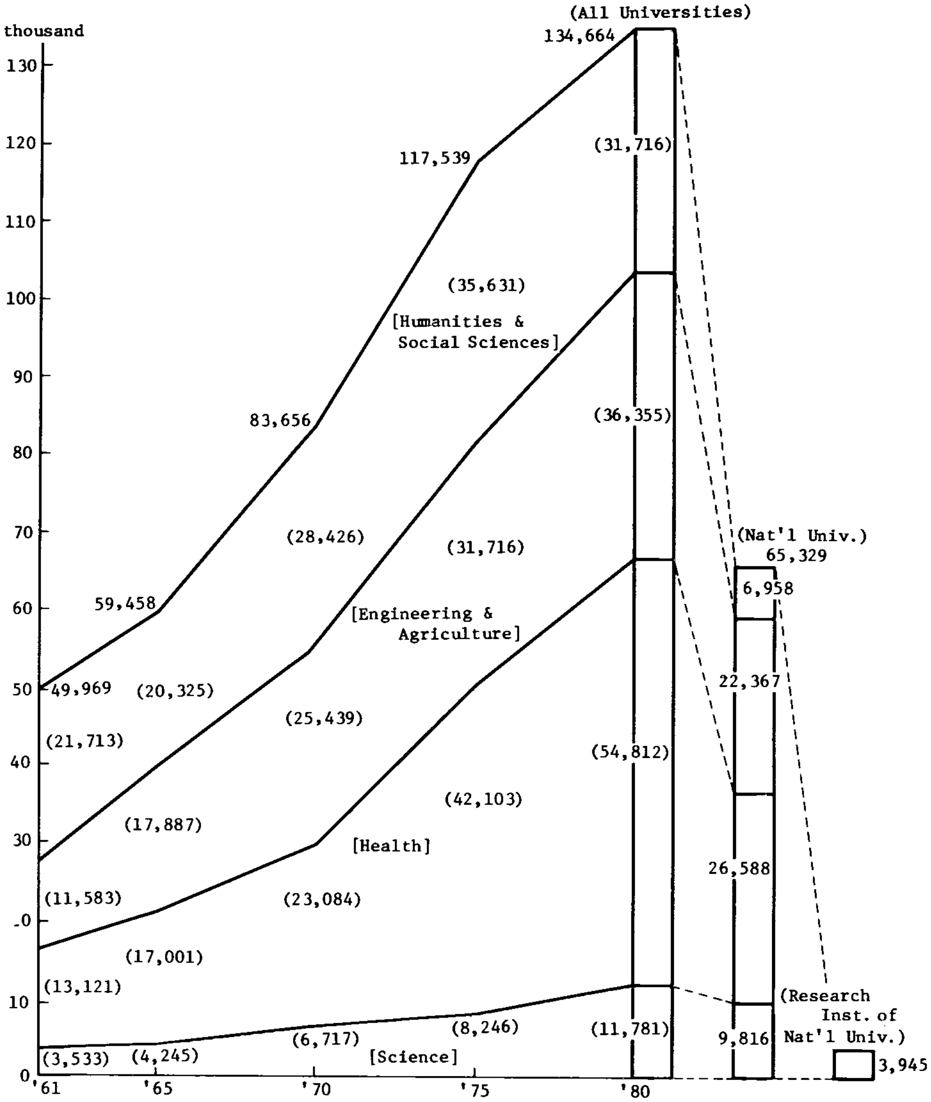


FIGURE 3. Number of University Faculty Members

Source: *Sorifu Tokei Kyoku (Statistics Bureau, Office of the Prime Minister)* Kagaku Gijutsu Kenkyu Chosa Hokoku. *Report on the Survey of Research and Development, Showa 35 Nen (1960); Showa 40 Nen (1965); Showa 45 Nen (1970); Showa 50 Nen (1975); Showa 55 Nen (1980).*

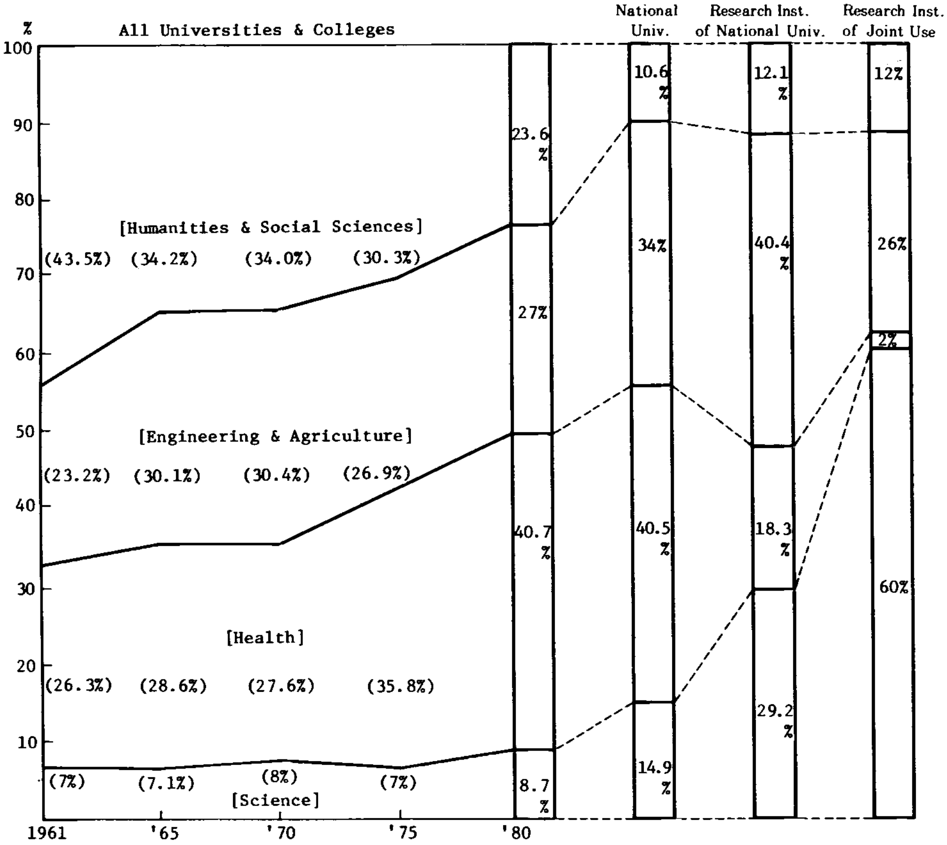


FIGURE 4. *Comparison of the Component Ratio of Number of Faculty Members by Fields of Science*

Source: Sorifu Tokei Kyoku (Statistics Bureau, Office of the Prime Minister) Kagaku Gijutsu Kenkyu Chosa Kokoku. *Report on the Survey of Research and Development, Showa 35 Nen (1960); Showa 40 Nen (1965); Showa 45 Nen (1970); Showa 50 Nen (1975); Showa 55 Nen (1980).*

C. National and Public Research Institutes and "Technopolis"

Efficiency in research activities is usually enchanced by the concentration of capable research manpower at well-equipped research centers. The government has made several endeavors to encourage such development. A prime example is the establishment, through an interministerial collaboration, of "technopolis." Located 60 km northeast of Tokyo, the facility contains 43 government research laboratories and educational institutions on its 2,700 hectares (6,672 acres). It was completed in 1980 and cost over the 15 year construction period, more than 1,100 billion yen. Most conspicuous of the 43 research laboratories are Tsukuba University, KEK, National Institute of Environmental Studies (NIES), the Space Center of National Space Development Agency, the nine laboratories of MITI, and the eleven laboratories of the Ministry of Agriculture and Forestry.

Tsukuba Science City has become an interdisciplinary research center with an international atmosphere. It is considered best suited for industry-academia-government cooperation. The International Science Exposition will take place there in 1985. Eventually this "technopolis" will have a population of about 200,000 people. The construction of the whole infrastructure and facilities has been carried out with government funding but, in nearby areas, additional construction of private laboratories, with private funds, is taking place.

Secondly, government policy-makers are aware of the need to recruit the best and most creative minds in the world. Government officials and concerned academics are interested in founding the best-equipped laboratories to create sufficiently attractive employment opportunities for the most talented researchers. They believe that young researchers must be trained with an open perspective of the world. Some scholars, administrators, and bankers are making efforts to establish a research center for biotechnology and plan to invite a Nobel Laureate as its director.

If these attempts are successful there would be a "brain drain" in the direction of the Far East.

Finally, in view of the extremely small expenditure in Japan for weapons research, the opportunity exists to compensate with government investment in research and development. The government's share of the total amount of research expenditure in the nation is only 27 percent. The total national, public, and private research expenditure is only 3 percent compared to 6 percent in France and the United States. The establishment of more research institutes, dedicated to non-weapons research, should expand in the future.

D. Priority Areas

Research activities today are highly specialized because of the rapid progress in science and, in some areas, enormous amounts of funding are required. There are also increasing demands and expectations for scientific research to aid in the solution of social problems. Science policy should secure a steady progress among various branches of science by supporting research activities in a variety of areas, while at the same time, allocating funds based on priorities.

Two examples of development in science and technology which had government priority are MITI's support for development of the computer industry and Nippon Telegraph and Telephone Public Cooperation's (NIT) success in achieving innovations in information technology. Space science and nuclear research, which were initiated by universities, are followed mainly by STA; energy mainly by MITI; information science by MESC, NIT and MITI; environmental research by MESC and the Environment Agency; disaster prediction by the Meteorological Agency and MESC; and cancer studies by the Ministry of Health and Welfare (MHW) and MESC, etc.

Government support in these strategic areas, during the past two decades, was no doubt effective in the development of science and technology. Their success was paralleled by higher education and research at the universities.

E. Universities and MESC as the Centers and the Sponsors of Basic Research

Universities play the most important role as the center of basic research in all fields of natural sciences, social sciences, and the humanities. University researchers comprise 44% of all the scientific researchers in the nation. National universities account for 47.2 percent of all university researchers. In the natural sciences, these same universities account for 57.1 percent of the researchers and 60.6 percent of the graduate students. Therefore, national universities are the principal partners in scientific research.

While undergraduate faculties comprise the foundation of higher education, the centers of research and research training are graduate schools. There are 257 universities that have graduate schools, of which 88 have only Masters programs, and 169 have Doctoral programs. Enrollment as of 1 May 1980 by levels and fields is shown in Table 1.

In as much as higher education and basic research are the two primary mandates of universities, the promotion of scientific research is one of the responsibilities of MESC. In the formation of science policies, MESC consults the Science Council (MSC), which functions as an advisory body to the Minister. Figures 3 and 4 indicate that policy has been especially designed to promote basic science. Figure 3 illustrates that the national universities share of researchers in the science faculties is especially high: 9,816 of 11,781 (83.3 percent), as opposed to 26,588 of 54,812 (48.5 percent) in health, 22,367 of 36,335 (61.5 percent)

TABLE I. Number of Students at Graduate Schools (as of 1 May 1980)

	Master's Program				Doctor's Program			
	Total	National	Municipal	Private	Total	National	Municipal	Private
Humanities and Social Sciences	9,519	2,430	305	6,784	5,290	2,038	280	2,972
Natural Sciences	22,648	17,147	847	4,654	12,233	8,075	762	3,396
Science	3,741	2,885	153	703	2,589	2,105	156	330
Engineering	14,864	11,152	433	3,279	2,358	1,779	88	491
Agriculture	2,546	2,198	113	235	1,095	971	37	87
Health	1,497	912	148	437	6,191	3,222	481	2,488
Other	3,614	2,505	148	961	688	533	44	111
TOTAL	35,781	22,082	1,300	12,399	18,211	10,646	1,086	6,479

Source: Monbusho (Ministry of Education, Science and Culture, Japan) Monbu Tokei Yoran, Showa 56 Nen Ban *(Statistical Abstract of Education, Science and Culture), Monbusho, 1981.*

in Engineering and Agriculture, and 6,958 of 31,716 (21.9 percent) in the humanities and social sciences.

Furthermore, the share of science personnel is significantly larger in policy related institutions. Figure 4 illustrates that in national universities the percentage is 14.9 percent, in the research institutes of national universities it is 29.2 percent, and in research institutes of joint use it is 60 percent. These figures indicate clearly that MESC policy gives priority to research in science.

II. BASIC RESEARCH SUPPORT PRACTICES

A. Outline of Research Budget

The total amount of research and development expenditure in Japan in 1980 was approximately 4,607 billion yen. Industrial companies accounted for 57.8 percent, universities accounted for 27.8 percent, and the national and public research institutions accounted for 14.3 percent (see Fig. 5).

The total government budget for research and development in the 1981 fiscal year was 1,398 billion yen, of which 49 percent went to MESC, 22 percent went to STA, and 17 percent went to MITI (see Fig. 6).

The MESC scientific research budget, in the 1981 fiscal year, amounted to 828 billion yen. Among the major items were 1) funding of national universities (75.3 percent); 2) subsidies to private and municipal universities (17.6 percent); and 3) grants-in-aid for scientific research (14.7 percent)(see Fig. 7).

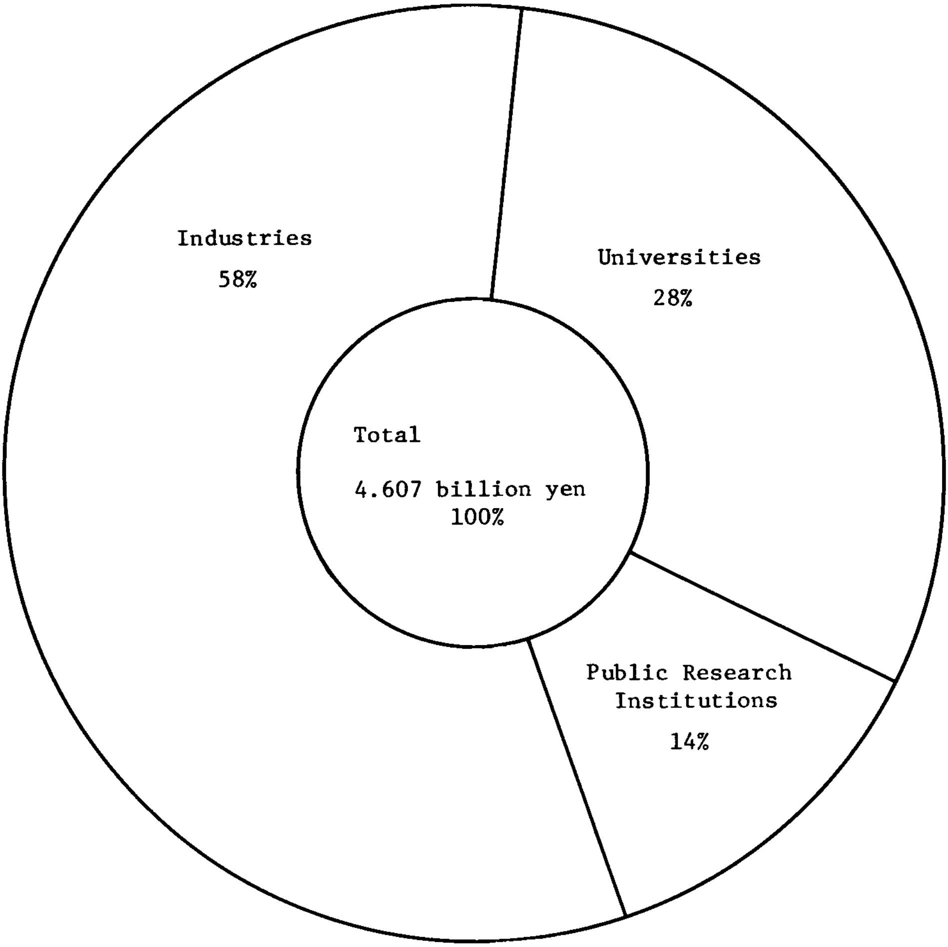


FIGURE 5. Expenditure on R & D Research Sectors, in Fiscal Year 1979

Source: Sorifu Tokei Kyoku (Statistics Bureau, Office of the Prime Minister) Kagaku Gijutsu Kenkyu Chosa Hokoku. *Report on the Survey of Research and Development, Showa 55 Nen (1980).*

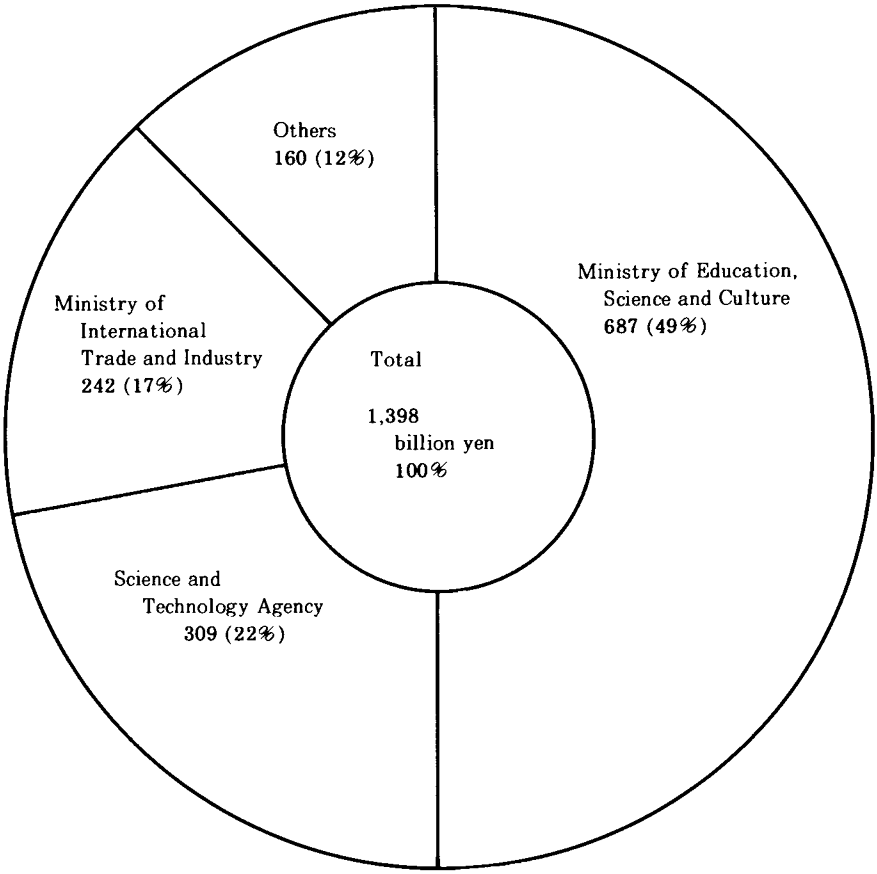
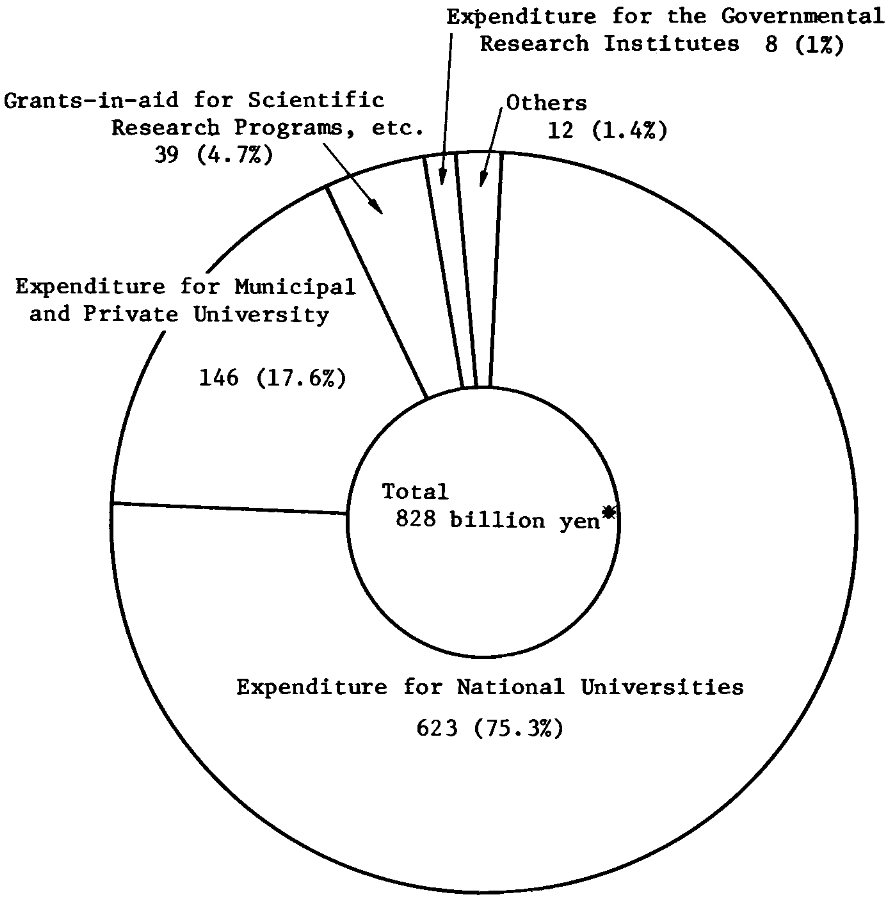


FIGURE 6. Government Budget for Science and Technology by Ministries, in Fiscal Year 1981

Source: *"Showa 56 Nendo Kagakugijutsu Kankei Yosan (Budget for Scientific Technological Research for FY 1981-82).* Gakujutsu Geppo (Japanese Scientific Monthly) *Vol. 34, No. 2 (May, 1981; Tokyo, Japan Society for the Promotion of Science) pp. 6-16.*



**The difference between 828 billion in this figure and 687 billion for MESC in Fig. 6 is due to the exclusion of current expense subsidies for private universities in the latter figure.*

FIGURE 7. MESC Budget for the Promotion of Scientific Research, Fiscal Year 1981

Source: Ministry of Education, Science, and Culture, "Monbusho's Budget for the Promotion of Scientific Research" (including research in social sciences and humanities), (mimeo), August 1981, p. 12.

B. Government Budget for Science and Financial Difficulty

Table 2 shows the government budget for science and technology. The energy and university items include the STA estimates of science and technology expenditures.

TABLE II. Government Budget for Science and Technology, FY 1981

		Billion yen	*% Increase from FY 1980*
General Account	*Government Expenditure for the Promotion of Science and Technology*	*374.8*	*6.4*
	Research Expenditure for the Development of Energy Sources	*176.8*	*3.9*
Subtotal		*551.6*	*5.6*
Special Account	*Research Expenditure for National Universities*	*629.1*	*6.6*
	Special Account Expenditure for Research Related to Energy Sources	*152.7*	*30.5*
	Others	*64.9*	*3.0*
Subtotal		*846.7*	*10.0*
TOTAL		*1398.2*	*8.2*

Source: "Showa 56 Nendo Kagakugijutsu Kankei Yosan (Budget for Scientific Technological Research for FY 1981-82)," Gakujutsu Geppo (Japanese Scientific Monthly) *Vol. 34, No. 2 (May 1981; Tokyo, Japan Society for the Promotion of Science), p. 7.*

TABLE III. Government Expenditures for the Promotion of Science and Technology (unit: billion yen; figures in parentheses: growth rate)

Expenditures	FY 1976	FY 1977	FY 1978	FY 1979	FY 1980	FY 1981
Space Development	*80.7*	*86.2*	*86.3*	*88.5*	*90.5*	*91.2*
	(14.8)	*(6.8)*	*(0.1)*	*(2.6)*	*(2.2)*	*(0.8)*
Ocean Development	*3.2*	*3.4*	*4.9*	*6.0*	*6.7*	*8.5*
	(-7.6)	*(5.4)*	*(47.0)*	*(22.3)*	*(11.6)*	*(25.8)*
Large-Scale Industrial Technology	*13.9*	*13.7*	*13.8*	*13.7*	*13.4*	*13.3*
	(16.9)	*(-1.0)*	*(0.4)*	*(-0.7)*	*(-2.1)*	*(-0.6)*
Computer Technology R & D	*14.9*	*8.6*	*10.1*	*8.6*	*5.8*	*6.2*
	(2.4)	*(-42.1)*	*(16.3)*	*(-14.4)*	*(-32.8)*	*(7.4)*
Government Laboratories	*95.9*	*104.5*	*117.9*	*143.4*	*137.4*	*143.1*
	(9.8)	*(9.0)*	*(12.8)*	*(21.6)*	*(-4.2)*	*(4.1)*
Antarctic Observation	*2.1*	*2.1*	*2.4*	*3.5*	*9.2*	*11.4*
	(24.7)	*(-3.7)*	*(16.7)*	*(46.3)*	*(162.9)*	*(23.8)*
Grants-in-Aid for Scientific Research and Other Subsidies	*36.2*	*40.6*	*44.8*	*50.9*	*53.8*	*60.8*
	(12.8)	*(12.0)*	*(10.4)*	*(13.6)*	*(5.7)*	*(13.0)*
Other Other	*23.2*	*26.4*	*29.2*	*32.5*	*35.2*	*40.3*
	(9.6)	*(13.7)*	*(10.5)*	*(11.3)*	*(8.5)*	*(14.2)*
Total Totals	*270.2*	*285.5*	*309.4*	*347.1*	*352.1*	*374.8*
	(11.4)	*(5.7)*	*(8.3)*	*(12.2)*	*(1.4)*	*(6.4)*

Source: "Showa 56 Nendo Kagakugijutsu Kankei Yosan (Budget for Scientific Technological Research for FY 1981-82)," Gakujutsu Geppo (Japanese Scientific Monthly) *Vol. 34, No. 2 (May 1981; Tokyo, Japan Society for the Promotion of Science) p. 8.*

Table 3, on the other hand, traces the rate of increase in government funding for the promotion of science and technology from 1976 to 1981.

Reorganization of the national budget was proclaimed a key issue by both the Ohira Cabinet and the Suzuki Cabinet. The national budget has been tightened across the board. However, the budgets for science and technology, as can been seen from Tables 2 and 3, were given exceptional priority in the 1981 budget. Thus government appears to recognize the importance of scientific and technological development in the future progress of the nation. This trend may continue in 1982 and beyond. Indeed, the policy guidelines recommended by the Second Extraordinary Council on Administration Review, confirm the priority of science and technology.

It appears, on the other hand, that the educational budget will be severely reduced. Budgets for the national universities and subsidies for private universities will be, at best, the same as the previous fiscal year. There was harsh criticism of the current practices of the national universities by the Provisional Commission for Administrative Reform. There may be even harsher cut-backs in the national university budget in the process of continuing administration reforms.

C. Processes of Decision-Making

In the determination of the MESC related budget for scientific research, initial plans for founding research institutes, research facilities, and research equipment are conceived of and discussed by scientists in the fields concerned. The plans are often advocated through the Science Council of Japan (SCJ), a representative body of scientists under the administration of the Office of the Prime Minister, and receive the latter's recommendation. In turn, MESC, in consultation with MSC, deliberates those plans that are strongly advocated as to their advisability and the means for their realization.

MSC is a central advisory committee, consisting of 27 members, and is charged to provide recommendations to MESC on basic guidelines for the promotion of scientific research, priority issues concerning scientific research, and allocation of grants-in-aid for scientific research. Taking into consideration the advice of MSC, MESC examines the budgetary implications of plans as submitted by universities, etc., and submits those it selects to the Ministry of Finance as an MESC budget request for the next fiscal year.

The Ministry of Finance and MESC deliberate on each plan and sometimes the approved plan is modified from the MESC original. Approved plans are included in the draft of the government budget and are submitted to the Diet for approval. Plans approved by the Diet are implemented at the start of the new fiscal year. In cases where new legislation is required, the necessary law must be enacted by the Diet.

D. Some Characteristics of Japanese Universities

Japanese Universities receive 28 percent of all reserach expenditures. The majority of higher level achievements in basic research are made by the researchers of national universities, especially in such traditional universities as the University of Tokyo and Kyoto University.

Scientific research activities by individual researchers are strongly affected by the research policies of the institutions where they are engaged. The science policies of the government are formulated in such a way as to influence the research policies of the individual institutions wherever possible. However, the policies are usually in harmony with the existing science policies of the individual institutions.

At national universities which have a large number of top level researchers such as the University of Tokyo, the faculty can over-rule decisions regarding education and research in which they are engaged. University presidents and college deans usually do not exercise a strong leadership in these matters. Each college of a university conducts its own faculty meetings. By law, faculty have tenure. Because of the large faculties and the diversity of disciplines represented, each faculty devises its own method of operation to suit the needs of its college.

Usually, the faculty does not intervene with the research projects of individual researchers. Each faculty member is allocated a certain lump sum of research funds annually from the university's budget. The individual researchers are completely free to select and plan research projects on their own. (This system, which is most convenient to individual researchers, invites occasional criticism that research funds are wasted by some researchers who are inactive in research activities.) The faculty meeting intervenes when new research projects require additional allocation of funds from the university's budget. When new plans for research involve creation of a new research team with additional research personnel and the purchase or installation of new research equipment or facilities, a faculty meeting is called to discuss coordination of the new research and balance among the disciplines. Since the consensus of the faculty meeting is essential, the conclusions of the faculty meeting tend to be conservative. Consequently, rather conservative research policies prevail at most institutions.

As a direct consequence of the concerns of research scientists and science administrators with such conservatism, the formation of newly organized institutes was planned. Research institutes for joint use, for example, are staffed by top level research scientists who are relieved from undergraduate teaching and recruited not only from Tokyo and other prestigious universities, but also from foreign countries. Efforts in this direction ought to be further developed in order for Japan to remain a leader in scientific research.

E. Research Institutions and Programs for Joint Use

Joint use research centers, institutes, and research centers at universities are established with varying degrees of linkage to universities.

National inter-university research institutes have been established: four institutes in natural sciences and three institutes in the humanities and social sciences. In addition, there are nine national research institutes under the jurisdiction of MESC which are closely related to university research.

There are 71 research institutes attached to national universities, 12 of which are open to use by people from other universities.

There are many research facilities attached to universities which, unlike the above, are not established by law. These include three inter-university research facilities, 62 intra-university research facilities, and 234 intra-faculty research facilities.

Finally, there are research institutes in private and municipal universities, i.e., the KEK and the Okazaki National Research Institute.

Large scale, interdisciplinary programs are very costly. However, computers are being installed in major universities that are linked to a large scale network. They are indispensable for achieving a breakthrough in the field.

International cooperation is also underway. For example: Japan is participating in the UNESCO sponsored WESTPAC research in marine science; construction of an emulsion chamber in Tibet is being planned in cooperation with the Chinese; a telescope built in Hawaii by the British will be shared with Japanese scientists; use was made of TRIUPH in Canada and future cooperation in nuclear studies is planned; United States-Japan cooperation in science (i.e., energy research, nuclear fusion, space sciences, cancer research, etc.) is being carried out actively.

F. Several Issues and Trends

Universities and industries are the major organizations for research and development in Japan. However, cooperation between universities and industries is a problem; the solution of which is most difficult. The government cannot force cooperation by provision of policies. A flexible and cumulative inter-dependence among universities, industries, and government needs to be achieved. The government may be able to play the role of catalyst.

MESC is asking its Science Council for suggestions to facilitate cooperation between universities and industries through the encouragement of contractual research. The handling of patents also is receiving consideration as it is a barrier to university-industry cooperation.

The conservative nature of university faculties is another serious barrier to cooperation. In order to counter this conservatism and to promote scientific research, new types of research centers are being created. Many professors strongly feel that research institutions, without a student body, will become stagnant without the pressure from youth to provide constant stimulation. It is difficult to foresee to what extent the new type of research institutes will replace universities in research but no one can doubt the merit of these institutions.

Another weakness of Japanese universities is the lack of a sabbatical and the looseness in working hours of university faculty members. This makes it difficult for faculty to engage in research away from their institution and to work at a different institution with excellent research. There is a problem organizing project research among Japanese universities. Some efforts are made, but much more systematization seems necessary to encourage mobility.

An optimum balance, between the per capita research fund and grant-in-aid for scientific research, needs to be achieved. The former, for national universities, is roughly 80 billion yen and the latter, for all universities is about 32 billion yen. It is desirable and appears likely that the amount of grant-in-aid for scientific research will catch up with the per capita research funding in the near future.

Grants-in-aid for scientific research do not include the cost of employing research personnel. This, together with lifelong tenure of all university faculty members, probably impedes progress as it prohibits, for all practical purposes, the mobilization of research personnel toward a topic of special importance. Along with the founding of new research institutes, ways and means to mobilize people to work on important research projects are needed very much in the future.

III. EXAMPLES OF SOME RECENT LARGE-SCALE BASIC STUDIES

A. Basic Studies on Information Science

The MESC has been sponsoring a series of project studies on information science over the past decade through the Grants-in-aid for Scientific Research.

Stimulated by the success of a preceding project study, entitled "Advanced Information Processing of Large-Scale Data over a Broad Area," and by the urgent need for organizing scientific information, enthusiastic requests for a new project study were made by researchers (not only in information science but also in broad scientific disciplines) and endorsed by the Science Council of Japan (SCJ). In response to this request, the MESC allocated 1,015,150,000 yen (approximately $4,400,000 U.S. dollars), for the period beginning April 1976 and ending March 1979 for the project study entitled "The Formation Process of Information Systems and the Organization of Scientific Information." This project study thus became one of the largest projects in basic scientific studies involving more than 500 researchers from universities, colleges, and scientific research institutions in Japan.

The project was administered by the Computer Center, University of Tokyo, under the supervision of its director. To assist the director in planning, directing, and coordinating project activities, a Steering Committee was formed that consisted of a chemist, a physicist, three information scientists, two control engineers, and an electronics engineer. The objective of the project study was to explore problems and solutions for organizing scientific information in a broad range of disciplines (i.e., natural sciences, social sciences, and humanities) and to promote research and development activities for the formation of information systems for scientific purposes. In view of the very broad area to be covered and the rather limited funds available, an interdisciplinary approach was taken in which research and development efforts were concentrated on selected topics while close coordination across disciplinary boundaries was maintained. For this purpose more than 500 researchers, invited from a large variety of disciplines, were organized into 69 research units and four development committees. The research units were categorized into five research groups: input processing, structure recognition, storage and retrieval, systems approach, and research trend analysis. The development committee included those on computer networks and data base management systems. The activities of the research units and the development committees were coordinated by the Steering Committee.

The impacts of the project study include the following.

1. The study provided a concrete proposal for the organization of a science information system in Japan. The proposal was immediately taken up by the MESC and through consultation with the Science Council, a mast plan for the construction of a science information system was issued in January 1980. Based upon this new system, studies were conducted to deploy the system.

This deployment included a science information center, university libraries, computer centers, and a large number of terminals interconnected by a public service digital data network. It is expected that the system will start service in 1984.

2. As a result of the experience acquired in the project study, the interdisciplinary characteristics of the studies on information management and processing were acknowledged by the MESC and a new interdisciplinary category, "Information Studies," has been formed within the framework of the Grant-in-aid for Scientific Research. Two hundred million yen (approximately one million U.S. dollars) are allocated per year to this project.

3. The project study resulted in a fully developed computer network called "N-1 Architecture," for the interconnection of computer centers and terminals. The architecture has been accepted as a standard protocol and implemented in a number of computer centers including seven inter-university computer centers that provide nation-wide services. An on-line data base access system known as "TOOL IR" was also developed for bibliographic retrieval services.

4. The work of one of the project research units was picked by the MESC as a subject for further development. This project, "Studies on Original Document Data Base Accessible On-line from Remote Terminals," is intended to demonstrate the feasibility of on-line library services that store and retrieve original document information, including photographs and drawings, and to provide them with on-line remote terminals. The MESC is providing, for a three year period, financial support amounting to 137 million yen (approximately 650,000 U.S. dollars) for the construction of a pilot system for feasibility demonstration.

B. Establishment of National Inter-university Research Institutes (NIURI) by Universities with an Accent on a High-Energy Physics Program

Recent large-scale, basic science research programs in Japan have been centralized in the National Inter-university Research Institutes. The first example of a NIURI facility was the National Laboratory for High-Energy Physics (KEK) established in 1971 for study of the physics of elementary particles by use of large accelerator facilities. From 1971 to 1981, about ten NIURI facilities were established in various fields, e.g., polar research, molecular science, biological science, and space science. The list of NIURI facilities is given in Table 4. NIURI facilities belong to the same legal family as the national universities, but are directly supervised by the Minister of MESC. The concept is a research institute run by a board with nation-wide representation and open to a wide community of users from many institutions. Consequently, it could be called a "truly national laboratory"[1] for basic science as it also includes the national museum and the research material center for Japanese Literature, Ethnology, and History.

1. Brief History of KEK

The KEK began in 1955 when Japanese nuclear physicists decided to build a 1 GeV electron synchrotron at the Institute for Nuclear Studies (INS), at the University of Tokyo. While INS was affiliated with the University of Tokyo, it was open to all the nuclear physicists in Japan. As nuclear physics grew rapidly, a number of new technologies were developed. One of the new technologies was the particle accelerator which used high-energy particles to probe sub-atomic structures. However, to reach

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[1] *This name was originally used by L. Ledermann, the present director of Fermi National Accelerator Laboratory, the counterpart of the KEK in the United States.*

TABLE IV. List of National Inter-university Research Institutes (NIURI)

Name of Institute	Acronym	Location	Founded	Budget[a]	Personnel (Researchers)	Present Director
National Laboratory for High Energy Physics	KEK	Tsukuba, Ibaraki	1971	12,901	349 (154)	Tetsuji Nishikawa
National Institute of Japanese Literature	NIJL	Shinagawa, Tokyo	1972	702	77 (35)	Teiji Ichiko
National Institute of Polar Research	NIPR	Itabashi, Tokyo	1973	1,946	108 (34)	Takeshi Nagata
National Museum of Ethnology		Suita, Osaka	1974	3,003	122 (63)	Tadao Umesao
Okazaki National Research Institutes	ONRI	Okazaki, Aichi	1981	4,103	72	Masutaro Kuwabara
Institute for Molecular Science	IMS		1975		82 (47)	Saburo Nagakura
Institute for Basic Biology	IMB		1977		51 (33)	Masutaro Kuwabara
Institute for Physiological Sciences	IMP		1977		50 (31)	Koji Uchizono
National Center for Development of Broadcast Education		Makuhari, Chiba	1978	1,281	24 (10)	Kenji Fujita
Institute of Space and Astronautical Science	ISAS	Meguro, Tokyo	1981	13,321	284 (101)	Daikichiro Mori
Museum of History[b]		Sakura Chiba	1981	1,752	30 (19)	Mitsusada Inoue

[a] Budget in millions of yen, Fiscal Year 1981; [b] English name is tentative

deeper, unknown regions of the microscopic world of the nature, larger and more powerful accelerators were needed. This raised complex problems associated with the budgets and the manpower required to provide the new, large instruments which employ the most advanced technologies.

Research in high-energy physics dramatically increased on a world-wide scale after the Second World War. In Japan, however, experimental research programs in this field were largely retarded for two reasons: 1) the economic difficulties of the post-war period; and 2) the official action by General McArthur's Headquarters, GHQ, that prohibited nuclear science research in Japan—including the construction of any new accelerators. The peace treaty was signed in 1951, just a year before the first proton synchrotron of 3 GeV, the Cosmotron, was completed at the Brookhaven National Laboratory. About that time, some pioneering physicists in Japan, like the late Professors S. Kikuchi, H. Kumagai, S. Tomonaga, and H. Yukawa, were aware of the great importance of promoting nuclear physics programs with large accelerators in Japan. Discussions on the establishment of a new laboratory for this purpose were held by a special committee under the Science Council of Japan (SCJ). The SCJ, as part of the Japanese Government, is a democratic organization, i.e., members of the SCJ and their sub-committees are elected by votes from scientists throughout the country. Therefore, it takes a long time to reach a decision, particularly in the case of a large-scale scientific program. Long debates were held on different proposals from scientists or groups of scientists. These debates considered political problems arising from questions concerning the government's commitment and the scientists' autonomy. In 1953, however, the SCJ recommended that the government establish the Institute for Nuclear Study as a nation-wide nuclear physics program affiliated with the University of Tokyo to minimize interference from the government.

INS was officially established in 1955 with a 60" cyclotron as its first major facility; construction of a 1 GeV electron synchrotron started in 1956. The electron synchrotron was completed in 1961, just after the Brookhaven AGS and the CERN CPS were completed. By this time, these largest proton accelerators in the world had diameters more than twenty times that of the new Japanese electron machine.

Thus, in the early 1960s Japanese scientists and the public felt that Japan was not yet ready to jump into the frontier of high energy physics. Despite such feelings, some determined physicists strongly felt that a multi-GeV proton accelerator laboratory should be built in Japan after the completion of the electron machine. This desire crystallized in a proposal for a 12 GeV high-repetition proton synchrotron, and later for a 40 GeV ordinary proton synchrotron. In 1962, the SCJ adopted the proposal as part of a larger national program for research in basic science and recommended it to the government. The government allocated 100 million yen for R & D studies on the high-energy accelerator. A study group was organized at INS in 1964.

However, almost another decade was lost with discussions on the scale of the budget, effects on and relation to research programs in other fields of science, and the organizational problems involved in the establishment of a new national laboratory. Not only the SCJ continued discussions, but also the government, where MESC had established a new Science Council (SCM) to report to MESC on general science policy and specific issues concerning research program. Although both the SCJ and the SCM recommended high-energy physics programs with a high priority, a strong dispute arose between them around organizational problems and around procedures for determination of scientific policy at the new laboratory. The chief issues discussed reflected opinions from would-be users and the directorship of the laboratory on the process of staff appointments and on exchange or cooperation between universities and the central laboratory.

Fortunately, the site selection proceeded rather smoothly as the Japanese government had been planning to build a new academic town dedicated to scientific research and education in Tsukuba (approximately 60 km northeast of Tokyo). After geological and geotechnical surveys of possible sites, about 200 hectares (494 acres) in the northern part of Tsukuba Science City were selected for the new accelerator laboratory.

During the last decade of debate, accelerator and detector R & D progressed within the study group. This set a foundation and direction for the KEK program to follow. At this time, only a small number of scientists had experience in experimental high-energy physics and in modern accelerator arts. These scientists simply promoted R & D programs under the leadership of Prof. S. Suwa who became the first director of the KEK. The study group tended to avoid the political dispute. They felt they would solve any problems, either technical or political, by taking one step at a time.

After a great effort by determined people, both on scientific and governmental sides, the establishment of KEK was authorized in 1970 as the first NIURI facility. It was generally agreed that the whole project proposed by scientists seemed so enormous that the total budget was reduced by 75 percent, with a proviso for future expansion. This has also been assured by the large site allotted to the KEK. The first principal instrument of the KEK, a 12 GeV proton synchrotron, was completed on schedule in 1976.

2. *KEK Status*

The present organizational chart of the KEK is shown in Fig. 8.

KEK started with four departments: the Accelerator Department, the Physics Department, the Engineering Reserach and Scientific Support Department, and the Administration Department.

The Board of Councilors is an advisory council for the laboratory director and consists of fifteen members appointed by

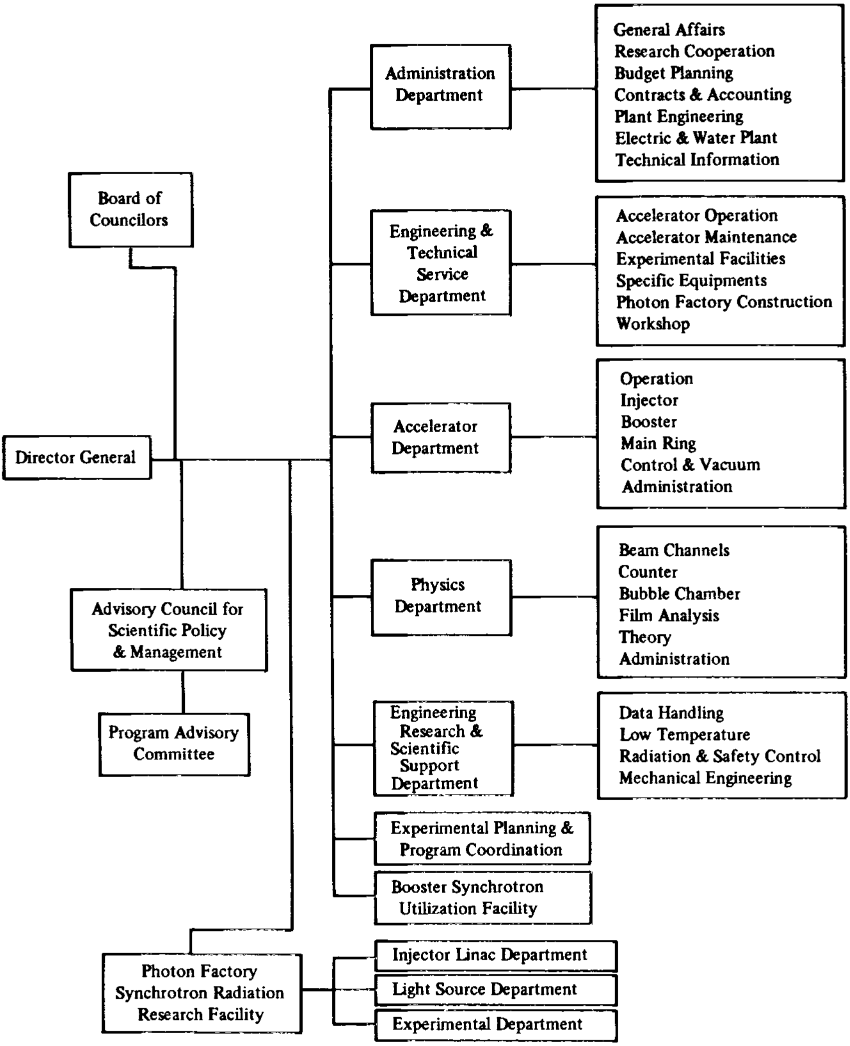

FIGURE 8. Organization of KEK

the Minister of MESC. Council members are presidents of universities, directors of other institutions in the field, and other eminent scholars. The Board of Councilors gives advice to the director with respect to the policy of KEK and also nominates the director of the KEK.

The Advisory Council for Scientific Policy and Management is for discussing the scientific policy and management of KEK and consists of 21 scientists. Members of this council are formally appointed by the Minister of MESC on the recommendation of the director. Half of the members are senior scientists of KEK and the other half are senior scientists from the users' group. This Council summarizes and presents opinions of physicists with respect to the scientific programs and policies of KEK. They also give recommendations to the director on the employment and promotion of scientific staff.

In April 1977, just before the first scheduled experiments by the joint-use participants with the KEK proton synchrotron (hereafter KEK-PS), the Program Coordinator's Office implemented changes and the engineering and technical support staffs were reorganized into a new department. All experimental proposals, either from in-house scientists or from outside users, were examined by the Program Advisory Committee (PAC) with respect to both their physics merits and their technical feasibility. About forty proposals have been approved by PAC and half of them have completed experimental runs. Another quarter are underway, and the remaining quarter are on stand-by. These experiments involve both high-energy physics and nuclear physics as well as other applications. KEK-PS is currently the only one proton synchrotron in the world active at ten GeV energy region. Thus, this synchrotron is open also for the use of foreign scientists. The primary and secondary particle beams are very stable and reliable with strong intensities and good qualities.

The accelerator is operated around the clock on a two-week cycle. Each operation starts on Tuesday or Wednesday morning and

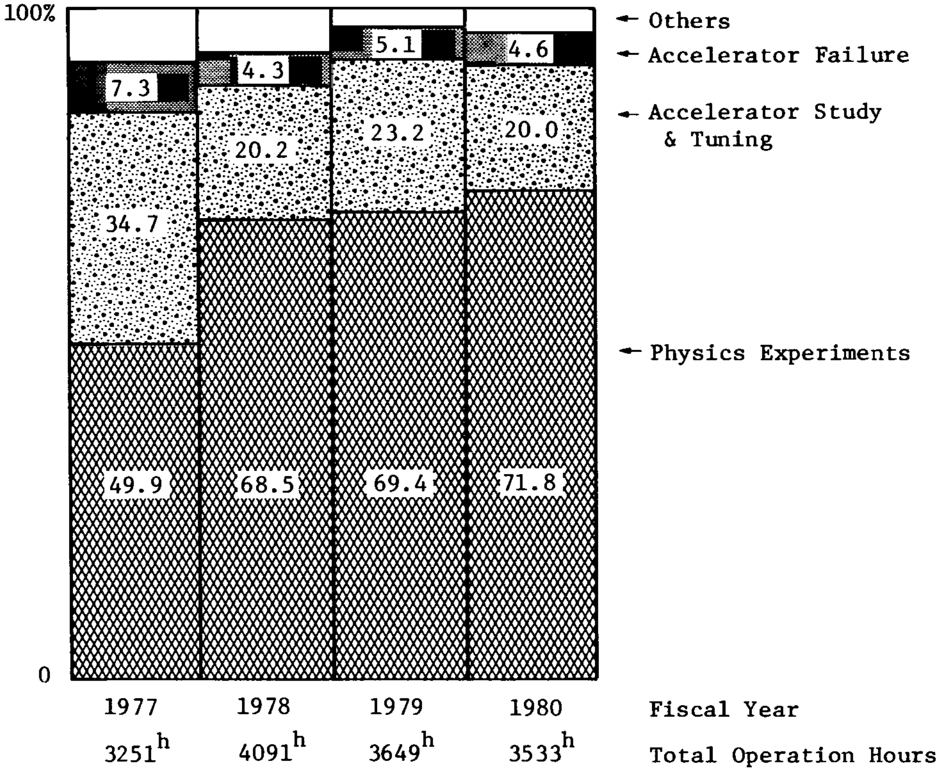

FIGURE 9. Data on the Operation of KEK PS

ends on the Saturday morning of the next week. Data on the operation of the KEK-PS is illustrated in Fig. 9, and shows an average downtime as low as 5 percent. More than 70 percent of machine time is used for physics experiments and another 20 percent for accelerator studies.

In 1978, construction started for the Booster Synchrotron Utilization Facility and the Photon Factory (a dedicated synchrotron light source). Both of these high-energy accelerators are for research programs other than high-energy physics.

The booster is the third stage of KEK-PS that consists of four separate accelerators. It is able to provide surplus protons at the 500 MeV level for applications as only one-quarter of the booster beam is injected into the main, 12 GeV synchrotron. The

Booster Synchrotron Utilization Facility was constructed with input from users. Of the various possible research programs using the booster beam, three have been promoted, i.e., the pulsed neutron source, pion and muon science, and the medical applications. The neutron project has been promoted mainly by the Tohoku University group and the π-μ project, with a superconducting muon channel, has been funded and executed by the University of Tokyo; both were completed in June 1980. The medical research center was initiated by the University of Tsukuba and will be completed in 1982.

The synchrotron radiation "Photon Factory" has been under construction since 1978. It consists of a 2.5 GeV electron linac and a storage ring of the same energy so that it will yield a number of intense pencil beams of photons at available wave lengths from 0.1 to 10^3 angstroms. The research instrumentation and the optical channels are being prepared in cooperation with the users groups. This group represents a wide scientific field, e.g., chemistry, biology, medical science, pharmacology, crystallography, mineralogy, solid-state physics, lithography, etc. The facility will be ready for use in 1982. Originally, this project was planned as an independent institution; however, it was finally established as part of KEK.

Encouraged by initial success, KEK is about to enter the world frontier of high-energy physics. The project called by the acronym TRISTAN (Transposable Ring Intersecting Storage Accelerators in Nippon), has been approved by the Japanese government for the 1981 fiscal year with a five year construction plan of its first phase. It is a large colliding beam facility with a total circumference of more than 3 km; its layout on the KEK site is shown in Fig. 10. A detailed design study has been made for the construction of a colliding beam complex using the 12 GeV proton synchrotron with a 2.5 GeV electron linac as primary injectors. Electrons will be accelerated up to 25 $\sim$ 30 GeV and protons more than 300 GeV with concentric storage rings installed in the same

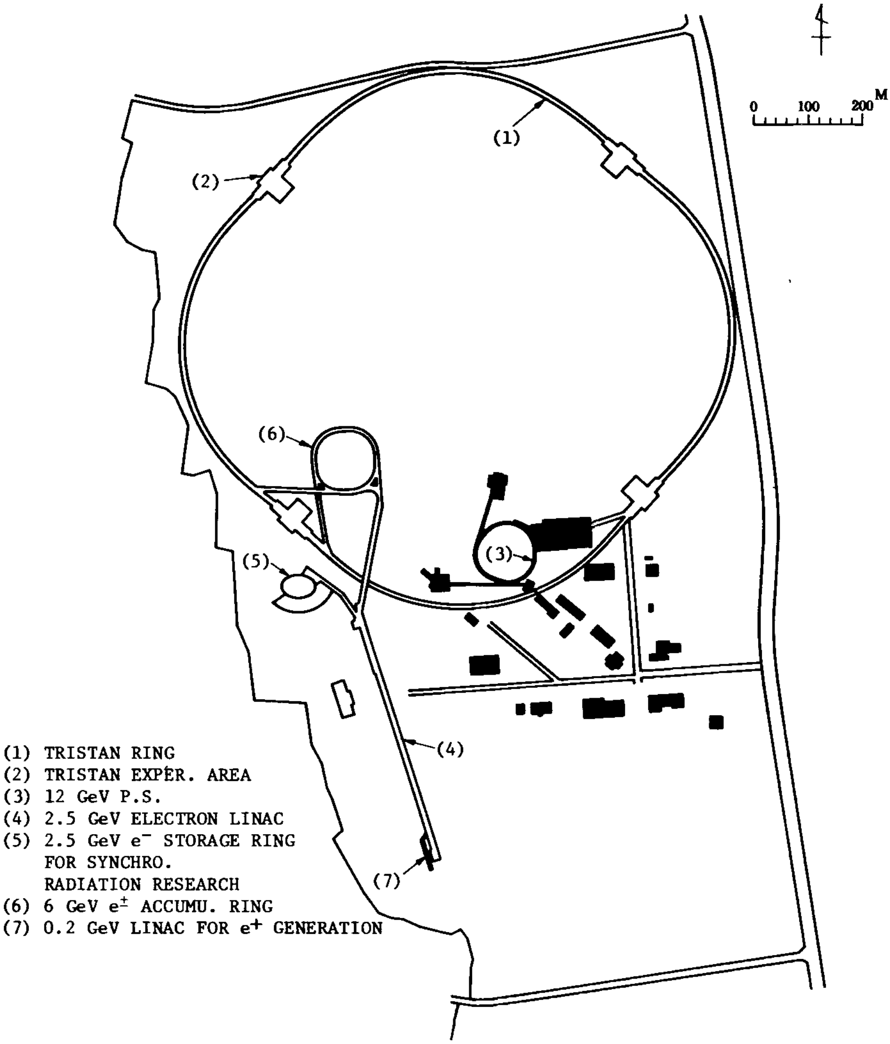

FIGURE 10: Plan view of TRISTAN ring at KEK site

tunnel. At various stages of development, TRISTAN will be able to study $e^+ e^-$, $e^\pm p$, pp, and $p\bar{p}$ interactions by beam selection. While only a single electron ring for $e^+ e^-$ colliding beam experiments will be built in phase 1, it will become, by the time of its scheduled completion, the world's largest and highest energy machine of this type.

It should be mentioned that in the course of proposing and planning this KEK future plan, there has been strong support both from the scientific community and the government. One reason for this support is the growth of the Japanese economy during these decades. However, the success of the KEK program won support from both interested individuals and from the general public.

Figure 11 shows the growth of both the KEK budget and the KEK staff over time. The numbers of visiting researchers from various institutions are given in Table 5. In every sense, KEK is now the national center for high-energy physics and related fields of science. It is not only the center for nation-wide cooperative research, but also for programs involving international cooperation. A count of visiting scientists from other countries who stayed more than one month at KEK for research collaboration is given in Table 6.

In addition, since 1979, a well-thought-out cooperative research program in high-energy physics has been established under the sponsorship of MESC and the United States Department of Energy in accordance with the Agreement between the Government of Japan and the Government of the United States on Cooperation in the Field of Energy Research and Development.

Under this program, the KEK director represents Japanese interests and serves as co-chairman of the joint committee. More than twenty Japanese physicists are now collaborating with United States scientists at such major U.S. high-energy physics laboratories as Berkeley, Brookhaven, Fermi, and SLAC. A total budget of 1.56×10^9 yen was funded by MESC (fiscal 1981) for cooperative studies. KEK is also promoting cooperative programs with other

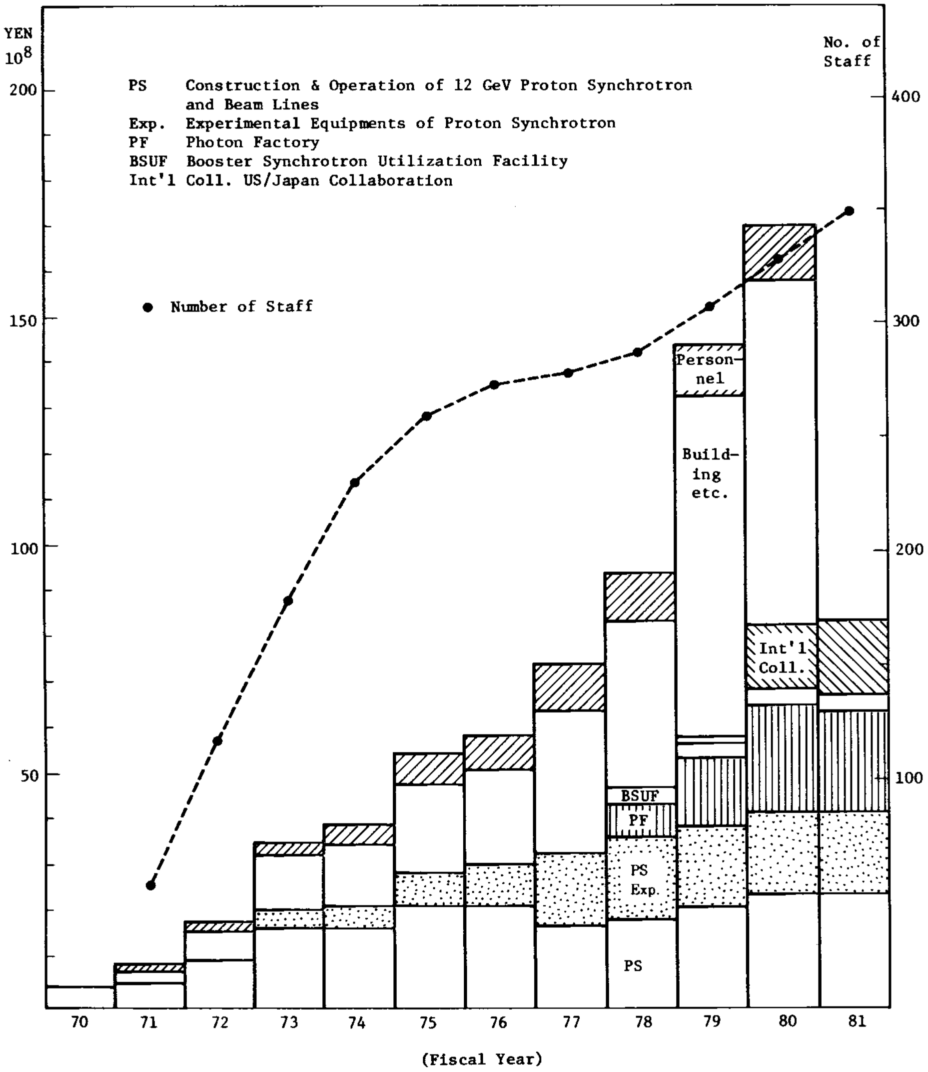

FIGURE 11: KEK Annual budget and number of staff

TABLE V. Visiting Researchers at KEK (number of persons and man-days given in parentheses)

Fiscal Years	National Universities	Public Universities	Private Universities	Others (mostly Graduate Students)	Totals
1976	156 (1,729)	10 (174)	11 (50)	87 (3,828)	264 (5,781)
1977	233 (3,850)	16 (361)	18 (117)	104 (7,105)	361 (11,433)
1978	286 (4,459)	14 (544)	21 (100)	142 (10,420)	463 (15,523)
1979	425 (4,683)	31 (202)	44 (362)	196 (13,864)	696 (19,111)
1980	512 (6,047)	35 (374)	72 (456)	288 (13,957)	907 (20,834)

TABLE VI. Countries of Foreign Scientists who Stayed at KEK More Than One Month (by fiscal year)

Countries	*1971*	*1972*	*1973*	*1974*	*1975*	*1976*	*1977*	*1978*	*1979*	*1980*	*Totals*
China								*9*	*4*	*2*	*15*
France					*1*	*2*	*2*	*3*	*3*	*1*	*12*
West Germany				*1*		*1*		*1*	*1*	*2*	*6*
Great Britain					*1*		*2*	*1*	*2*	*1*	*7*
United States	*3*	*3*	*2*	*2*	*1*	*4*	*5*	*4*	*3*	*9*	*36*
Other Countries		*1*	*3*		*1*	*2*	*2*	*3*	*4*	*5*	*21*
Totals	*3*	*4*	*5*	*3*	*4*	*9*	*11*	*21*	*17*	*20*	*97*

countries, but on a smaller scale. Western Europe and Japanese directors from CERN and KEK exchanged the memorandum on cooperation in 1980.

3. Other Examples of National Inter-university Research Institutes (NIURI)

National Institute of Polar Research (NIPR). This institute was established in 1973. Research activities cover many scientific disciplines, including upper atmosphere physics, meteorology, glaciology, solid earth science, biological science, and polar regions engineering. The present main effort is directed toward the Antarctic in close cooperation with the Japanese Antarctic Research Expedition (JARE). NIPR has as its objective the implementation of scientific and logistics programs of the JARE, and is responsible for maintaining two Antarctic stations. The Institute has also participated in international scientific programs such as the Dry Valley Drilling Project, the United States-Japan Meteorite Search Project, and the International Magnetospheric Study.

NIPR is responsible for collecting, processing, and utilizing various records and samples collected by JARE and other expeditions. It maintains the national SCAR (Scientific Committee on Antarctic Research, International Council of Scientific Unions) data center for biology, geology, glaciology, logistics, seismology, etc.

The Institute, headed by a director and deputy director, consists of four divisions: Research, Data Collection and Processing, Office of Expeditions, and Office of Administration, and a library.

Okazaki National Research Institutes (ONRI), located in Okazaki City 300 km southwest of Tokyo, consists of three institutes:

1. The Institute for Molecular Science (IMS), founded in 1975;

2. The national Institute for Basic Biology (IBB), founded in 1977; and

3. the national Institute for Physiological Sciences (IPS), founded in 1977.

IMS was established for theoretical and experimental studies of molecular structures and their functions. IBB and IPS were founded for integrated research in fields of basic biology and for integrated research in physiological science, respectively. For making research activities more efficient, the latter two institutes, in their closely-related fields, formed the National Center for Biological Sciences. These three institutes were integrated into the ONRI in fiscal year 1981. They share the Administration Bureau and many facilities, such as the central library, the central computer, the machine shops, the facilities for laboratory animals, the radio-isotope laboratory, the energy supply center, the waste material processing plant, visitor's accommodations, etc.

Brief descriptions of research activities in each institute are as follows:

Institute for Molecular Science (IMS)

IMS has five research divisions: theoretical studies, molecular structure, electronic structure, molecular assemblies, and applied molecular science. There are five research facilities: computer center, instrument center, low-temperature center, chemical material center, and development workshop. Construction of a synchrotron orbit radiation facility for photoelectric spectroscopy with the far-ultraviolet light source has been in fiscal year 1981.

IMS has promoted two special research projects: "Investigation of Energy Conversion Processes at the Molecular Level," and "Molecular Designing for Interesting and Useful Materials." IMS also coordinates a United States-Japan cooperative program for research and development of new energy sources in the field of photosynthesis.

Institute for Basic Biology (IBB)

The IBB consists of three research divisions: cell biology, developmental biology, and biological regulation, and a research facility for culture and rearing research. A large spectrograph and a computer system for biological studies are also in the facility for culture and rearing research.

Two special research projects on "Formation of Segmentation Mechanism and Control of Cell Multiplication," and "Mechanism of Cell Motions" have been promoted.

Institute for Physiological Science (IPS)

The IPS consists of four research divisions: molecular physiology, cellar physiology, information physiology, and biological control system, and a facility for physiological research. The facility has a high voltage electron microscope especially designed for biological samples.

The IPS has promoted a special research project entitled "The Sensory Function and the Central Nervous System."

Institute of Space and Astronautical Science, (ISAS). The old ISAS was established in 1964 at the University of Tokyo. It was formed by combining the Aeronautical Research Institute of the University, the space engineering group from the Institute of Industrial Science of the University, and some space scientists. The old ISAS was established for coordinating and conducting the national and international cooperative space research programs. The Institute was also responsible for the development of balloons, sounding rockets, mu-family satellite launchers, and scientific satellites, as well as for the launching of and data acquisition from these space vehicles. In April 1981, the space science and engineering part of the old ISAS was reorganized and ranked as a NIRUI, i.e., the new ISAS. The new ISAS has the same functions as the old ISAS in space research.

Each year about 20 large, space observation balloons are launched from the Sanriku Balloon Center; several rockets are launched from the Kagoshima Space Center for space observations. Since 1970, five engineering test satellites and seven scientific satellites have been put successfully into orbit around the earth by a lambda-type launcher and by mu-type launchers. With these space vehicles, observations in aeronomy, magnetosphere physics, astronomy, and astrophysics have been made with fruitful results.

In addition to the national space research activities described above, ISAS has been engaged in international cooperative programs. So far, space observations by balloons or by rockets have been made jointly with the United States, Canada, India, the Netherlands, and other countries. The program will be extended to satellite observations and space shuttle experiments in the near future.

The new ISAS has nine research divisions: space astrophysics, space plasma, planetary science, basic space science, space system engineering, space transportation, space propoulsion, spacecraft engineering, and space applications, as well as a Space Operations Division and an Engineering Support Division.

4. Remarks

The unique concept of NIURI has brought great progress in large-scale research programs in absic science in Japan under the sponsorship of MESC. All NIURI are known not only as the nation-wide research center but also as the international representative organization for research programs in related fields. NIURI have organized and hosted a number of national and international conference and symposiums.

The direct sponsorship of MESC makes it possible to promote, emphatically and efficiently, important research programs in basic science, to negotiate necessary budgets directly with the government, and to develop new ideas or systems for promoting national and international cooperative programs. Nevertheless, as shown in Table 4, the number of laboratory staff in some institutes is far from sufficient to make progress. For instance, the number of staff at high-energy physics laboratories in other parts of the world, exceeds thousands while the total number of the present KEK staff is only 350. This is due to the currect strict regulations on the number of national or governmental employees in Japan. It is strongly hoped to find a break-through for such important research programs.

Another feature of NIURI is the giving of legal status almost equivalent to that of national universities, i.e., scientists are nominated as professors, associate professors, and research associates. This is very benefitical in encouraging exchange of researchers between NIURI and universities. In addition to researchers in national universities, scientists in private universities can join and use the research programs or facilities at the NIURI. Further exchange or cooperation between NIURI and other independent national or private institutions is also in progress. It is desired that the relation of NIURI to graduate schools or graduate students be discussed and improved. In some institutes, graduate students are actively participating with their professors in research programs at NIURI. Also, guidance of doctoral studies of some graduate students have been asked from NIURI professors by their home universities. However, the status of the graduate student at NIURI is still somewhat uncertain; discussions are being held on the functional differences between NIURI and universities of research and education.

Finally, there is increasing recognition of the great importance of the supporting staff and the facilities for large-scale basic research through the NIURI programs. At universities in Japan, the lack of such supporting systems occasionally caused serious difficulties in promoting advanced scientific research.

The importance should be more qualified, appreciated, and evaluated in daily research activities and laboratory management.

C. Government Support for Industrial Research and Development

As was briefly mentioned early, the MITI has been responsible for supporting industrial R & D activities. There are two types of government support: 1) Contract, where in principal, the government pays the whole cost of the project; and (2) Subsidy, where the government bears, in general, 50 percent of the cost. Following are some major examples.

1. Contract

a. Large-scale industrial technology development. Since its start in 1966, it has provided 127 billion yen to promote 18 projects. Nine of them have been completed already.

Some of the major projects are: "Super High-Quality Computer" (1965-1971); "Desalination of Sea Water" (1969-1977); "Electric Vehicles" (1971-1977); "Pattern Recognition Processing System" (1971-1980); "Flexible Manufacturing System" (1977-1983); "Opto-electronic Measurement and Control System" (1979-1986); and "High-speed Computer System for Science" (1981-1988).

b. New Energy Development (so-called Sunshine Project). Started in 1974, four main areas have been identified, namely: solar energy, coal conversion, geothermal energy, and hydrogen utilization. The budget for 1980 is 28.6 billion yen, of which 23 billion is allocated to the New Energy Development Organization that was established in 1980.

c. Energy Conservation Technology Development (so-called Moonlight Project), commenced in 1978. Its 1980 budget was 8.1

billion yen.

The major programs are: High-efficiency Gas Turbine; Waste Heat Utilization; Magnetohydrodynamic Electric Power Generation; and Advanced Battery Energy Storage.

d. Basic industrial technology development for the next generation. This new scheme, launched in 1981, is to support industrial efforts for basic technology yet to be explored in the context of industry-academia-government collaboration. Three broad areas have been identified: new materials; biotechnology; and new functional component-elements.

The fiscal 1981 budget is 2.7 billion yen. The total budget requirement for the coming ten years will be around 100 billion yen.

e. Creative scientific technology development, launched in 1981 to reinforce the creative activities of scientists and engineers through increased linkage across organizations. In spite of the traditionally poor mobility of scientists and engineers in Japan, this scheme is expected to explore a new frontier of better cooperation in the scientific world. Four areas of interest have been identified; the 1981 budget was 700 million yen.

2. Subsidies

a. Super LSI technology. This four year project ended in 1979. The government spent 29.5 billion yen to subsidize 40 percent of the total cost of the R & D. The project involved five major electronics companies.

b. Civilian aircraft. This four year project started in 1978 in cooperation with the Boeing Aircraft Company of the United States to develop a new 200 seat passenger airplane. The Japanese government will pay 16 billion yen (50 percent of the total R & D cost) to help the Japanese companies engaged in this project.

c. New jet engine. This is another example of overseas R & D cooperation. Since 1980, Japanese companies have been cooperating with Rolls-Royce of the United Kingdom in an eight year project.

ACKNOWLEDGMENTS

Sections of this chapter have been made possible through the valuable information received from many persons at individual institutions of NIURI. Although the names and affiliations of these persons are not listed here, we would like to thank all of them for their kind cooperation.

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THE THEORETICAL BASIS FOR GOVERNMENTAL SUPPORT OF R & D: TRADITIONAL ARGUMENTS AND NEW REALITIES

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I. INTRODUCTION

Historically, the federal government has played, and continues to play, an important and ever-evolving role in the production and use of new technology in the United States. The nature of this role has depended upon agreed perceptions of what was in the national interest which, in turn, has depended upon the international environment, upon domestic needs, values, and ethical norms, and upon assessments of what could be accomplished by the private sector without federal action.

These conditions have been changing fundamentally during recent decades and the future will bring, most likely, more rapid

The views set forth in this paper are solely those of its author. The Department of Commerce has not reviewed this paper and takes no position on its validity or on the appropriateness of relying upon it in the formulation of federal policy.

SCIENCE POLICY PERSPECTIVES:
USA-JAPAN

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and fundamental changes in world economic, political, and social patterns—all of which influence, and are in turn influenced by, technology. Many knowledgable people have recently argued that, in today's dynamic environment, macroeconomic policies are not sufficient to ensure the development and use of the new technologies necessary to maintain industrial competitiveness in world markets and to achieve national economic and social goals. They believe that a new, cooperative approach between government and industry is needed which will utilize micro, as well as macro, policies and programs.

Summarized herein will be: the traditional, theoretical arguments for governmental support for Research and Development (R & D) vis-a-vis the private sector; consideration of the new realities of international competition that face the United States today; and some personal observations concerning new arguments for government support and the practical problems of implementation.

II. THE PROBLEM

There is a widespread perception that the United States economy is declining and that this is significantly related to a decline in the United States technological performance relative both to our past record and to our current economic competitors. Recent lackluster rates of economic growth, high rates of inflation, and stagnating employment are now part of our national consciousness and have had a substantial impact on the outcome of the 1980 presidential election.

Economic indicators, such as balance of trade, market share, and productivity, provide more specific and worrisome details. In the 1970s, the United States had a trade balance deficit for six of the ten years. A large part of the deficit was due to oil imports, but industrial performance also was not very encouraging.

The R & D-intensive trade balance, reflecting traditional United States export strength in technology-based manufactured goods, had been positive and had steadily increased since 1960. However, in 1976 this indicator leveled off and in 1977, the latest year for which data are available, it declined slightly. In three of the six deficit years, there was an overall deficit in manufactured products; in major trade categories, the United States had gone from being a net exporter to a net importer of automobiles, telecommunications apparatus, and inorganic chemicals.

Much of the analysis done in this area has been supported by the United States Department of Labor. In recent Congressional testimony, Labor officials warned that:

> *The United States still has a comparative advantage in technology-intensive products in world markets... There are several indications, however, that U.S. dominance in world trade of high-technology products is being eroded. This is troublesome because these are the sectors which contribute the most to productivity growth and holding down inflation.* (1)

The troublesome indicators above include the fact that increases in imports of many high-technology products into the United States are higher than increases for manufacturing imports as a whole, and that the United States has become a net importer in several such technology-intensive products (1).

From the businessman's point of view, the best single measure of competitive performance and the most reliable indicator of future business success may be that of market share. The United States share of the domestic market is generally measured as the percent of manufacturing sales in the United States sold by U.S. manufacturers; the United States share of the world market is generally measured as the percent of manufacturing exports of industrial nations sold by United States manufacturers. Although world trade is becoming increasingly important to the United States, the United States is playing an increasingly smaller role in the world economy.

Trends of the United States market share of manufacturing, for both domestic and world markets, are not encouraging. United States manufacturers have lost ground over the period from 1960 through 1979 within the domestic market, decling from 98 percent to about 93 percent of market share. More dramatic over the same period was the decline in the United States share of the world market for manufactured goods from about 25 percent to 17 percent. Moreover, this trend seems to be accelerating. According to a recent article in *Business Week,* this loss of market share in the 1970s resulted in $135 billion in lost production and a loss of 2-million industrial jobs (2).

A Department of Labor study of United States export market shares for commodities found that there were trend declines between 1962 and 1979 in 71 percent of the United States exports, compared to 26 percent for Japan and 24 percent for West Germany. A comparison of United States export performance with four major competitors (France, Germany, Japan, and the United Kingdom) in contested third world markets showed that of the top 17 United States export commodities, 14 showed a loss of market share between 1962 and 1969, and all 17 showed a loss between 1970 and 1979. The United States still has one of the largest export market shares in high-technology products, but in 1977 fell behind Germany in this regard, while Japan's share has been growing rapidly until it is now third in size (1).

Although many factors affect international trade and industrial competitiveness, this Department of Labor study concluded that the explanation for declining United States trade performance is changing world resource supplies (capital and labor) and technological capabilities. The loss of United States market share over the last twenty years can no longer be explained on the basis that the national economies destroyed during World War II are rebuilding. This study argues that United States manufacturers have, in effect, given up the markets in which they are losing share by not staying abreast of technological and/or managerial innovation, or by not designing products for non-domestic markets.

The rate of productivity increase in the United States in the 1970s has fallen far below earlier levels, and since 1970 has grown less than in any other major developed country. In the private business sector, the average annual rate of productivity growth declined from 3.2 percent from 1948 to 1965, to 2.3 percent from 1965 to 1973, to 0.9 percent from 1973 to 1978. In 1977 and 1978, productivity fell to 0.3 percent (3). In a recent study Professor John Kendrick developed estimates of total factor productivity which is a more accurate measure than labor productivity. His figures show a productivity decline in the United States domestic business economy from 2.7 percent from 1948 to 1966, to 1.6 percent from 1966 to 1973, to only 0.7 percent from 1973 to 1977 (4).

The decline in United States productivity performance appears to exist pretty much across the board. The communications industry is the only sector to show a higher rate of productivity increase from 1973 to 1978 than in the preceding time periods. The productivity decline has been particularly severe in the mining and utilities industries. Manufacturing productivity has steadily dropped from 3.0 percent, to 2.4 percent, to 1.6 percent; transportation has dropped from 3.2 percent, to 2.9 percent, to 0.3 percent (3).

Not only is the recent decline of United States productivity growth relative to our own past causing concern, but also the longer-term trends relative to those of our principal economic competitors. Acknowledging that international comparisons of economic data do present difficulties, available data show that recent United States productivity growth has been significantly less than that exhibited by other major developed countries.

Comparative productivity growth rates for all industries and for manufacturing industries from 1960 to 1978 in ten industrialized countries show the United States with the lowest percentage in both cases, and Japan the highest—by a substantial margin (3).

Indexed data on productivity growth in manufacturing from 1950 to 1978 for six countries (1967 being selected as the base year which equals 100) show the United States and the United Kingdom with the lowest growth from 1967 to 1978—only 28.9 percent and 28.6 percent respectively; and Japan, France, and Germany with corresponding growth rates of 115.7 percent, 80.2 percent, and 75.3 percent (5).

It is true, of course, that many countries started at an absolute level of productivity that was much lower than that of the United States, so percentage improvements would naturally be higher. But this comparative differential in productivity growth rates has been occurring now for 25-to-30 years, and although the United States still maintains an absolute productivity edge, the trends are ominous. If present trends continue, both Germany and Japan will achieve higher *absolute* levels of productivity in the next 5-to-10 years. Since these trends are already 25-to-30 years old, there is little to suggest that this will, indeed, not happen, even if a major effort is made to turn the United States around.

The decline in United States productivity has been attributed to a number of causes: a slow-down of the labor ,shift from lower-productivity agriculture to higher-productivity sectors; shifts in the age-sex composition of the labor force; decreasing capital-to-labor ratios; government regulations; the increasing importance of the service sector in the total economy; cultural attitudes toward work; and technological change. Technology is a crucial element because it enhances our international technological competitiveness both directly and through its impacts on productivity. R & D and the development and application of new technology are believed to be major factors contributing to productivity advances, although limitations in analytical techniques have made empirical validation difficult. However, in the study referred to earlier, Prof. Kendrick determined that "advances in knowledge" or "technological progress" contributed more to total factor productivity than any other source in all three time periods, and that a "slowdown in technological progress" was one of the major factors responsible for the declines from 1948 to 1966 and from 1973 to 1977 (4).

The productivity measure may, in fact, seriously understate the competitive problem that the United States is facing because in the output numerator of the productivity fraction there is no easy way to capture the concept of quality. Technology can be applied to do more than reduce input costs; it also can improve the quality of the output. A quality improvement of this type may not affect productivity measures, but it will affect market behavior in terms of consumer preferences—and product quality is the basis on which many of our competitors appear to be successfully attacking our markets.

There is another relationship between innovation and productivity that may be important here. What we know about the product life cycle and the learning curve indicates that incremental innovation (product and process improvements) in technology and organization enable productivity increases to continue for some time after a major new product line is established (6). As those product lines evolve into "maturity," however, the marginal opportunities for even incremental innovation become less and less, and a continual stream of major innovations or new product lines is required for measurable productivity increases to again become possible. If, as some have suggested, the character of United States industrial R & D has been changing from major, long-term innovation toward incremental, short-term innovation, then the recent productivity decline may again be understating the competitive problem. In fact, by maintaining the current level of productivity growth—as low as it is—through incremental innovation, there may not be as many major new product lines coming on stream in the future when they will be needed to renew productivity opportunities. Productivity trends, in other words, may lag behind even more fundamental technological ones.

Indicators of innovation output and R & D input also provide cause for concern. Data on the number of patents filed by and granted to United States citizens, on the origins of a sample of major innovations studied, on venture capital and the health of small, high-technology business, and on R & D spending and manpower indicate slight downward trends. As Mary Mogee recently concluded in her analysis of a large number of innovation indicators,

> *...there are trends in a number of both input and output indicators of industrial innovation that may be interpreted to mean decling U.S. innovation performance relative both to past levels and to foreign competition.* (5)

Many of these indicators suffer from deficiencies that will not be debated here. Although any single indicator of industrial innovation may have limitations, consistent patterns do appear in a large number of indicators. Trends in the same direction of a large number of indicators of the same variable do give some confidence that we are observing real phenomena, despite their individual shortcomings.

III. TRADITIONAL, THEORETICAL ARGUMENTS

The essential economic role of government in a market economy is to correct market imperfections or failures (7). When such imperfections or failures are shown, direct Federal involvement to provide corrective action has traditionally been deemed appropriate. The following will present the traditional, theoretical arguments on why private industry cannot, or will not, support the optimal amount of R & D and technological application that is deemed socially desirable or necessary. Accepted forms of federal intervention are noted for each argument.

A. The Collective, Public Goods Argument

Market imperfections needing remedy include cases where external consumption effects on more than one individual are involved. A familiar textbook example is the provision of lighthouse services by the government. Attempts to provide such a service privately would likely fail since user fees would be impossible to collect. Even if by some means user fees could be collected, private provision of this service need not be socially optimal, since the cost of letting an extra ship use the service would be zero and, should any ships be discouraged from using the service because of a user charge, a "social economic" loss would result.

Certain functions are thus the responsibility of government because it would be impractical or inefficient for individuals or organizations to perform them or because their benefits are indivisible. Perhaps the best example of this is in the area of national defense, where it would not be practical for individuals or groups to establish and support military bodies to defend themselves against foreign aggression, and where the benefits of protection provided by the United States Government accrue to every citizen, whether they want it or not. R & D and technological development and application in support of the national defense is thus considered to be a public good, and is appropriately funded by the federal government—even when a private commercial industry also benefits, e.g., the semiconductor industry. Similarly, the development and maintenance of industrial standards at the National Bureau of Standards is accepted as an appropriate government function.

Another market imperfection covered under this argument is the case where average costs per unit of output fall steadily as volume of output increases and a national market is required—i.e., a monopoly situation occurs with government regulating the industry. Thus, the economic regulation of certain industries based on the application of technology, as in the case of telecommunications, is also accepted.

B. Appropriability of Benefits Argument

Research and technology development requires an investment of resources, from which a return is expected. The inability of the firm to fully capture or appropriate the returns from its R & D investment—and to prevent competing firms from sharing those benefits without making the investment—is the second major kind of market imperfection that has traditionally been an acceptable rationale for federal action.

In the now classic 1962 paper, Kenneth Arrow analyzed the economic biases that lead to misallocation of resources in research and development (8). While Arrow's analysis is highly theoretical, the implications can easily be understood by considering the relationship between supply and demand for a mixed good. Mixed goods are those that generate public benefits in excess of private benefits. Defense spending is typical of a pure public good, while production of such consumer items as apples, salt, and bread are examples of pure private goods. In the case of private goods, an informed buyer purchases a good or service whose benefits are fully appropriable by the producer. In the case of mixed goods, both the producer and the public secure benefits from transactions that take place. When the public benefits exceed the private, the discrepancy can lead to a pattern of underinvestment by the private sector.

This can be seen in Figure 1. In this figure the innovation results shift the aggregate supply schedule from S to S'. (This is equivalent to having more units of output of a product from the same value of inputs). The new equilibrium price falls to P' and quantity increases to Q'. The change in consumer or public surplus (the cross-hatched area), plus the change in producers

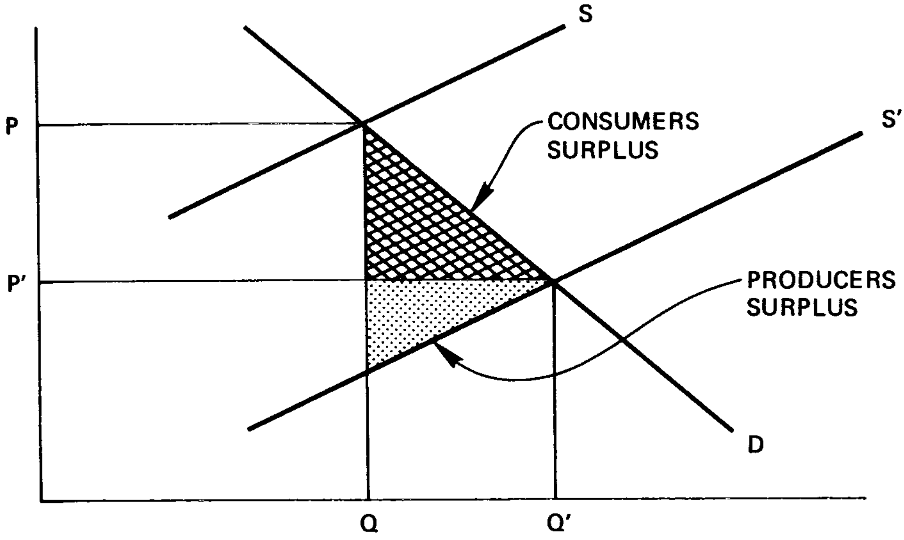

Figure 1

surplus (dotted area), equals total social benefits. Comparing the stream of inputs relating to the innovation with the social benefits realized provides an estimate of the social rate of return from the investment in the new innovation. As illustrated in this figure, total social benefits are considerably greater than producers surplus. These social benefits are not appropriable by the producer, and so his investments in innovation are less than what would be socially desirable.

In the case of new products, the displacement of old products must be explicitly taken into account.

Several economists have empirically demonstrated the validity of this argument. Mansfield's studies show that the social (or public) returns from industrial innovations—the development and use of new technologies—significantly exceed the private benefits from those innovations. Mansfield analyzed innovations in both the product and process areas. From the data it was demonstrated that the median social rate of return for his sample of innovations was 56 percent while the median private rate of return

TABLE I. Social and Private Rates of Return from Investment in 17 Innovations

Innovation	*Rate of return (percent)*	
	Social	*Private*
Primary metals innovation	*17*	*18*
Machine tool innovation	*83*	*35*
Component for control system	*29*	*7*
Construction material	*96*	*9*
Drilling material	*54*	*16*
Drafting innovation	*92*	*47*
Paper innovation	*82*	*42*
Thread innovation	*307*	*27*
Door control innovation	*27*	*37*
New electronic device	*Negative*	*Negative*
Chemical product innovation	*71*	*9*
Chemical process innovation	*32*	*25*
Chemical process innovation	*13*	*4*
Major chemical process innovation	*56*	*31*
Household cleaning device	*209*	*214*
Stain remover	*116*	*4*
Diswashing liquid	*45*	*45*
Median	*56*	*25*

(before taxes) was about 25 percent (see Table I)(9). Moreover, the results indicated that,

> *...in about 30% of the cases, the private rate of return was so low that no firm, with the advantage of hindsight, would have invested in the innovation, but the social rate of return from the innovation was so high that, from society's point of view, the investment was well worthwhile.* (9)

While the selection of the examples studied by Mansfield cannot be considered a random sample, other researchers support his results by reaching similar conclusions. For example, Fellner reports "...all reasonable ways of looking at the matter lead to the conclusion that social rates of return are very high (for technological advances)..." (10); Griliche's investigations into hybrid corn and hybrid sorghum innovations also produced high social returns estimates (11).

The problem of non-appropriability of benefits from R & D or innovation and the consequent under-investment by private industry in those crucial activities, is perhaps most vividly expressed by the imitation rather than innovation strategy. Once scientific and/or technical knowledge is produced, it cannot be perfectly locked up and kept secret from competitors. Moreover, the cost of producing such knowledge is usually much greater than the cost of acquiring it. Therefore, many corporate strategies regarding product innovation today favor a "fast follower" approach, letting the innovation leader bear the costs and market risks. A very revealing statement of this policy was made by Mr. Lee Iacocca when he described the Ford Motor Company's policy on product innovation to be "...last in, best dressed." Imitation *per se* is not necessarily a bad strategy for an individual firm; but if more and more United States firms start wanting to be second rather than first in new product development, there will be less and less innovation by United States industry.

Examples of federal policies and programs which are presently accepted under this argument include the following:

- Direct support of basic research. Basic research is essential to the science base from which technological innovations can be developed. Since private returns to basic research are typically very low, adequate support of such research by the private sector is highly unlikely. Recognition of this is reflected in the legislation creating the National Science Foundation in 1950.

- Education and training in science and technology have been supported because of the broad social benefits they confer.

- Research on weather, earthquakes, and other natural phenomena is an acceptable example of research supportable by public funds because private investment in such activity is likely to be less than socially optimal.

- Protection of intellectual property rights by patents, trade secrets, and copyrights are accepted methods of preserving the benefits of innovation for the innovator. Not all firms patent innovations, however, particularly where industrial processes are involved. Corporate secrecy is often a preferred way to retain private benefits from innovation.

C. The Externalities Argument

Negative externalities form another basis for federal government intervention in the marketplace. The economics of the externalities argument are closely related to the appropriability argument discussed above. The most frequently cited example of negative economic externalities is the pollution produced by a manufacturer maximizing private returns by dumping waste in nearby streams and rivers. The negative economic consequences for those downstream from such a plant are obvious. What is clear is that the reduction of these externalities benefits society as a whole rather than the individual firm, and that government has a role in regulating the internalization of the costs of waste treatment or in forcing the development and application of problem solving technology. This forms the underlying basis for a mission agency such as the Environmental Protection Agency (EPA). Other federal intervention has also been deemed essential to protect worker health and safety, consumers, etc.

The federal role in the control of industrial pollution has also resulted in both the direct support of R & D for pollution control technology development and its applications, and assistance programs for labor and local communities adversely affected in the short run by the imposition of pollution controls.

Similarly, the application of new technology and productivity increases in industry may result in negative externalities for displaced workers. To address this problem, the federal government has an accepted role not only in providing the normal welfare benefits to the unemployed, but also to engage in positive adjustment programs and to provide technical retraining and relocation incentives.

D. The Size and Risk Argument

A final kind of market imperfection occurs in cases where the size of the cost and/or the degree of risk involved in the technology development and application is just too great for private industry to bear alone. This occurs, in some instances, because of the absolute size of the undertaking—e.g., peaceful uses of atomic energy, syn fuels—and in other cases where the size of the undertaking relative to that of any individual industrial unit is substantial—e.g., disaggregated industries, agriculture.

The accepted federal role in these cases has taken various forms, using private and public resources to correct what would have resulted in under-investment in technology development and application. A variety of direct cost-sharing and risk reduction means have been used to stimulate industrial firms to invest in massive technological undertakings in transportation, energy, etc. Historically, the R & D and diffusion of innovation needs of the individual family farm units have been well served by direct federal R & D and the establishment of the state and land-grant university system with its research, training, and extension functions. In disaggregated industries such as furniture or textiles, a variety of experimental attempts have been made to aggregate a research effort and to directly support cooperative technology development and application.

At this point a special note must be made of small business. Technology-based new ventures and small business play a uniquely important role in the United States economy in major new product development. Because of their entrepreneurial determination and their organizational flexibility (and ability to respond quickly to a changing environment), small business is believed to be more adept in producing radical innovations than their big business counterparts which are management- and bureaucracy-oriented. Because of the inherently small size and resources of individual "small businesses," federal efforts to directly aid and assist them in a number of ways have become accepted in the Small Business Administration, the National Science Foundation, the Department of Commerce, etc. These ways include increasing the supply of venture capital for technology development, direct support for technology development, technical assistance, etc.

IV. GOVERNMENT SUCCESS STORIES

Direct federal involvement in technological development and application in areas traditionally accepted as being appropriate for government action has resulted in many strong domestic industries which are world leaders in technological and economic performance. These include the following:

Agriculture. The land-grant college-agricultural experiment station system in the United States has made a significant contribution to the success of United States agriculture.

Aircraft. The role of the government in developing United States commercial aviation, starting with the Wright Brothers, is crucial. Without the support of United States mail contracts and the National Advisory Committee on Aeronautics, commercial aviation would have progressed much more slowly.

CAD/CAM. The United States Air Force, in meeting its defense needs, was very important in the development of CAD/CAM, which is now in the forefront of United States manufacturing technology advances.

Semiconductors. The Department of Defense, in its early procurement of semiconductors, provided the initial demand-pull which permitted the amazing growth and development of that industry. The productivity benefits for United States industry from semiconductor advances promises to be barely short of revolutionary. Low cost robotics are but one of the applications which will have a major impact.

Nuclear energy. Nuclear energy would still be in its infancy had not R & D been funded by the government. This technology is simply too expensive and commercially risky for an individual firm to develop. Without federal support this energy source would be largely untapped, or else it might have been implemented largely under foreign license.

Synthetic rubber. Synthetic rubber is an example of direct government-supported research producing a solution to the need for a stable raw material source.

It has been often stated that the federal government has only been successful in influencing technology development and application when it was the sole or primary user, but this is too simple a view of the federal role. The government has made major contributions to stimulating commercial technology development and application in a number of ways—e.g.,

> ...*in* Creating or Guaranteeing an Initial Demand *(as it did for 100 octane gas, synthetic rubber, computers, and cargo aircraft)*; Breaking Down Bottlenecks *(as it did for synthetic rubber and catalytic cracking programs by eliminating barriers of secrecy, antitrust, transportation, and investment funds)*; Aggregating Demand *(as it did in setting sanitation, food contamination, commercial broadcast, or waste disposal standards or in purchasing super highways, waste disposal systems, airports, etc.)*; Aggregating Resources *(as it did through the Highway Trust Fund or when it allowed EPRI or Bell Laboratories to collect a mill rate on energy production or telephone calls)*; Extending Time Horizons *(as it did in setting the 27½ mpg fleet mileage standards for 1985 automobiles)*; Taking Unusual Risks *(as it did in underwriting prototypes and alternative technolgies in the synthetic rubber and catalytic cracking programs)*; Providing Incentives *(as it often has done in allowing greater profits, tax relief, depreciation or depletion allowances, etc. in priority end-use areas)*. (12)

V. NEW REALITIES

Although a direct federal role in some forms of technology development and application can be justified under the arguments and conditions discussed above, the world has fundamentally changed in the past decade in ways which affect this role. There are new realities which relate to the problems which United States industry is having in remaining technologically competitive internationally, and which have been used to justify an expanded role for the federal government in the industrial innovation process. Chief among these are the direct roles that foreign governments—

United States competitors—are playing in industrial innovation.

Although the classic free market system governing domestic and international economic transactions has never been entirely "free," there is a growing realization that the rules of the international economic game in the Western World have fundamentally changed. The governments of major developed countries in the West are playing a more significant role in their national technological development and industrial performance which directly affects the competitiveness of their products vis-a-vis the United States. (In addition, the governments of resource-rich developing countries in OPEC have organized a cartel which has artificially, in the free market sense, raised the prices of petroleum fifteen to twenty times what they were less than a decade ago.)

The prototype of the direct governmental role in national technology development and industrial performance is Japan, although European governments are also acting in a similar fashion. The essential element in this expanded governmental role is that the government analyzes the nation's industrial position in the world and then develops a national strategy to achieve national objectives concerning growth, exports, quality of life, etc. This is not detailed economic planning in the socialistic or communistic sense, but a collective means to organize, focus, and guide an otherwise diffused national effort.

An analysis of the recent Japanese "Trade and Industrial Policy Vision for the 1980s" is instructive (13). The Japanese do not draw back from identifying and selecting specific areas of technology and specific industries on which to focus government attention and resources. They do not avoid the reality of international factor prices and comparative advantages; some industries must decline or be restructured—this can happen in an orderly fashion when forecasts and early decisions provide enough time to make adjustments and a national strategy exists for doing so. But specific lead industries and technologies with high leverage for the entire economy, which take advantage of Japan's strength in technology and people and address Japan's weaknesses in energy and natural resources, are proposed for direct governmental support and promotion.

The successes that foreign governments—not only Japan—have had in promoting technological and industry performance have persuaded some to question the notion that the market system will automatically continue to provide satisfactory solutions to U.S. international economic problems. Japan's success in this area, however, should not be considered apart from the important elements of their society and culture that help to make such policies work, and does not mean that the United States should copy what Japan and other foreign governments do. Rather, the United States can learn from the experience of other countries and, in any event, must somehow deal with the reality of the direct involvement of foreign governments in the international economic system.

Other new realities include the importance of international trade and changing conditions in the macroeconomic environment. The existence and importance of OPEC in the pricing of petroleum and the resultant impacts on the United States economy, particularly on the balance of trade, need no further emphasis here. Other countries have understood for some time the importance of being able to export enough goods and services in order to be able to pay for what must be imported. Above and beyond the real needs of individual consumers for energy, there is a collective, public good at stake—i.e., keeping the national economy going is in the national interest economically and socially. Traditionally, United States companies have depended upon the large domestic market and have not had to worry much about exports.

Under these new conditions, the federal government may have to take a more direct role in international trade. Deficits in the United States balance of trade stem from an inadequate capability to develop and exploit comparative advantages with trading partners. In addition to assisting industries with established export potential to expand their foreign markets, the government might consider assisting in the development of new, technology-intensive products for export, in order to more fully exploit our demonstrated comparative advantage in this area. These exports would pay for the energy and raw materials that must be imported. In addition, of course, technology development and application to reduce the dependence on these imports, and to meet the domestic market demand with competitive United States manufactured products, is to the national advantage and may be essential for national security.

The macroeconomic environment in the United States is crucial in several ways to R & D, innovation, and international competitiveness.

> *Expectations of continuous and real* growth *strongly stimulate innovation. Expanding markets are very forgiving and decrease the actual (and perceived) risks always involved in innovation. More rapid growth stimulates both larger scale innovation and selected demands. As total demand grows, small niches appear for highly specialized solutions. Innovations satisfying these specialized demands frequently become economic for wider applications, creating whole new industries and fueling further innovation and growth. Growth also eases the problems of substituting new innovative industries for old maturing industries. Such substitution is essential to free the economy from dependence on tasks which might be more appropriately performed in more labor intensive economies abroad. This encourages a more modern, competitive investment base and new products for export to the world. Expected demand tends to precede technological development. Consequently, expected continued growth should stimulate innovation on a broad front.*
>
> *As the* price of money *increases, longer-term investment projects in the private sector are discriminated against, particularly R & D, radical product innovations requiring long entry times, and innovative plant facilities facing potentially long legal or regulatory delays. Many published articles attest to the shift in industry toward short-payoff marketing gimmicks rather than toward longer-term innovative and facilities investments. Since money prices are reflected through the prime interest rate, increased*

> *debt prices drive down stock price/earning multiples. Higher money prices for entrepreneurs and small businesses become major barriers to start-up and development of new enterprises. This discourages the innovativeness which has traditionally come from small businesses and their capacity to pressure large enterprises to innovate. The combination creates a strong downward pressure on total innovation and productivity in the U.S....*
>
> *Anticipated* inflation *increases the price of debt with the consequences noted above. Inflation's other impacts on innovation and productivity are less obvious but equally damaging. Tax and accounting practices only allow depreciation on capital assets, based upon their original cost. Competitive pressures therefore cause pricing decisions to lag behind the real capital flows needed to replace existing assets at their inflated prices. The combination means that many businesses and industries, instead of building or modernizing capital assets, are actually living off past capital. While some would argue that inflation and 'Generally Accepted Accounting Practices' allow companies to recover low current dollar investments with inflated future prices, the effects on internal cost-of-capital 'hurdle rates' and the perceived uncertainty of any long-term investment force most businessmen to the opposite conclusion...* (12)

From the data, it is clear that the *stock of capital* per worker in the United States has been growing more slowly than in most other countries. The reasons for this are very complex, and involve factors such as the restructuring of the United States economy, over time, away from manufacturing and toward less capital intensive services. Several factors are at work here. Deficit spending by government, although it is not a large percentage of the total gross national product (GNP), is a very significant percentage of gross capital formation. This increases uncertainties for innovators and places added pressures on the capital market.

The United States *savings rate* (personal income as a percentage of disposable income) has dropped from a long-term trend of around 6 percent to as low as 3.4 percent during late 1979 and early 1980.

This shift has simultaneously increased demand for short-lived consumer goods and decreased the availability of capital for other purposes. The result of all of these factors has been less investments made in longer-term industrial innovation and productivity activities.

Private industry has, as its goal, the maximization of profits and/or market shares. Technological innovation options compete with alternatives such as expanding capacity without altering technology, product diversification, increased marketing effort, acquisition of other firms, either forward or backward integration, debt reduction or stock repurchase, etc. Increasing industrial management investments in technological innovation thus requires developments which alter their perception of the risk-return ratios offered. In some instances, corporate management has even preferred to invest in short-term money markets or real estate rather than technology development and application.

Generally speaking the high interest rates, produced by rising inflationary pressures over the past few years, have been a major deterrent to investment in longer-term technological innovation. At a discount rate of 15 percent, the net present value of returns available in four years would be reduced by about one-half. Many new production facilities, including large scale mines, electric power plants, petroleum refineries, aluminum plants, and integrated steel mills require 5 to 10 years before they yield significant profits. Thus, management's tendency to focus on shorter-term projects and incremental technological improvements may be seen as a practical response to its operating environment. The growing pressures on money managers in capital markets for short-term gains have also been transmitted to corporate management. An example in *Forbes Magazine* (January 9, 1979), documents the experience of one corporate executive addressing a meeting of security analysts. He stated that if he were to announce a development project that would double his corporation's earnings in two years, but would reduce earnings over the next three quarters, he would expect the security analysts to recommend the immediate sale of the company's stock. His expectation was confirmed by the security analysts.

As described above, the recent macroeconomic environment in the United States has not provided a very favorable climate for industrial R & D or innovation. Macroeconomic policies are, of course, traditionally accepted as appropriate functions of the federal government, and the new administration has made this area its number one domestic priority. More will be said about this later.

VI. PERSONAL OBSERVATIONS

The following are personal observations on how the government role for the support of R & D evolved in the United States over the past few years. In the previous administration, the above cases of market imperfections or failures were extended and adapted to include a number of new situations which were thought to merit federal action.*

The first of these situations can occur in emerging or technologically dynamic industries where the basic pattern for industrial support of R & D consists of firms plowing back a significant share of their profits from sales into further R & D, and where that plowback is dependent upon current profits. If the technological potential for further breakthroughs is increasing more rapidly than present profit growth allows for, and if foreign governments are filling this gap with respect to their own industry, then in competitive environments there may be an under-investment in R & D. (This assumes that technological

I am indebted to Dr. Francis Wolek, Deputy Assistant Secretary for Science and Technology, United States Department of Commerce, for the identification and clarification of the issues discussed in Section VI of this paper.

leadership in a given commercial field is viewed to be in the national interest.) An example of this kind of situation would be the merchant house segment of the semiconductor industry.

A second situation can occur in industries where most of the innovation traditionally comes from supplier firms: equipment manufacturers or materials producers. In many cases, these supplier firms are small relative to the size of their customers. Although they will introduce incremental product and/or process innovations, these supplier firms are much less likely to engage in developing radical, new technologies that would result in industry breakthroughs, knowing that such developments would only disrupt—and might even threaten the existence of—their individual customers. As a result, much work remains to be done on promising new technologies, such as blow molded apparel.

A third situation occurs where very eclectic technologies, which have been around for decades or longer, are applied in or cut across many industries. In some of these technological areas, e.g., welding and joining, the industry structure in both the supply and applications sides is not conducive to the performance of R & D. The supply side firms are not integrated as the "welding industry," but exist as small independent producers of welding equipment, welding materials, etc., while the industries in which welding technology is used could appropriate only a small portion of any benefits that would result from R & D in this field.

Finally, there are a few industries in which, although there may be a few large competing companies, there is a single, very large firm which dominates the domestic industry—for example, computers, telecommunications, and automobiles. Without penalizing the legitimate results of past and present commercial success, which are reflected in growth, and without foregoing the advantages that size brings to international competition, it is still important to point out that the healthy aspects of dynamic market competition may not be operating perfectly in these situations.

Some of the practical problems of implementation that have been observed in attempting to address some of these situations mentioned above will now be discussed. In doing so, consideration will be given to both the budget process in the federal government, particularly the changing relationships between the Office of Management and Budget (OMB) and mission agencies, and problems that occur when government attempts to work cooperatively with industry.

Prior to the Carter Administration, the federal budget process was based on justification of and negotiations concerning the incremental increase over the previous year's budget. One of the primary goals of the past few administrations, however, has been to gain more control over the federal budget in order to reduce its size and rate of increase. This has been attempted through the operations of the OMB, which has centralized authority in the executive branch over the budget process.

The Carter Administration introduced the use of zero base budgeting (ZBB) into the budget process in an attempt to reduce expenditures. In ZBB, the entire appropriation—from the "zero base—not just the incremental increase must be justified and negotiated with the OMB.

The details of ZBB implementation in the federal government or its actual or potential effectiveness will not be discussed here. However, although the Carter Administration was unable to balance the federal budget, by the end of the Carter Administration there had been even more of a shift in power from the operating agencies to the OMB. This shift affected R & D budget decisions as well as others. As a result of this change, the burden of proof concerning programmatic and policy decisions for R & D was placed on the mission agencies rather than on OMB. This often took the form of OMB questions, directed to the operating agency, such as, "Why can't you do it the way we think it should be done?" In cases of a difference of opinion between an agency and the OMB, it was very difficult to respond effectively to such questions.

In the new Reagan Administration, of course, the further evolution of budgetary power transfer to the OMB has greatly accelerated—at least for the civilian agencies.

A somewhat surprising aspect of the budgetary process (at least to this author) was its insulation—at least in the absence of a crisis—from the actions of the president. Presidential approval, and even directives for the implementation of policies or the initiation of programs, did not necessarily mean positive action reflected in the federal budget! The budget process would just continue, automatically considering ZBB rankings of agency priority expenditures; either the agency or the OMB could effectively negate the president's expressed wishes—unless the matter was important enough to be brought to his attention.

In order to be successful in R & D budgeting, it is necessary to become expert in both the politics and personalities of the budget process. In the Department of Commerce, this meant starting with the internal Office of Budget, Planning, and Evaluation, and continuing through relationships with the OMB and Congress. Intimate knowledge of the technology and know-how that makes this system work are essential. The only way to overcome this process is political: creating and aggregating a need that the public identifies with and responds to, e.g., national security.

Beyond the implementation problems of the R & D budgetary process, however, are those problems involved in attempting to work cooperatively with industry. In our experience, this has proved to be very, very difficult.

A large portion of United States private industry appears not to be interested in working with the government on significant R & D or technological change. Many in industry tend to think incrementally, with a focus on the improvement of existing technology rather than on major new products or processes that will be internationally competitive in ten to twenty years. As company resources allocated to cooperative efforts tend to be taken from existing R & D budgets, R & D executives, generally, are not supportive. No matter how basic the R & D might have been, it was very difficult to find suitable research areas that some firms were not already working in—or said they were working in—thus automatically disqualifying them from a cooperative effort.

In terms of size of effort, a basic Catch-22 situation existed regarding government credibility—i.e., a small cooperative effort would never be taken seriously by industry; yet the potential of a larger cooperative effort always became a threat to existing institutions, and thus the subject of attack. Complaints of this nature came from major non-profit R & D institutes, from federal laboratories, from universities, from trade associations, as well as from individual companies. Even in technologically backward industries, threatened by foreign competition, leading companies did not want the general technical level of the industry raised as it might reduce their advantage over domestic competitors. When there was industry support for cooperation, it often became apparent that industry had its own political objectives in mind—usually tax breaks and regulatory relief. There was also a significant problem in the government staffing a cooperative effort of any substantial size.

Thus, although a few cooperative efforts between government and industry have proven, under special conditions, to be successful in other countries, there are many practical problems to such endeavors in the United States.

VII. THE NEWEST "NEW REALITY"

The newest "new reality," of course, took effect January 20, 1981 with the inauguration of the Reagan Administration. Although this paper does not speak for the administration or its policies, the general policies and directions of the new administration as they relate to this discussion are fairly clear.

This administration will not generally accept the notion of market imperfections or failures as they relate to direct federal involvement in the commercial stages of technology development. It is clear that the reliance for international technological competitiveness of United States industry will be placed on the private sector and the free market.

It is also clear that the major domestic priorities of this administration will focus on macroeconomic policies that are designed to stimulate United States industry. Major attempts to spur economic growth and decrease inflation are underway—significant federal budget cuts and tax breaks that have been enacted into law—including accelerated depreciation and tax credits for R & D. A major effort is also being made to reduce the federal regulatory burden placed on industry. Micro-policies aimed at assisting or supporting specific industry sectors in any way will not generally be utilized.

On the other hand, the more traditional forms of government support for R & D appear to be accepted, albeit within a general policy of tight budget constraints. Notwithstanding extreme proposals by economist Milton Friedman, basic research in the National Science Foundation has not been severely cut back; R & D budgets for defense related purposes have been greatly increased; in general, commercialization activities on the "D" end of the R & D spectrum and ancillary activities have been reduced or even eliminated, but research has emerged relatively unscathed.

Research on atomic energy is one exception to this general rule, in which federal technology development and commercialization activities are not being significantly reduced. National security may also present an acceptable rationale in the future for a further federal role in the technological upgrading of our national industrial base. The only certain reality may be that things will change.

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