Chapter 7

Foreign Information Technology Research and Development

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International Trends in Information Technology Research and Development

Several trends demonstrate that the United States is experiencing greater international interdependence in the area of information technology research and development. They include: 1) the large and growing world market for computer and communications products; 2) the increasing adaptation of information technology products and standards for international markets; 3) the growing number of multinational information technology firms; 4) the increasing number of international technology exchange agreements; 5) the increasing percentage of U.S. information technology-related patents granted for foreign inventions; 6) the greater utilization of foreign contributions in U.S. scientific and technical journals; 7) and the growing number of foreign students enrolled in technical and scientific programs at U.S. universities.

These trends indicate two significant factors, both of which make foreign organization and activities relevant to U.S. R&D efforts. First, they indicate a growing number of links between other nations' R&D efforts and those of the United States. Second, these trends point to a growing participation of foreign nations in information technology innovation and markets, which has led to a relative decline in the U.S. market share. Thus, the United States, which in the past has developed policies for its internal markets that were largely unaffected by foreign manufacturers, may now need to take greater account of foreign information technology research and development efforts.

International Trade

World trade in computer products is growing rapidly. For each of the major supplier nations, overseas shipments are a steadily rising share of both total output and consumption. Table 28 shows this trend towards a glo-

Table 28.—Computer Production and Apparent Domestic Consumption[a] of Six Leading Supplier Nations

	1982 production ($ million)	Percent change 1981-82	1982 ADC[a] ($ million)	Percent change 1981-82
United States	$33,550[b]	12.30/o	$26,888	15.3'%0
Japan	7,179[c]	21.0	6,276	10.2
France	3,834[d]	–5.0	4,720	8.4
West Germany	3,511	7.5	3,789	5.3
United Kingdom	1,929[d]	11.8	2,898	NA
Italy	1,076	11.0	1,343	3.2
Total	$51,079	10.80/0	$45,914	NA
Estimated share of world total (percent)	*89*		*80*	

[a] Apparent Domestic Consumption (ADC) is production minus exports plus imports

[b] Estimated by Bureau of Industrial Economics

[c] Does not Include parts

‘Preliminary.

SOURCE U S *Industrial Outlook*, 1984, Bureau of Industrial Economics, U.S Department of Commerce, 1984 bal computer market as it has evolved over the last few years, and figure 35 illustrates major sources and destinations. This trend results in part from the rapid rise in demand for computer-related products in the developing world, a steady demand in traditional markets for products that incorporate information technology, and increasing overseas activities of multinational subsidiaries.[1]

For the United States, increased global participation in the information technology market has meant a rapid rise in imports and a decreasing world market share. During the period 1978-82, U.S. imports of computers and computer-related products rose by approximately 30 percent. (See table 29.)

The telecommunications market is also becoming internationalized as equipment manufacturers look beyond maintaining traditional markets (the national telecommunications service monopolies, or PTTs) toward expanding international trade.[2] Table 30 illustrates this trend and summarizes the current positions of the United States, the United Kingdom, France, and Japan.

The internationalization of the telecommunications market, as in the case of the computer market, has weakened the relative U.S. position in telecommunications trade. Although U.S. exports have increased at a rate of 13 to 18 percent per year, a continuing increase in foreign imports (24 to 30 percent a year) has diminished the U.S. trade surplus (table 31). Japan supplied about 50 percent of U.S. imports, resulting in a U.S. trade deficit with Japan of $250 million (figs. 36 and 37).[3]

Adaptations of Technology for International Markets

The growing international trade in information technology products has led to increased efforts to develop international standards for information technology products in order to allow access to foreign markets and to allow interconnections of services. For example, following a recent meeting of the Commission of European PTTs (CEPT), European countries agreed to develop technical standards not only for basic equipment such as telephone handsets, but also for videotex systems and other sophisticated data communications systems. The CEPT program will also suggest other areas where national telecommunications practices might be standardized. This could eventually lead to a unified European network of approximately 400 million subscribers. The European Program for Research and Development in Information Technology (ESPRIT) has a group working on international standards specifically designed to enable various European-manufactured products to communicate with each other.

In markets where standards do not exist, information technology products, such as computer software, must be tailored for international sale. Because personal computer hardware has proliferated worldwide without a parallel growth of indigenous software companies, many American software companies are developing products for the international market.

For example, Lotus Development Corp. has been tailoring its software packages to the language and idioms of other nations. The Lotus International Character Set enables the program to generate different currency signs and different versions of international day and date displays. Although the cost of converting programs for international markets can be quite high, Lotus Corp. reportedly believes that the return on its investment will also be substantial. They expect that international sales will eventually generate between 30 and 40 percent of the company's income.[4]

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[1] *High Technology Industries: Profiles and Outlooks: The Computer Industry,* **U.S. Department of Commerce, International Trade Administration, 1983, p. 22.**

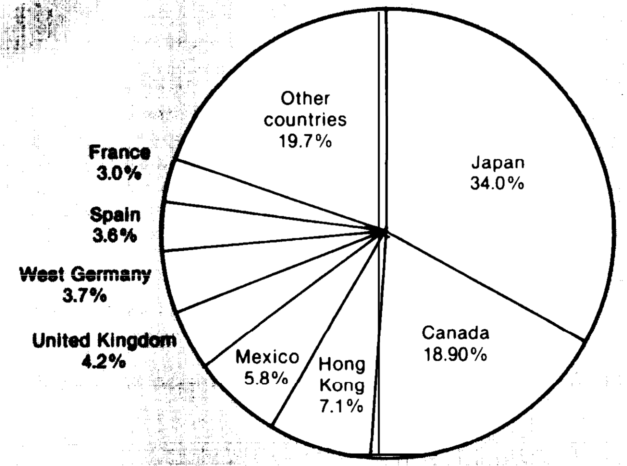
[2] *High Technology Industries: Profiles and Outlooks, The Telecommunications Industry,* **U.S. Department of Commerce, International Trade Administration, 1983, p. 18.**

[3] **Although the French, the British, and the Japanese are increasing their participation in information technology markets, particularly in the computers and telecommunications areas, the degree to which this trend is linked to information technology R&D remains unknown. The traditional skills needed for success in the marketplace range from basic research, to applied R&D, to production and distribution, and to marketing skills; it is therefore difficult to attribute success in the marketplace solely to R&D efforts or to any other single factor. See ch. 2 for a more complete discussion.**

[4] **Michael Schrage, "Firms See Boom in Software,"** *The Washington Post,* **Mar. 4, 1984, p. H, 4.**

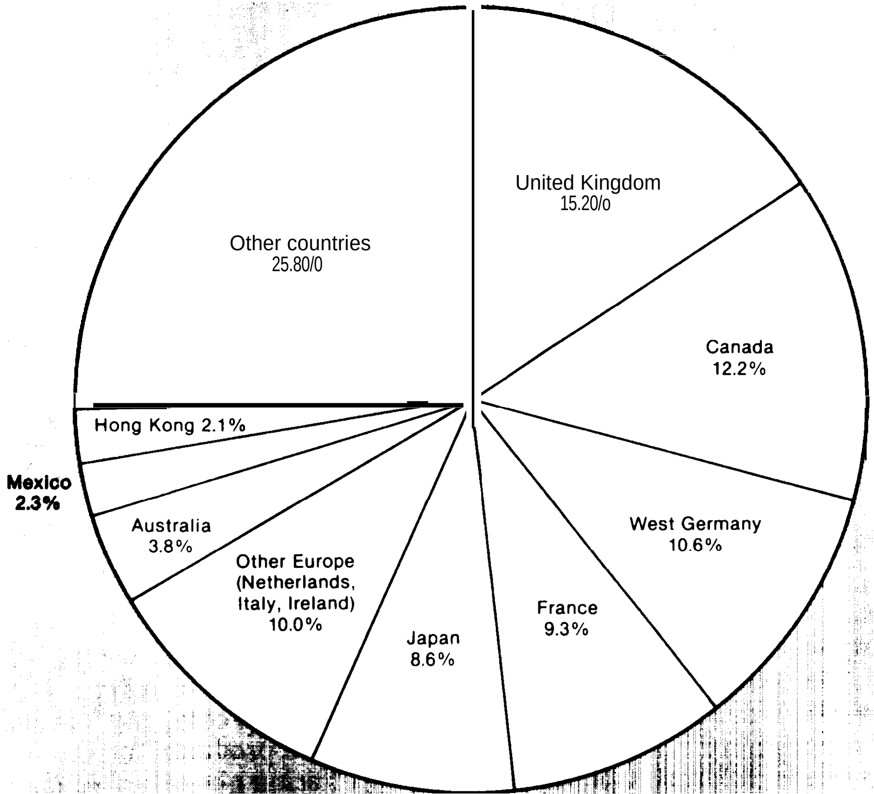
Figure 35.—U.S. Computer Trade (SIC 3573) Imports by Source; Exports by Destination

Shares of U.S. Imports (1982)



Total value of 1982 Imports: $2.14 billion (SIC 3573 only)

U.S. Export shares, by destination (1982)



Total value of 1982 Exports: $9.04 billion (SIC 3573 only)

NOTE: SIC 3573 includes: Computing equipment (equipment, peripherals, and services).

SOURCE: High Technology *Industries: Profiles and Outlooks: The* Computer *Industry,* International Trade Administration, U.S. Department of Commerce, 1983.

Table 29.—U.S. Computer Trade @W 3573): Origins and Destinations, Flow Value, and Annual Growth 1981-82, percent of value) (millions of U.S. dollars)

1982 Imports		
Japan	$ 729	(+88.20/o)
Canada	404	(+ 0.0%)
Hong Kong	151	(–21.60/o)
Mexico	123	(+27.00/o)
United Kingdom	90	(+ 12.2%)
West Germany	79	(+12.90/o)
Spain	78	(+25.3%)
France	64	(– 2.6%)
Total	$2,140	(+29.9%)

United States	Imports	Exports
1978	$ 755	$4,194
1981	1,646	8,493
1982	2,295	8,957
1983	4,100	10,300
1984	6,470	12,360
Growth (1978-82) .	+29.8%	+21.2`%

1982 Exports		
United Kingdom	$1,374	(+15.3%)
Canada	1,103	(–11.2%)
West Germany	958	(– 6.20/o)
France ., ...	841	(+ 7.0%)
Japan	777	(+ 8.30/o)
Netherlands	380	(+ 14.0%)
Australia.	344	(+ 0.0%)
Italy.	298	(– 4.1%)
Total	$9,040	(+ 4.5%)

NOTE: SIC Code 3573 includes: Computing equipment (equipment, peripherals, and services).

SOURCE: *H/gh Techrro/ogy /mWstr/es: Profiles arrd Outlooks: The Computer Industry,* International Trade Administration, U.S. Department of Commerce, 1983.

Table 30.–World Trade in Telecommunications Equipment (SIC 3661) (millions of U.S. dollars)

	1977			1981		
Principal producer countries	Imports	Exports	Balance	Imports	Exports	Balance
Japan	**$ 24**	**$ 363**	**+$ 339**	**$46**	**$ 911**	**+$ 665**
Sweden	36	458	+422	65	776	+71 1
West Germany	104	562	+458	128	809	+681
Netherlands.	126	228	+ 102	128	398	+270
France	57	168	+111	86	320	+234
United States	129	257	+ 128	494	653	+ 159
Canada	93	80	–13	143	298	+ 155
United Kingdom	91	247	+ 156	235	331	+96
Belgium/Luxembourg	76	248	+ 172	118	262	+ 144
Italy	50	97	+47	101	143	+42
Total	786	2,708	+ 1,922	1,544	4,901	+3,357

NOTE: SIC Code 3881 includes: Telephone and telegraph apparatus.

SOURCE: *High Tec/rno/ogy hrdusfries: Prof//es and Outlooks: The Telecommunications Industry,* International Trade Administration, U.S. Department of Commerce, 1983.

Table 31.–Aggregate Trends in U.S. Telecommunications Equipment Trade (SIC 3661) (millions of U.S. dollars)

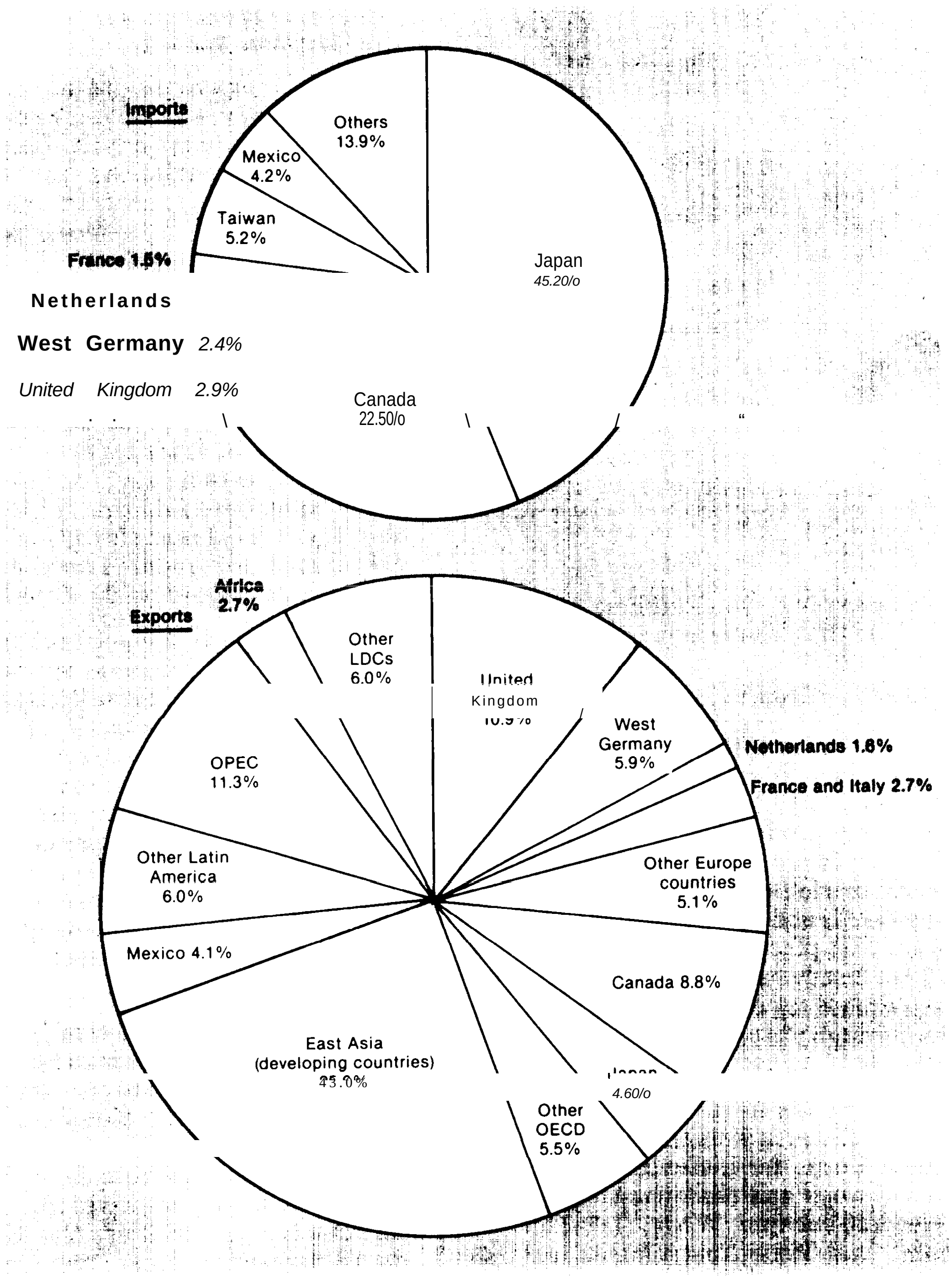
	1972	1977	1979	1980	1981	1982	1893	1977-83 growth rate
Exports	$76	$257	$448	$557	$653	$725	$850	+22.1 “/0
Imports	86	129	319	421	494	635	790	+35.3%
Balance	–10	+ 128	+ 128	+ 136	+159	+90	+60	– 11.1%

NOTE: SIC Code 3881 includes: Telephone and telegraph apparatus.

SOURCE: *U.S. /ndustrla/ Out/ook, 1983,* Bureau of Industrial Economics, U.S. Department of Commerce, 1983.

International marketing is also an important component for Microsoft, a U.S. software company whose overseas market accounted for approximately one-third of its estimated $75 million 1983 revenue. Microsoft already has development operations in Japan and subsidiaries in the United Kingdom, France, and West Germany. Like Lotus, Microsoft has revised many of its software programs for foreign use. The company has closely tailored its software products for the Japanese market by offering phonetic Japanese versions of BASIC, and it has translated its Multiplan program (business applications program) and

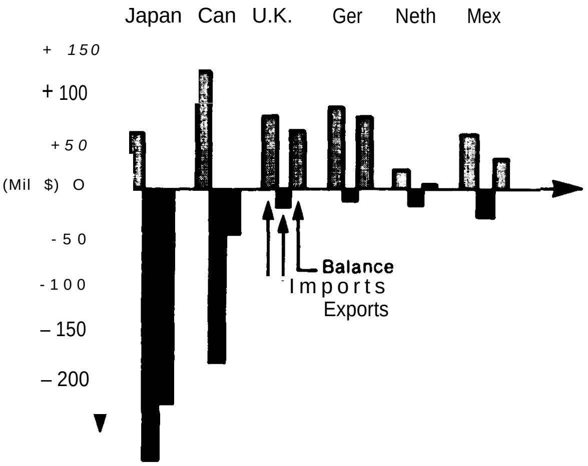
Figure 36.—Sources of U.S. Imports (1982) and Destinations of U.S. Exports (1982) of Telecommunications Equipment (SIC 3661)



NOTE: SIC 3661 includes: Telephone and telegraph apparatus.

SOURCE: *High Technology Industries: Profiles and Outlooks: The Telecommunications Industry,* International Trade Administration, U.S. Department of Commerce, 1983

Figure 37.–U.S. Bilateral Trade Position in Telecommunications with Selected Countries (1981)



SOURCE: *High Technology Industries: Profiles and Outlooks: The Telecommunications Industry,* International Trade Administration, U.S. Department of Commerce, 19S3.

its MSX operating system (home computer program) for the Japanese market.

Multinational Corporations

Rising innovation costs and the accompanying size of financial risks, as well as increasing equipment costs, have intensified the need for expanding production and have forced many manufacturers beyond the limitations of domestic markets. For a variety of reasons including tariffs and other forms of protective legislation that place imported products at a competitive disadvantage, multinational firms have attempted to capture specific foreign markets through the establishment of foreign subsidiaries.

Many U.S. firms have opened production and R&D facilities in foreign nations. Digital Equipment Corp., for instance, operates six plants in Europe and three more in the Far East. Hewlett-Packard, Wang, Data-General, Datapoint, and Texas Instruments are U.S. minicomputer manufacturers that also operate foreign production facilities. Apple Computer has plants in Ireland and Singapore. Amdahl and Trilogy Systems, manufacturers of plug-compatible mainframes, have opened facilities in Ireland, intended in part to supply the Common Market.

Many foreign firms operate subsidiaries in the United States and other foreign countries. For example, Japan's NEC Corp. has established three subsidiaries in the United States and has won major contracts to supply U.S. manufacturers with Japanese technology. In addition, NEC has subsidiaries in Germany, the United Kingdom, and countries in Africa and South America.

This growth of international activity has not only led to increased trade in information technology products, but has also encouraged the performance of R&D by firms in various nations. After establishing foreign subsidiaries, many companies find that R&D is necessary to support local manufacturing when the requirements or standards for the foreign marketplace are significantly different.

U.S. companies are performing an increasing amount of research and development abroad. Since 1975, total R&D conducted by U.S. subsidiaries overseas has more than doubled and in 1981 amounted to $3.2 billion-9 percent of total U.S. private R&D funding. Table 32 illustrates the increasing amount of electronics R&D which is performed abroad by foreign affiliates of U.S. companies. In contrast, in 1979, total expenditures for electronics research and development performed by U.S. affiliates of foreign companies increased to $148 millions

Many governments actively encourage foreign subsidiaries not only to establish production facilities, but also to conduct R&Din their nations. The United Kingdom has, for instance, implemented a series of incentives for foreign firms to innovate. In addition to providing financial incentives for establishing manufacturing facilities, the United Kingdom's Support for Innovation Program (SFI)

'*Science Indicators, 1982,* **National Science Board, National Science Foundation, 1983, p. 25.**

Table 32.—industry R&D Performed Abroad by Foreign Affiliates of U.S. Domestic Companies by Selected Industry: 1975 and 1981
(millions of U.S. dollars)

Industry	1975	1981	Percent increase
Food and kindred products. . .	23	66	187
Chemicals and allied products	269	651	142
Industrial and other chemicals	85	275	124
Drugs and medicines	184	376	104
Stone, clay, and glass products	7	15	114
Primary metals		9	
Fabricated metals.	(a)	26[b]	N—A
Machinery	331	585	77
Electrical equipment	245	455	86
Electronic components	7	47	571
Transportation	412	893	117
Motor vehicles and other transportation equipment .	373	791[b]	112
Aircraft and missiles	39	102[b]	161
Professional and scientific instruments	49	101	106
Other manufacturing industries	105	147	40
Nonmanufacturing industries .	4	12	200
Total … … … … … .. .	$1,454	$3,157	117

[a] Included in the other manufacturing industries group
[b] Estimated
NA—Not available

SOURCE: Science *Indicators,1982*, National Science Board, National Science Foundation, 1963

offers grants of up to 33 1/3 percent towards the cost of significant research and development of high technology products. About 200 information technology firms are located in “Silicon Glen” in Scotland. U.S. firms there include IBM, Honeywell, NCR, Hewlett-Packard, Digital Equipment, and National Semiconductor.

Multinational information technology corporations are also forming cooperative international research and development arrangements. This new type of international arrangement is exemplified by the recent establishment of Europe’s first multinational research institution for information technology. Following an agreement made last September, Europe’s three largest computer manufacturers, France’s Compagnie des Machines Bull SA, Britain’s International Computers Ltd. (ICL), and West Germany’s Siemens AG, will operate a jointly run and jointly financed European Computer Research Centre (ECRC). Located in Munich, close to a number of electronics firms, the ECRC will begin operations with an initial capital investment of $655,000 and a staff of four researchers from the three firms. The number of researchers is expected to reach 30 to 35 by 1985, and approximately 50 within 2 years.

Technology Exchange Agreements

Table 33 illustrates some of the recent technology exchange agreements between U. S., European, and Japanese companies. Such technology exchange is seen by firms as a way to spread the risk in large projects, to enter international markets where politics or national market specifications hinder entry into domestic markets, and to allow competitors to pursue a dominant position in a specific market.[6]

An example of a technology exchange agreement is the reciprocal development and marketing agreement for office telecommunications equipment between AT&T and Ing. C. Olivetti & Co., a major European supplier of office automation equipment. In accordance with this agreement, AT&T will increase its stake in Olivetti over the next 4 years to acquire 25 percent ownership in the company. The arrangement gives AT&T access to Olivetti equipment such as workstations, word processors, typewriters, and data processing systems for domestic marketing. In turn, Olivetti will market AT&T communications controllers for voice, data and networking applications, and a variety of micro-computers.[7]

Other technical partnerships include those of LM Ericsson of Sweden with Honeywell, and Atlantic-Richfield in the United States with Thorn EM I in the United Kingdom. In Italy, Italtel is cooperating with Telettra and the U.S. company GTE in the public switching field. The British firm, ICL, has links with Mitel, and Plessey (another U.K. company),

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[6] “Bulls on Skis,” *The Economist*, Feb. 4, 1984, p. 76.
[7] In addition to its technical exchange agreements with Olivetti, AT&T has also made exchange agreements with Philips.

Table 33.—international Technology Agreements

Sector/partners [a]	Date	Technology	Agreement
Communications:			
Hitachi and *Western Electric*	1981	Communication equipment	Patent exchange—technological agreement
Fujitsu and Ungermann-Bass (CA)	—	Local networks	Industrial and commercial agreement
NTT and *Hughes*	—	Telecommunications by satellite	—
Sperry-Univac and Mitsubishi	—	Local networks and communication and data processing system	Technological agreement
Motorola and NEC	1982	Portable paging systems	Agreement for manufacture and commercialization in Japan
Exxon Office Systems and Mitsubishi	—	Telecommunications equipment	Technological agreement
ATT and Philips	1983	PBX	Commercial agreement
Honeywell and *Ericsson*	1983	Telecommunications and office automation	Technological and commercial agreement
GTE and Italtel	1982	PBX	Technological and commercial agreement
Plessey and Stromberg Carlson	1982	PBX	Purchase of Stromberg-Carlson by Plessey
General Instruments and Thomson	1983	Videocommunication and teledistribution by cable	Technological and commercial agreement
Micro V and Jeumont-Schneider	1982	PBX	Technological and commercial agreement with partial acquisition of Micro V and creation of a joint subsidiary
Data processing:			
Honeywell and *NEC*	1984	Main frame computers	Technological agreement
Exxon Office Systems and Toshiba	—	Office automation	Technological agreement
TRW and *Fujitsu*	—	Data processing	Joint venture now controlled 100 percent by Fujitsu
Sperry and Mitsubishi	1982	Office automation	Technological agreement
Vertimag and Teijin (Osaka)	—	High-density magnetic memory	Technological and commercial agreement
Amdhal and Fujitsu	1982	Computers and peripherals	Take-over by Fujitsu
Drexler Technology and Toshiba	—	Smart card	Technological and industrial agreement
Olivetti and Docutel	1982	Office automation	Control of Docutel by Olivetti
Olivetti and Stratus	1982	Minicomputers	Control of Stratus by Olivetti
Nixdorf and Auragem	1983	Minicomputers	Control of Auragem by Nixdorf
Philips and Micom	1977	Office automation	Purchase by Philips
ATT and Olivetti	1983	Data processing, office automation, communications	ATT acquires 25 percent of Olivetti
Fortune and Thomson	1982	Microcomputers	Thomson acquires 17 percent of Fortune
Tandy Corp. and Matra	1982	Microcomputers	Technological and commercial agreement
Matra and Tymshare	1982	Terminals	Commercial joint venture in the United States
Cii Honeywell Bull and *Trilogy*	1980	Main-frame computers	Technological agreement with Cii Honeywell Bull having minor share in Trilogy
Cii Honeywell Bull and *Honeywell*	—	General data processing	Technological and commercial cooperation
AMD and IBM	—	Computer-aided design	Commercialization by IBM of Catia

Table 33.—International Technology Agreements—continued

Sector/partners[a]	Date	Technology	Agreement
Electronics and components:			
/rite/ and NEC	1982	VLSI microprocessors and circuits	Technological agreement
Texas Instruments and Fujitsu	1979	Integrated circuits	Technological agreement
Hewlett-Packard and Hitachi	—	Integrated circuits	Technological agreement
Western Electric and NTT	—	Integrated circuits	Technological agreement
IBM and NTT	—	Integrated circuits	Technological agreement
Zilog and Toshiba	—	Microprocessors	Technological agreement
Western Digital and Siemens	1982	Integrated circuits	Production and commercial agreement
United Technologies and AEG Telefunken	1982	Custom-made semiconductors	Production and commercial agreement
Philips and Signetics	1975	Components	Purchase by Philips
Philips and Magnavox	1977	Consumer electronics	Take-over by Philips
Philips and Sylvania	1980	Consumer electronics and tubes	Purchase by Philips
GCA and Matra	1982	Microelectronic equipment	Technological and commercial agreement
Harris and Matra	1981	Components and integrated circuits	Technological, industrial, and commercial agreement
Motorola and Thomson	1978	Components and integrated circuits	Technological, industrial, and commercial agreement
/rite/ and Matra	1981	Integrated circuits	Technological, industrial, and commercial agreement
Thomson and *RCA*	1971	Color tubes	Technological agreement
Rhone-Poulnec and *Siltec*	1983	Silicon	Joint venture
Rhone-Poulnec and Dysan	—	Magnetic disks	Technological agreement
Sagem and Motorola	—	Bubble memories	Technological agreement
Thomson and Diasonic	1983	Medical instrumentation	Technological and commercial agreement

[a] The technologically dominant partner is italicized.

SOURCE: Office of Technology Assessment. Compiled from *Research and Development In Electronics.' USA-France, 1982/7983,* French Telecommunications Council, 1984.

now owns Stromberg-Carlson. In addition, France and the United States have arranged joint ventures whereby American semiconductor firms have exchanged technical know-how for access to the French markets-particularly to the French telecommunications market (normally well protected by the French PTT). These joint ventures in which the French partners hold controlling interests include Thomson and Motorola, Saint-Gobain and National Semiconductor (in a firm named Eurotechnique), and Matra and Harris.

U.S. companies also have technical exchange agreements and other business relationships with Japanese firms. Intel Corp., for example, has a 5-year cross-licensing, cross-compatibility, and technology exchange agreement primarily in the area of controllers and peripheral equipment with NEC Corp. Amdahl Corp. currently uses a semiconductor chip developed and manufactured by Fujitsu in its U.S.-manufactured computers. Moreover, when Amdahl had difficulties raising capital for expansion, Fujitsu bought 40 percent of Amdahl Although Amdahl might have been sold to another American firm, Amdahl management preferred to sell its stock to Fujitsu in order to facilitate technology exchange agreements, which involve cross-licensing, financing, and information exchange.[8] Fujitsu Ltd. has also recently agreed to supply Texas Instruments with gate array technical know-how; Texas Instruments will produce the Japanese gate arrays and ship them back to Fujitsu.

Other joint technical agreements between American and Japanese information technology firms include Sperry's high technology cooperative agreement with Mitsubishi, which covers joint activities in manufacturing, re-

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[8] Patricia Keefe, “Many U.S. Firms Have Japanese Ties, ” *ComputerWorld,* May 2, 1983, p. 73.

search and development, and marketing of computer systems. Mitsubishi also has a joint agreement with IPL Systems to develop an IBM-compatible processor. The technical exchange agreement between the two firms combines Mitsubishi's” computer-aided design and large scale integration technology with IPL's design expertise. Under the agreement, both firms are granted the right to market the jointly developed products. Mitsubishi and Westinghouse have also arranged a joint venture to design and manufacture integrated circuits. In addition to technical exchange agree ments between private firms, the U.S. Department of Defense encourages Japan to transfer defense-related electronics technologies to the United States. In 1981, for example, the U.S. Government asked Japan to provide advanced very large scale integration (VLSI) technology to enhance air and antisubmarine defense capabilities.

Patents

A large number of U.S. patents are granted to foreign individuals and corporations (see table 34). Foreign patenting activity in the United States has been related both to increased foreign inventive activity and to a growing interest in the U.S. information technology market. Moreover, studies have shown that foreign patenting activity in the United States by selected OECD countries correlates significantly with industrial R&D in those countries. This correlation is especially high in the electrical and electronics industries.[9]

Foreign patenting in the communication equipment and electronic components category was as much as 40 percent of the total number of U.S. patents granted during 1979-81, while the percentage of U.S. owned foreign patents in the same category was 13 percent.[10]

Table 34.-Number of U.S. Patents Granted to Selected Foreign Countries” in All Product Fields and in Communications Equipment and Electronic Components (1963-81)

Country of inventor	All fields	Communications equipment and electronic components
United States	865,124	101,914
Foreign	369,519	41,242
West Germany	91,359	7,850
Japan	77,450	13,013
United Kingdom	51,138	5,976
France	35,244	4,455
Switzerland	21,622	1,258
Canada	20,241	1,773
Sweden	13,368	1,007
Italy	11,958	847
Netherlands	11,103	2,701 [b]
U.S.S.R.	5,111	454
Belgium	4,459	360
Austria	4,080	273
Australia	3,585	198
Denmark	2,520	161
Mexico	1,075	21
Other foreign[c]	15,206	895
Total	1,234,643	143,156

[a] Countries were selected on the basis of being in the top 10 of at least one of the Standard Industrial Classifications.

[b] Indicates ranking among the top five foreign countries in this particular Product field.

[c] Other foreign includes patents granted to foreign countries not shown separately.

SOURCES: Office of Technology Assessment; compiled from information in Office of Technology Assessment and Forecast, U.S. Patent and Trademark Office, *Indicators of the Patent Output of U.S. Industry IV (1963-81)*, 1982; in Science *Indicators*, 1982, National Science Board, National Science Foundation, 19S3,

Table 35 and figure 38 show that Japan has the largest number of foreign U.S. patents in communications equipment and electronic components, although West Germany had been the foreign leader in this field throughout the 1960s and mid-1970s. Since 1970, Japan has doubled its patent activity in communications equipment and electronic compnents, food and kindred products, primary metals, and professional and scientific instruments.[11] Data for the period 1970-81, presented in table 36, show that the percentage of U.S. patents in information technology areas decreased more than 20 percent while the Japanese share of U.S. patents increased by over 2oo percent.[12]

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[9] Keith Pavitt, "Using Patent Statistics in Science Indicators: Possibilities and Problems, " *The Meaning of Patent Statistics*, National Science Foundation, 1979.

[10] The fields that have relatively high percentages of U. S.-owned foreign patents are the areas corresponding to U.S. direct investment and research activity abroad. It is possible that U.S. laboratories abroad supported R&D that resulted in patented innovations. *Science Indicators, 1982*, National Science Board, National Science Foundation, 1983, p. 14.

*'*Science Indicators, 1980,* National Science Board, National Science Foundation, 1981, p. 21.

[12] The Office of Technology Assessment and Forecast, U.S. Patent and Trademark Office.

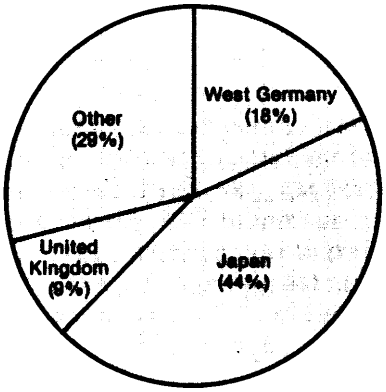
Table 35.—Share of Foreign Patenting in the United States for the Three Most Active Countries by Selected Product Fields (1981)

Product field	Total foreign	West Germany	Japan	United Kingdom	Other foreign
			Percent of foreign		
Chemicals, except drugs and medicines	100	28	27	11	34
Drugs and medicines	100	23	22	14	40
Nonelectrical machinery	100	26	27	9	38
Electrical equipment, except communications equipment	100	21	37	8	34
Communications equipment and electronic components	100	18	44	9	29
Motor vehicles and other equipment except aircraft	100	26	34	9	31
Aircraft and parts	100	28	42	10	21
Professional and scientific instruments	100	22	43	8	27
			Number of patents		
Chemicals, except drugs and medicines	5,338	1,520	1,452	566	1,800
Drugs and medicines	1,288	300	288	182	518
Nonelectrical machinery	8,166	2,088	2,240	731	3,107
Electrical equipment, except communications equipment	2,541	535	952	202	852
Communications equipment and electronic components	3.027	534	1,338	279	876
Motor vehicles and other transportation equipment except aircraft	1,652	429	563	151	509
Aircraft and parts	777	216	323	75	163
Professional and scientific instruments	4,100	892	1,760	329	1,119

SOURCE: Office of Technology Assessment and Forecast, U S Patent and Trademark Office, *Indicators of Patent Output of U.S Industry (1%53-81); in Science Indicators, 1982,* National Science Board, National Science Foundation, 1983.

Figure 38.—Share of Foreign Patenting in the United states for the Three Most Active Countries (1981)

Communications equipment and electronic components



SOURCE. *Science Indicators,1982,* National Science Board, National Science Foundation, 1983

While the foreign patenting activity in the United States has been increasing, U.S. patent activity abroad has been decreasing over the past decade. Over the past 10 years, the U.S. proportion of foreign patents decreased from 45 to 37 percent in the United Kingdom and from 32 to 28 percent in France. Overall, from 1971 to 1981, U.S. patenting in Canada, Japan, and in the European Economic Community declined approximately 40 percent.

Scientific and Technical Literature

U.S. utilization of foreign engineering and technical literature is growing. Between 1973 and 1980, U.S. citations of foreign research findings in engineering and technology fields increased by 4 percentage points and by 7 percentage points in the field of mathematics. Although the U.S. utilization of foreign research has grown, U.S. use of foreign research literature is lower than other nations' use of foreign research literature.[14]

The number of jointly authored articles by scientists and engineers from different coun-

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[13] *Science Indicators, 1982,* National Science Board, National Science Foundation 1983, p. 15.

[14] Ibid, p. 12.

Table 36.—U.S..Owned and Foreign-Owned U.S. Patents in Information Technologies[a]

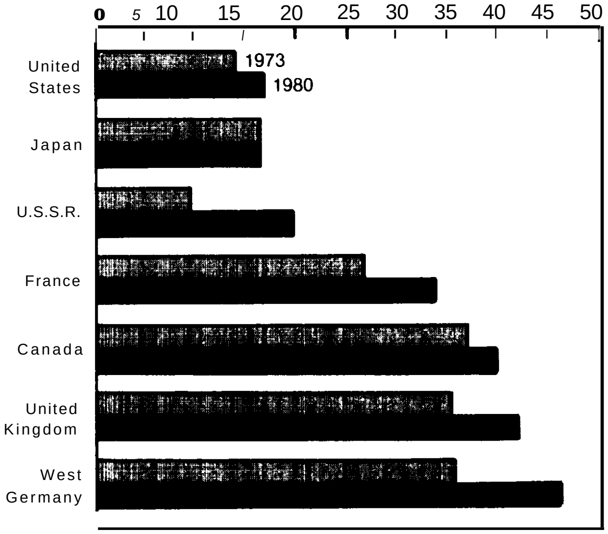
U.S. patent ownership	Percent ownership 1970	Percent ownership 1981	Percent change
United States	76	58	–23.7
Japan	6	19	+216
United Kingdom	4	4	0
France	3	4	+33
West Germany	5	8	+60

[a] Information technologies included here comprise SIC 357—Office computing and accounting machines; and SIC 365-367—communications equipment and electronic components.

SOURCE: The Office of Technology Assessment and Forecast, U.S. Patent and Trademark Office. Information technology numbers were calculated from data developed under the support of the National Science Foundation, Science Indicators Unit.

Figure 39.—index' of International Cooperative Research by Country

(Percent)



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

NOTE: Based on the articles, notes, and reviews in over 2,100 of the influential journals carried on the 1973 *Science Citation Index* Corporate Tapes of the Institute for Scientific Information.

SOURCE: Science *Indicators, 1982,* National Science Board, National Science Foundation, 1963.

tries is also increasing. International coauthored engineering and technology-related articles as a percentage of institutionally coauthored articles have risen from 13 percent in 1973 to 16 percent in 1980. In 1980, more than 40 percent of all jointly authored articles in mathematics were international collaborative efforts.[16] Moreover, the United Kingdom, France, and West Germany had a greater percentage of internationally co-authored articles (as a percentage of all institutionally co-authored articles) than the United States. Japan and the United States had the lowest percentages of internationally co-authored articles. (See figure 39.)

Science and Engineering Students

The number of foreign students in scientific and technical fields in U.S. universities is increasing. In mathematics and computer science the number of foreign students enrolled in U.S. universities was 22,620 in 1981 -82.[16] (See table 37.) Table 38 illustrates the large proportion of doctoral degrees awarded to foreign students in mathematics and computer science during 1981. In 1982 non-U.S. citizens were awarded 38 percent of the 542 doctorates in electronics and electrical engineering and 54 percent of the 72 doctorates in computer science.[17] Although some of the foreign engineering and mathematics students choose to remain in the United States (if permitted), a large number of them return to their native countries.

Although the number of foreign graduate science and technology students in U.S. universities has been increasing, the number of U.S. students enrolled in technical programs at foreign universities has been decreasing. The number and percent of U.S. graduate students studying abroad was highest during 1971, but now only constitutes about 1 percent of U.S. graduate students.[18] The decline of U.S. graduate students studying in foreign universities could be attributed to employment considerations and cost of living differences. Currently, as other industrialized nations' technical capabilities improve, the low number of graduate students abroad could inhibit the U.S. ability to keep abreast of the latest foreign research methods and developments.

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[15] Ibid, p. 31.

[16] *Science Indicators, 1980,* National Science Bored, National Science Foundation, 1981, p. 240.

[17] " Washington Newsletter,"*Electronics,* Jan. 12, 1984, p. 70.

[18] *Science* Inculcators, *1982,* National Science Board, National Science Foundation, 1983, p. 29.

Table 37.—Distribution of Undergraduate and Graduate Foreign Students by Field of Study in U.S. Universities (1954/55-1981/82)

Field of study	[illegible]		1959/60		1964/65		1969/70		1975/76		1978/79		1979/80		1980/81		1981/82	
	Number of students	Percent	Number of students	Percent	Number of students	percent	Number of students	Percent	Number of students	Percent	Number of students	Percent	Number of students	Percent	Number of students	Percent	Number of students	Percent
Engineering	7,618	22.3	11,279	23.3	18,084	22.0	29,731	22.0	42,000	23.4	76,000	28.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
Business/ management	[illegible]3	.6	4[illegible]4		[illegible]6	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		46,960	1[illegible].4	[illegible]	[illegible].4	59,420	18.2
Natural and life sciences	[illegible]	10.7	6,261	12.9	[illegible]	14.3	17,006	[illegible]	[illegible]	[illegible]	24,190		21,880	7.6	[illegible]	7.4	[illegible]	[illegible]
Social sciences		14.7	6,782	14.0	[illegible]2.	15.4	17,272	[illegible]	[illegible]	[illegible]	23,360		22,530	7.9	[illegible]	7.8	[illegible]	[illegible]
Education		4.3	2,483	5.1	3.[illegible]	4.9	7,779		[illegible]		14,790		12,340	4.3	[illegible]	3.8	[illegible]	[illegible]
Mathematics and computer science	[illegible]	[illegible]	[illegible]5	2.[illegible]	[illegible]70	3.3	4,400	3.3	9,060	5.[illegible]	4,740	5.6	15,390	5.4	19,180		[illegible]	
Fine and applied arts	1,997	5.8		[illegible]	3,946	4.8	6,297	4.7	8,320	4.6	[illegible]	[illegible]	14,350	[illegible]	15,450	[illegible]	[illegible]	4.7
Humanities	5,502	16.1		[illegible]	12,137	14.8	20,211	14.9	15,030	8.4	[illegible]	[illegible]	11,340	[illegible]	13,070		[illegible]	3.9
Health professions	3,184	9.3		[illegible]	4,918	6.0	5,969	4.4	7,180	4.0	[illegible]	[illegible]	10,950	[illegible]	11,320		[illegible]	3.5
Agriculture	1,199	3.5		[illegible]	3,211	3.9	3,667	2.7	5,270	2.9	[illegible]	[illegible]	8,750	[illegible]	8,660		[illegible]	2.7
Other	1,164	3.4		[illegible]	1,624	1.9	7,040	5.2	9,380	5.2	[illegible]	[illegible]	44,900	[illegible]	50,030	[illegible]	[illegible]	17.8
Total	34,232	100.0	[illegible]	[illegible]	82,045	100.0	134,959	100.0	79,340	100.0	[illegible]		286,340	[illegible]	311,880	[illegible]	[illegible]	100.0

[1] After 1978/79 includes students in a new category called Intensive English Language.

[2] Includes undeclared majors.

SOURCES: *Open Doors 1978/79* (Washington, DC: Institute of International Education, 1980), pp. 18-19. *Open Doors 1980/81*, p. 16, and *Open Doors 1981/82;* in *Science Indicators, 1982,* National Science Board, National Science Foundation, 1983.

Table 38.—Doctoral Degrees[a] Awarded to Foreign Students as a Percent of All Doctoral Degrees from U.S. Universities by Field 9-81)[b]

Field	1959	1963	1967	1971	1975	1979	1981
Science and engineering	14.8	15.5	17.5	18.7	22.1	21.1	22.1
Physical sciences	12.6	14.0	15.7	16.7	22.9	21.0	22.0
Physics and astronomy	14.9	14.5	16.9	18.6	27.6	25.7	26.1
Chemistry	10.5	12.2	14.6	15.6	19.8	19.7	21.2
Earth sciences[c]	17.1	19.9	17.2	14.6	22.1	16.6	17.1
Mathematical sciences	13.4	15.2	14.6	17.5	24.3	25.5	30.8
Mathematics	A	NA	NA	NA	NA	26.7	33.7
Computer sciences		NA	NA	NA	NA	21.3	26.3
Engineering	24.5	20.8	23.7	29.8	42.1	46.8	51.5
Life sciences	17.6	17.5	19.6	18.2	19.5	16.5	19.8
Biological sciences	15.5	16.5	16.2	14.3	14.9	12.1	11.1
Agriculture and forestry	24.9	21.0	32.4	33.6	37.4	35.2	37.6
Social sciences	10.7	11.6	13.5	13.7	13.7	12.9	13.0
Psychology	5.5	4.0	4.4	5.6	5.8	4.0	3.9
Other social sciences	15.5	17.6	19.9	19.3	20.2	22.4	24.0
Conscience total	6.0	6.5	7.4	8.0	8.7	10.1	11.0
All fields	11.7	12.3	14.0	14.4	16.2	16.1	17.2

[a] Percent of those whose citizenship is known.

[b] Fiscalyear of doctorate,

[c] Includes oceanography.

NA—Not available.

SOURCE: *Doctorate Record **File**, Special Tabulations,* unpublished data; National Science Foundation, ***Science** Indicators, **1982**,* National Science Board, National Science Foundation, 1983

Implications for U.S. Information Technology R&D Policies

Given the strong links between other nations' information technology research and development activities and those of the United States, and economic competition from countries such as the United Kingdom, France, and Japan in information technology innovation and international markets, foreign R&D initiatives are a concern for the United States. For the U.S. Government to participate in international research and development and, at the same time, successfully compete with these nations' R&D initiatives, the United States will need to understand other nations' economic and social goals for technological development, government, and industry roles in information technology R&D, and the significance of targeted national information technology R&D programs.

Although the philosophy of industrial competition is prevalent in other economies-particularly in the United Kingdom and Japan–these industrialized nations have coordinated their R&D efforts at a national level. Industrial and governmental cooperation is viewed as a means to achieve common national technological objectives and enhance the competitiveness of the entire national information technology industry in global markets. Coordination for R&D includes efforts at the national level to disseminate information on technological developments, share research results, and divide research activities among enterprises. Moreover, in coordinating R&D efforts between government, university, and industry participants, these nations have attempted to link trade competitiveness strategies more closely with R&D policies.[18]

In the United States, competition in technological development among firms is viewed

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[18] Wilson P. Dizard, "U.S. International Information Trade," *The Information Society,* vol. 2, No. 3/4, 1984, p. 189.

as a variant of other forms of competition, such as competition in production efficiency, product quality, and marketing. Consequently, the United States relies heavily on open market competition and private initiative to spur industrial R&D.[20] Moreover, trade competitiveness factors are not always considered in the formulation of U.S. R&D policy.

Since other industrialized nations target information technology research and development programs at the national level, the question has been raised whether the United States should adopt a similar national industrial strategy for technological development. Although a number of nations that pursue coordinated industrial policies have relatively weaker overall economic performances than the United States, those that target information technology as a national priority may improve their competitiveness.

In response to foreign coordinated national R&D programs, a number of legislative options (several of which are modeled on foreign initiatives) for coordinating and targeting industrial sectors have been proposed in the United States. There is also evidence, presented in this report, that the United States may already be responding in ways particularly suited to its social, governmental, and economic traditions. For instance, the government-industry technology transfer activities stimulated by the Stevenson-Wydler Technology Innovation Act of 1980 (Public Law 96-480) (described inch. 2) and the recently forming university-industry cooperative joint ventures (described in ch. 6) may be indications that the United States is beginning to develop indigenous mechanisms to pursue common technological objectives.[21]

If, however, the United States is to develop coordinated national industrial strategies in response to other nations' targeted efforts in the area of information technology, the use of other nations' national R&D organizations and activities as models should be carefully considered. As a result of major differences in the historical, cultural, and economic characteristics of each nation, there appear to be differences in their respective approaches to science and technology policies, as well as government and industry participation in information technology R&D. Moreover, the United Kingdom, French, and Japanese national information technology research and development programs differ in overall goals and organization and vary significantly from current U.S. R&D efforts.

Science and Technology Policy Goals

Although the United Kingdom, France, and Japan each developed science and technology policies in part to strengthen and modernize their economies, each of these nations varies in its conception of what technology policy should comprehend and what its objectives should be.[22] In some nations policy is aimed at strengthening the competitiveness of targeted industries. Other nations are concerned with developing information technologies for social needs or national security applications. In other nations, the perception of technology policy is much broader, and constitutes a part of a more general plan of how the economy should be structured in the future. Many of the goals for science and technology policy of the United Kingdom, France, and Japan are rooted in history. At the finish of World War II, each of these nations' societies and economies were severely damaged. These nations' governments therefore perceived a need to actively promote the growth of a high technology industry in order to aid their ailing economies.

Since World War II and particularly in more recent times, science and technology policies have become increasingly politicized. This reflects the view that science and technology is linked to nations' economic well-being (e.g., trade, productivity, and employment) and social welfare (e.g., quality of life, education, and training). Moreover, the widespread belief that

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[20] Jack Baranson and Harold B. Malmgren, "Technology and Trade Policy: Issues and an Agenda for Action, " Bureau of International Labor Affairs, U.S. Department of Labor, and the Office of the U.S. Trade Representative, 1981, p. 5.

[21] See for example, Jan Johnson, "America Answers Back, " *Datamation*, May 15, 1984, p. 40-57.

[22] Jack Baranson and Harold Malmgren, op. cit., p. 6.

"the nation that dominates the information processing field will possess the keys to world leadership in the twenty-first century, "[23] has caused nations to look to the development of information technology for their future well-being. Evidence of the movement of science and technology policies into the political arena, for instance, can be found in both the recent Thatcher (United Kingdom) and Mitterand (France) political platforms in which information technology research and development funding and programs were emphasized. However, these two leaders differ in their policies for technological development. These differences are important in understanding and evaluating the roles of these governments in information technology research and development.

The various current approaches to science and technology policy and the different objectives of each nation's research activities underlie the distinct goals of each country's national research program. For example, Japan's concerns lie in developing information technology for improving Japanese society (which entails developing an information-based infrastructure) and improving its world trade position in information technology products. Consequently, Japan's goals for its national information technology research program, the Fifth-Generation Computer Systems Project, is to develop a fifth-generation computer for social applications and to develop a technological knowledge base which will enable Japan to maintain and improve the volume of information technology exports that is so vital to the Japanese economy.

Like Japan, the United Kingdom is also concerned with its economic survival in world markets, as exports also play an important role in the U.K. economy. The basic goal, therefore, for the U.K. Programme for Advanced Information Technology is to improve the competitiveness of the U.K. information technology industries in the world market in order to reverse its negative balance of information technology trade.

French governmental interest and efforts to expand advanced information technology research and production are directed at two major goals: strengthening France's international competitiveness and the development of an information technology-based infrastructure for the preservation and continued development of French culture and society. Reflecting French national goals, France's national information technology research and development program, La Filiere Electronique, has as its long-term goals: to place France on a technological level closer to that of the United States and Japan; create a trade surplus in information technology products; create new jobs; assure a sound technological base; and accelerate the production of information technology products.

The Europeans, through the European Economic Community (EEC), are also concerned about their basic economic survival in world markets. Consequently, Europe's major goal is to establish a strong technological base through collaborative research on various long-range projects that may not be adequately funded within individual nations. The European Strategic Program for Research in Information Technology (ESPRIT), involves the 10 EEC member countries. ESPRIT's major objective is to keep Europe competitive with the United States and Japan in advanced information technology fields.

Government Role in Information Technology Research and Development

The level of government funding for research and development varies widely. The ratios of civilian research and development expenditures to gross national product (GNP) presented in figure 40 show that the United States devotes a lower proportion of its GNP to civilian R&D than Japan, but a higher proportion than the United Kingdom. An examination of the annual growth rates of national research and development expenditures for electrical and electronics industries reveals that the United States lagged behind most of

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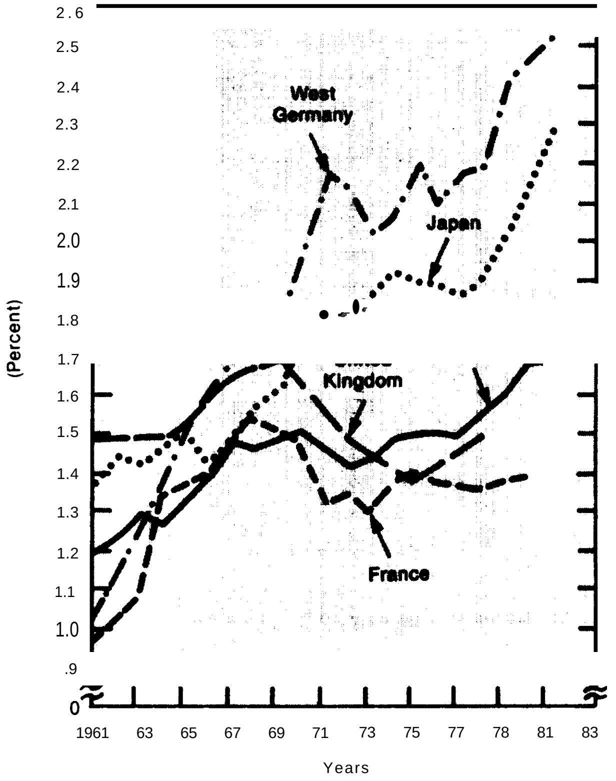
[23] Robert E. Kahn, "A New Generation in Computing, " *IEEE Spectrum,* **November 1983, p. 36.**

Figure 40.— Estimated Ratio of Civilian R&D Expenditures to Gross National Product (GNP) for Selected Countries[a]



National expenditures excluding Government funds for defense and space R&D

SOURCE: *Science Indicators, 7982,* National Science Board, National Science Foundation, 1983

the industrially developed nations during the 1970s.[24]

The United Kingdom, France, and Japan singled out information technology as an area for government promotion and support. This contrasts sharply with the U.S. Government, which at the present time has not singled out or targeted any specific industry or technology for government support. Although in market economies governments use a more or less standard set of policies to support research and development,[25] other nations differ from the United States in the extent to which each coordinates and targets these policies to support information technology research and development. Policy measures for R&D support include low interest loans, direct subsidies, or actual government contracts. Other incentives to stimulate information technology R&D include tax incentives, national development banks which channel funds specifically to information technology industries, public sector procurement, and merger/antitrust policies.

To varying degrees the governments of the United Kingdom, France, and Japan have established institutional mechanisms to facilitate coordinated research and development policymaking. Coordinated government intervention on the part of these industrialized nations is reflected in each of the governments' structure which centralizes the responsibility within one or a few government ministries, and in the establishment of planning councils. Moreover, the coordinated efforts of the British, French, and Japanese extend much further than the U.S. pluralistic and decentralized approach to R&D support, to the coordination of government, industry, and university information technology research and development objectives and activities.

Government/Industry/University Institutional Arrangements for Information Technology Research and Development

A major difference between the institutional arrangements for U.S. information technology research and development and those of the United Kingdom, France, and Japan is therelationship between government and industry. In the United States, government tends to be viewed as a regulator and enforcer of laws and social policies; U.S. industry generally perceives its relationship with government as adversarial. Moreover, the U.S. Government, which traditionally avoids involvement in the private sector, relies largely on private initiatives for risk-taking, innovation, job creation, and the generation of profits and capital.

Although this adversarial relationship between the public and the private sectors ex-

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[24] Reasons for the relative declining growth rate of us. Government R&D funding during this period include major decreases in funding for defense and space research and development, while civilian research and development was held constant. Currently, U.S. budget projections reflect increasing R&D funding for defense purposes.

[25] *International Competitiveness in Electronics* (Washington, DC: U.S. Congress, Office of Technology Assessment, OTA-ISC-200, 1983), p. 381.

Table 39.—Average Annual Growth Rates in the Engineering Industry

	United States	Japan	Germany	France	United Kingdom
	1970-79	1970-79	1971-79	1970-79	1969-78
Research scientists and engineers: [a]					
Aerospace	0.3	—	–5.3	1.1	–2.6
Electrical and electronics	–0.4	6.7	3.2	4.1	0.9
Machinery	5.1	2.5	6.7	3.9	3.6
Transport equipment	3.3	8.5	3.8	1.8	0.2
Total expenditure:					
Aerospace	– 1.1	—	–2.3	2.6	–0.5
Electrical and electronics	0.1	5.8	5.8	4.7	3.1
Machinery	5.5	5.2	9.8	0.9	1.5
Transport equipment	5.4	11.0	3.9	7.2	–0.3
Government funds:					
Aerospace	– 1.7	—	–1.0	1.8	–3.1
Electrical and electronics	–2.2	—	7.1	0.1	9.9
Machinery	1.0	—	10.0	—	1.1
Transport equipment	3.1	—	10.1	6.9	3.0
industry and foreign funds:					
Aerospace	0.6	—	4.1	5.0	(b)
Electrical and electronics	2.3	—	4.9	7.7	–0.7
Machinery	6.3	—	8.5	—	–3.4[d]
Transport equipment	5.9	—	3.3	7.4	– 1.4

[a] Japan not in Full-Time Equivalents.
[b] Large increases from a very low start.
[c] From abroad 4.91 per annum.
[d] Electrical and electronics. For R&D purposes the following subclasses are identified with this subgroup: ISIC 3832 and ISIC 638 nec.

SOURCE: *OECD Science and Technology Indicators,* OECD, 1964.

ists in most countries, the governments of the United Kingdom, France, and Japan have historically participated to a greater degree in industrial and technological development. For cultural, historical, and political reasons, these industrialized nations often regard government-industry relations as a partnership or perceive government as an institution for guiding and supporting targeted industries. Government-industry coordination has begun in some nations with the establishment of multipartite advisory groups representing government and private industry.[26] Formal and informal advisory councils have become in some nations, particularly in Japan, important forums for government-industry-academic consultations on industry policy and implementation. Particularly in information technology, these councils orchestrate joint research, development, and marketing schemes among information technology firms and government.

To coordinate more fully both their targeted policies and information technology R&D, the United Kingdom, France, and Japan have recently adopted major national programs. These programs, which have no counterpart in the United States,[27] have been established to pursue research projects cooperatively between government, private industry, and universities. The scale of funding for all the national programs is large and roughly comparable, representing a major commitment of between half a billion and several billion dollars over the first 5 years.[28] This funding is magnified because the companies which receive government research funds usually are required to match the funds.

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[26] Franklin Delano Strier, “On Economic Planning, Japan and West Germany Have a Better Idea,” *The Center Magazine,* January/February 1984, p. 36.

[27] “Some individuals contend that the Department of Defense (DOD) programs, such as VHSIC, are similar to the national research and development programs of the United Kingdom, France, and Japan. However, there are major differences between DOD programs and these other nations’ programs.

[28] Trudy E. Bell, “Tomorrow’s Computers-The Teams and The Players,” *IEEE Spectrum,* November 1983, p. 46.

Each nation, in structuring its cooperative research program, has looked to successful organizational examples both domestically and in other countries, borrowing organizational concepts and applying them in innovative ways. For example, the Institute for New Generation Computer Technology (ICOT), with its central research center, is unique to Japan. ICOT is organized for close cooperation of research activities among government, industry, and university participants. Japan's customary approach has been to have each participating research institution or company conduct research individually. ICOT is also contracting with outside companies and laboratories for some of the research and development—a technique often used for U.S. defense contracts, but unusual in Japan.

The institutional arrangements for the U.K. Programme for Advanced Information Technology are also unique, although the Alvey Committee closely modeled the program organization on Japan's Ministry of International Trade and Industry (MITI) and the U.S. Defense Advanced Research Projects Agency (DARPA). This new organization is intended in part to stimulate the transfer of basic research from academic environments to industry.

The ESPRIT program shares both similarities and differences with organizations such as ICOT and the Alvey Programme. Like these other new institutional arrangements, ESPRIT research is undertaken by teams of university, government, and industry scientists. In contrast to other nations' cooperative programs, ESPRIT represents a joint venture at the international level in which each project must involve researchers from at least two countries.

The success of these national programs in achieving both national aims and research goals remains undetermined. However, these new institutional arrangements raise some interesting questions for the United States. How will the cooperative research programs of the United Kingdom, France, and Japan alter their traditional research structures and serve as models for future research projects? What are the relative strengths of these new research programs versus traditional U.S. research environments? To what degree will these new national research programs affect U.S. technological development and market share?[29]

Industry Participation in Information Technology Research and Development

Funding of industrial information technology research and development varies from nation to nation. Table 40 represents industrial R&D funding patterns in industrialized nations and shows that industry has been a more dominant contributor in Japan (although the Japanese Government also provides a great deal of support through indirect subsidies) than in any other nation, including the United States.[30][31] The U.S. Government, in contrast, supported approximately half of the U.S. research and development activities in 1970. However, by 1979, U.S. industry had increased its share of industrial funding to 67 percent, approximately as much as the French industry's 71 percent support of its own research.

Table 41 illustrates industrial research and development support for electrical and electronics and computers categories in the industrialized nations. Japan and West Germany had the highest proportion of industrial R&D in the electrical and electronics category. In the computer category, however, the United States had the greatest proportion of industrial R&D followed by the United Kingdom, France, and then Japan.

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[29] Ibid.

[30] OECD *Science and Technology Indicators*, OECD, 1984, p. 119.

[31] *Science Indicators, 1982*, National Science Board, National Science Foundation. 1983. p. 9.

Table 40.—R&D Performed in the Business Enterprise Sector by Source of Funds (1970, 1975, and 1979)

Country and source	National currency (in millions) 1970	1975	1979	Percent 1970	1975	1979
France	***8,322.4***	15,616.5	*26,260.0*	100.0	100.0	100.0
Total domestic	***8,007.3***	14,393.5	*24,460.0*	*96.2*	92.2	93.1
Business enterprise	***5,310.0***	9,965.8	*18,723.0*	*63.8*	63.8	71.3
Government	***2,689.0***	4,376.8	*5,674.0*	*32.3*	28.0	21.6
Private nonprofit	***4.6***	47.2	*58.0*	.1	.3	.2
Higher education	***3.7***	3.7	5.0	—	—	—
From abroad	***315.1***	1,223.0	1,800.0	3.8	7.8	6.9
Japan	***895,020.0***	1,684,847.0	2,664,913.0	100.0	100.0	100.0
Total domestic	***894,193.0***	1,683,200.0	2,662,698.0	99.9	99.9	99.9
Business enterprise	***876,608.0***	1,654,502.0	2,624,843.0	97.9	98.2	98.5
Government	***17,585.0***	28,698.0	36,807.0	2.0	1.7	1.4
Private nonprofit	NA	NA	935.0	NA	NA	—
Higher education	NA	NA	113.0	NA	NA	—
From abroad	827.0	1,647.0	2,215.0	.1	.1	.1
United Kingdom[a]	680.3	1,340.2	2,324.3	100.0	100.0	100.0
Total domestic	647.7	1,255.5	2,138.8	95.2	93.7	92.0
Business enterprise	431.2	841.4	1,459.0	63.4	62.8	62.8
Government	216.5	414.1	679.7	31.8	30.9	29.2
Private nonprofit	NA	NA	NA	NA	NA	NA
Higher education	NA	NA	NA	NA	NA	NA
From abroad	32.6	84.7	185.5	4.8	6.3	8.0
United States[b]	18,067.0	24,187.0	38,226.0	100.0	100.0	100.0
Total domestic	18,067.0	24,187.0	38,226.0	100.0	100.0	100.0
Business enterprise	10,288.0	15,582.0	25,708.0	56.9	64.4	67.3
Government	7,779.0	8,605.0	12,518.0	43.1	35.6	32.7
Private nonprofit	—	—	—	—	—	—
Higher education	—	—	—	—	—	—
From abroad	—	—	—	—	—	—
West Germany[c]	7,114.0	14,469.0	20,720.0	100.0	100.0	100.0
Total domestic	7,090.0	14,005.0	20,070.0	—	*96.8*	96.9
Business enterprise	6,146.0	11,397.0	15,650.0	—	*78.8*	75.5
Government	939.0	2,596.0	4,400.0	—	*17.9*	21.2
Private nonprofit	5.0	12.0	20.0	—	.1	.1
Higher education	—	—	—	—	—	—
From abroad	24.0	464.0	650.0	—	**3.2**	3.1

[a] 1970 figures for the UnitedKingdom are from 1989, and 1979 figures are from 1978.

[b] Current expenditures plus depreciation only.

[c] 1970 figures fo, West Germany are from 1969.

NA—Not separately available.

NOTE: Details may not add to totals because of rounding.

SOURCES: *OECD Science and* Technology Indicators, *vol. B* OECD, *1982; Research and Development in Industry,* National Science Foundation, 1981; *in Science/n. dicators, 19S2,* National Science Board, National Science Foundation, 1983.

Table 41.—Percent of Industrial R&D in Selected Industries (1989-79)

Industry	United States 1970	1979	Japan 1970	1979	West Germany 1969	1979	United Kingdom 1969	1978	France 1970	1979
Six-industry total	71.2	70.2	61.5	55.6	71.1	72.4	58.4	60.7	NA	61.7
Aerospace	11.8	8.6	–	–	.1	.6	1.1	5.4	7.8	8.8
Electrical and electronics	19.5	17.6	24.9	23.4	29.3	26.9	20.4	16.0	16.5	20.2
Instruments	5.3	7.8	2.3	2.9	1.6	2.1	3.1	1.9	NA	1.2
Machinery	14.3	6.0	8.7	7.0	}7.0	}16.6		6.6	NA	
Computers	“	11.5	2.9	2.8			!;	5.2	NA	: : ;
Chemicals group[a]	20.3	18.7	22.7	19.5	33.1	26.2	22.1	25,6	24.2	23.4

[a] Includes chemicals and allied products and petroleum refining industries.

SOURCES: *OECD Science and Technology /nd/caters, vol. B* OECD, 1982; *Research and Development in Industry,* National Science Foundation, 1981; in *Science Indicators, 1982,* National Science Board, National Science Foundation, 1983.

In addition to direct funding, governments can support or discourage industrial research and development with tax incentives, fiscal and monetary policies which affect interest rates and the availability of capital, regulatory policies, procurement practices, patent policies, and antitrust policies.[32] Moreover, actions of a national government to define the structure of its information technology industry will have profound but unpredictable influence on industrial R&D. For example, France has recently nationalized some major information technology firms, whereas the United Kingdom and Japan currently are moving in the opposite direction by privatizing their telecommunications entities.

Conclusions

Cultural, social, and institutional differences among nations profoundly influence the way in which technological innovation occurs and underlie the considerable differences in R&D policies in the United Kingdom, France, and Japan. Therefore, many of these nations' successful research and development policies and endeavors may not be easily transferable or applicable to U.S. R&D environments. Nevertheless, cross-cultural comparisons of these individual nations, which have developed different methods of addressing similar public policy issues and technologies, can be useful to an individual society, such as the United States, in devising a conceptual framework for developing information technology domestic and international R&D policies.

International comparisons also provide a useful method for evaluating the status of U.S. information technology research and development activities and expenditures. However, making comparisons is difficult. Differences exist among countries in definitions, concepts, data collection methodologies, and statistical reporting procedures.[33] These problems are particularly prevalent in the area of information technology.[34] Although several international organizations such as OECD and the ITU have initiated the development of uniform definitions and standards for information technology products and facilitated the exchange of information on nations' R&D policies and activities, the U.S. Government currently does not have a designated agency or office within an agency to analyze and monitor foreign information technology R&D policies and practices.

The economic importance of industrial competitiveness and its close reliance on technological development emphasizes the importance of developing a program for periodic mapping of the pattern of technological advantages and disadvantages relative to foreign competitors.[35] Such surveys could help to alert government and industrial representatives to changes in the technological underpinnings of their competitive positions. These surveys could also be broadened to encompass nontechnological factors affecting competitiveness or future technological developments. These could include current or prospective changes in foreign government R&D policies that influence the competitiveness of their pro-

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[32] *Science Indicators,* 1982, op. cit., p. 10.

[33] *Science Indicators, 1980,* National Science Board, National Science Foundation, 1981, p.4.

[34] The U.S. SIC Codes, for example, do not have categories for information technology, but rather information technology products are encompassed within different and separate categories. Moreover, each nation has its own methods for categorizing information technology products and research and development expenditures and activities.

[35] See S. E. Goodman and M. R. Kelly, "We Are Not Alone: A Sample of International Policy Challenges and Issues," *The Information Society,* vol. 2, No. 3/4, p. 250-268.

ducers in export markets. Such a broader survey could provide the basis for a more effective assessment of changes in the current and prospective competitiveness of foreign R&D efforts than a narrow focus on technological capabilities alone.[36] As one analyst stated:

> Most governments, and most especially the U.S. Government, are organized to reflect primarily domestic interests and have great difficulty in dealing adequately with one of the consequences of science and technology—the gradual blurring of the distinction between domestic and international affairs . . . .
>
> Perhaps the most important observation [is] . . . that the general character of changes brought about by science and technology tends, overall, to lead to increased international interaction and integration, with correspondingly reduced relevance of national borders. The parallel spread and diffusion of technological competence that is eroding the dominance of one or a few nations in science and technology makes it imperative that we recognize the nature of the underlying changes taking place as we attempt to develop policies to deal with the specific implications of any given technology, or to influence the direction of development of technology itself.[37]

“Bela Gold, “Technological and other Determinants of the International Competitiveness of U.S. Industries, ” *IEEE Transactions on Engineering Management,* vol. LM 30, No. 2, May 1983, p. 58.

“Report by Eugene Skolnikoff entitled “Impact of Science and Technology on the International System, ” in “Overview of International Science and Technology Policy” hearings before Committee on Foreign Affairs, House of Representatives, 98th Cong., 1st sess., Aug. 2,3 and Sept. 21, 1983, p. 317.

Japan

Given Japan’s minimal domestic natural resource base and its high dependence on other nations for food, energy, and raw materials, the Japanese Government treats science and technology policy as a means of spurring overall economic growth and enhancing Japan’s competitive position internationally. Japan’s policies focus on maintaining a long-term, high volume of exports in order to gain technological and, thus, market leadership in a broad spectrum of high technology, high value-added products. This perception in Japan has led to a consensus in the nation’s government, business, financial, and academic communities to continue strengthening the nation’s technological base.

The coordination of science and technology policy to the promotion of economic development is rooted in Japan’s postwar recovery efforts. During the postwar recovery period, various science and technology institutions and laboratories were established on the assumption that they would help stimulate an economic recovery. Another major component of this strategy was to import and improve technology from the United States and Western Europe. Following the enactment of the law on Foreign Capital in 1950, the Japanese have signed more than 36,000 licensing agreements costing approximately $12 billion.[38] Agreements between Japanese and foreign firms were made under strict government supervision partly to control the outflow of foreign exchange and partly to concentrate technological resources into certain key industries. Products manufactured with these imported technologies initially served to develop the Japanese domestic market, bringing about a GNP growth exceeding 10 percent throughout the 1950s. For example, transistor technology imported and commercialized by the Japanese in the early 1950s provided a foundation for the modern electronics industry.

Although the general trend of importing technologies has been receding, the imports of technologies related to electronic computers increased by 16 percent over fiscal year 1980, with those relating to software accounting for over 166 imports. Broken down into sectors

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[38] Leonard Lynn, “Japanese Technology: Successes and Strategies,” *Current History,* November 1983, p. 366.

of industry, out of a total of 2,142 cases, the number of imports of foreign technologies during fiscal year 1980 in the electrical industry amounted to 413 cases.[39]

In concert with the policy of importing technology, Japan has sought to develop its own indigenous research base. The ratio of national R&D expenditure to national income has risen from less than 1 percent during the first half of the 1950s to 1 percent in 1957, 1.5 percent in 1960, 2 percent in 1971, and 2.36 percent in 1981. According to official plans, this percentage will be increased to 2.5 percent by 1985 and to 3 percent by 1990.[40] According to statistics released by the Japanese Prime Minister's Office, all Japanese R&D, publicly and privately funded, in the area of information processing (which includes software and computer systems development only) totaled Y 158.6 billion ($687 million) in 1979 and Y 164.6 billion ($713 million) in 1980.[41][42]

In Japan, a far lower percentage of total research funds is provided by government (Japan 27.7 percent, United States 51.1 percent, United Kingdom 51.7 percent) than in other nations.[43] In part, this difference can be attributed to the high level of expenditure on defense research by Western governments (approximately 15 percent of total research funds) relative to the small amount spent by the Japanese Government (0.7 percent). In some areas of information technology R&D such as integrated circuit development, low military R&D expenditure has helped Japanese industry. In general, military areas demand the highest state-of-the-art standards, regardless of costs. Therefore, these military developments sometimes result in expensive products which are so specialized that civilian or consumer applications can be limited. This is often the case with integrated circuit development in the United States. On the other hand, Japan has succeeded in developing integrated circuit products solely for commercial application.

Taking into account all funds spent on defense, the government of Japan still contributes significantly less to total scientific research expenditure than other countries.[44] More specifically in the area of information processing, the Japanese Government R&D expenditure in 1979 accounted for 8.2 percent in 1979 and 6.2 percent in 1980 of the total Japanese information technology R&D expenditures.[45] In Japan, this government R&D funding is concentrated in the national universities (13.5 percent), national research institutes (13 percent), with as little as 1.5 percent of government funding channeled to private industrial laboratories. Because government R&D funding, which is the major supporter of academic basic research, is relatively limited, reasons for Japan's perceived ineffectiveness in basic research can be clearly understood. As a result, current improvements in the Japanese academic environments for basic research as well as increases in funding levels for overall basic research are high priorities on the Japanese policy agenda.

Because Japanese Government R&D funding is small and for the most part channeled into university and national research institutes, Japanese industry funds constitute approximately 70 percent of R&D activities. Approximately 28 percent of all Japanese industrial R&D funding is devoted to information technology R&D. Although the Japanese Government does not directly make use of the vitality offered by private enterprise, the lack

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[39] "Import of Foreign Technologies in Japan, " *Science and Technology in Japan,* April 1982, p. 27,

[40] "Summary of fiscal year 1981 White Paper on Science and Technology, " Science and Technology Agency, Tokyo, Foreign Press Center, 1981.

[41] Barry Hilton, "Government Subsidized Computer, Software, and Integrated Circuit Research and Development by Japanese Private Companies, " *Scientific Bulletin,* Office of Naval Research Far-East, U.S. Department of the Navy, vol. 7, No. 4, October-December 1982.

[42] All Japanese yen figures are converted into U.S. dollars according to foreign exchange rates as of June 1, 1984, where ¥231 = $1.

[43] "Science in Japan," *Nature,* vol. 305, Sept. 29, 1983, p. 361.

[44] These low expenditures are also the result of the Japanese Governments current large budget deficits.

[45] Barry Hilton, "Government Subsidized Computer Software, and Integrated Circuit Research and Development by Japanese' Private Companies, " *Scientific Bulletin,* Office of Naval Research Far-East, vol. 7, No. 4, October-December 1982.

of government funding has intensified competition in the area of information technology research and development. This competitive effort is exemplified in Japan's computer and semiconductor industries which, in order to survive, must develop and efficiently produce high quality products as quickly as possible.

This "privatized" environment for R&D has given Japan advantages and disadvantages in its information technology R&D efforts. One result of the large percentage of privately funded R&D is the lack of basic fundamental research activities. Because the R&D is subsidized mainly by private firms, basic creative research, which is high-risk and long-term, is sometimes ignored in favor of cost-efficient, developmental, applied, commercialized R&D. This continued preoccupation with R&D efforts that bring quick economic results has resulted in a trend which places less importance on basic, innovative studies. The Japanese Science and Technology Agency (STA), for example, published a list of 15 basic discoveries in the fields of recombinant DNA and computer technology (superconductivity, optical fibers, lasers, Josephson junctions, tunnel diodes, and transistors). Japan was responsible for only two of the breakthroughs listed; America for nine; the United Kingdom and the Netherlands for four. This bias in Japan's overall research expenditures toward applied research and prototype development is reflected both in government-supported R&D and private sector research expenditure (see table 42).

On the other hand, in the area of development, the application of basic research results, the Japanese privatized R&D efforts are highly successful. Japan has clearly outstripped most Western nations in processing technologies and incremental engineering-rapidly refining existing designs and ideas by making them smaller, lighter, faster, and cheaper. Japanese engineers, for instance, reengineered the 16 K RAMs with finer features to produce a 64 K RAM within a 2-year period.

Table 42.— R&D Expenditure by Type of Activity

	Basic	Applied	Development
1970	18.9	28.2	52.9
1974	15.0	21.7	63.3
1975	14.2	21.5	64.3
1977	16.2	25.1	58.7
1978	16.6	25.1	58.4
1979	15.6	25.9	58.5

SOURCE: **Kagaku Gijutsu** Hydron (Indicators of Science and Technology) **Kagaku Gijutsu-Cho** (Science and Technology Agency) 1981. Note: **This** table covers all **R&D**, public and private.

Examples of Japanese strengths and weaknesses in information technology R&D are well documented in the area of software development. Software development, currently believed to be crucial for future information technology development, can be classified into various categories. Japan, with its industrial emphasis on applied R&D, has concentrated its efforts in production process-control software which has wide commercial industrial applications and which will reap significant economic benefits, both domestically in terms of the productivity and capacity utilization of industry, as well as internationally, in terms of the benefits of trade and technology transfer. However, in other categories of software development such as computer-aided design (CAD), the United States is technologically more advanced than Japan. Most of this technological lead resulted from billions of dollars that have been allocated for aerospace and defense basic research. As a result of this basic research for U.S. defense purposes, the U.S. computer simulation models and 3-D design programs are among the most sophisticated in the world.

Currently, Japanese industry is beginning to experience some difficulties with its emphasis on appliedborrowed technology. Japan has been slowly catching up to western technological innovations and has less input from foreign basic research patent licenses on which to base its refinements. Furthermore, Western firms are expressing a disinclination to sell patents to Japan, as they see the reengineered Japanese products competing with their own products. Moreover, Japanese firms that have sometimes neglected basic research, have fewer technological innovations worth offering

Western companies when they wish to inquire about the possibility of cross-licensing. In addition to the fear of the decreasing amount of innovative ideas which Japan can buy and perfect and the fear of being excluded from future U.S. and other Western nations' technical developments, national pride is also forcing Japan to put more effort into basic R&D.

As a result of some of these difficulties, the Japanese Government is beginning to place more emphasis on basic research activities. This movement towards increased basic research is reflected in both government and industrial R&D activities as well as in the current Japanese Government's institutional mechanisms for influencing and funding industrial research. Because the government mechanisms which influence and fund information technology R&D are mostly aimed at promoting R&D in the private sector (and many take the form of informal cooperation), it is difficult at times to disassociate government and private sector initiatives and roles in information technology R&D activities. However, for purposes of clarity and comparison, the role of government, universities, and industry environments for the conduct of information technology R&D will be separately described. Before discussing these environments in detail, it is also important to understand the size of Japanese participation in information technology markets.

The Size of Japanese Participation in Information Technology Markets

Utilizing its basic technology policy which historically dictated that Japan reengineer imported technological innovations, Japanese industry has developed a very strong position in world information technology markets. In many areas where Japan has managed to capture a substantial percentage of the world information technology market, it can largely be attributed to Japanese industry's strong capabilities in product development, market" ing strategies, and quality control.

Beginning in the 1950s, Japanese information technology industry efforts focused on microelectronics. Over the last three decades, there have been major shifts in Japanese consumer electronics production. Figure 41 illustrates the shift from the production of radios, to television sets, to audio equipment, and finally to videotape recorders. This production progression is particularly interesting in terms of technology because it not only illustrates the steady restructuring of an industry to higher and more complex technologies, but also illustrates the changing position of Japanese information technology industry in terms of global competition.[46]

In each shift in Japanese consumer electronics production, industry has been dependent on foreign technological innovations. For instance, Bell Laboratories supplied transistor technology, RCA licenses made Japanese color television production possible, and Corning Glass supplied glass tube technology. Perhaps more than any other of Japan's industries, the development of Japan's consumer electronics industry is the result of imported technology that competitive Japanese firms adapted, improved, and drove costs down. Figure 42 illustrates the Japanese share of world consumer electronics productions. The total value of production, second only to that of the United States, reached Y 8,683 billion ($37.6 billion) —or approximately 150 times that of 1955—making electronics one of Japan's major industrial sectors.

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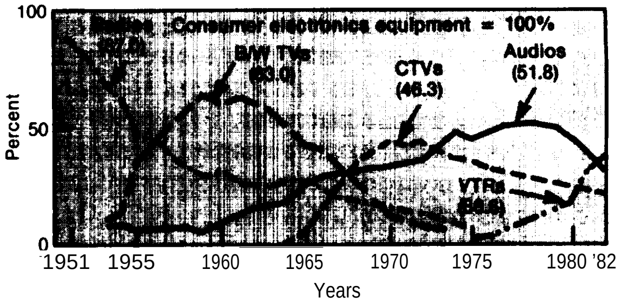
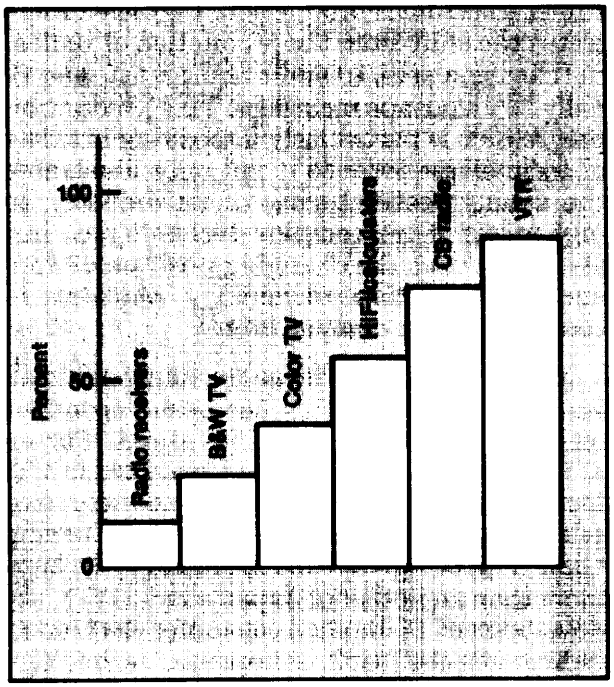
[46] **James C. Abegglan, and Akio Etori, "Japanese Technology Today, " Scientific American supplement,** 1983, p. J, 18.

Figure 41.—Trends in the Production Composition Ratio of Major Consumer Electronics Equipment



SOURCES: Annual Data on Japan's Electronics Industry, 1983 Edition, Electronics Industry of Japan, Tokyo, 1983; in James C. Abegglan and Akio Etori, "Japanese Technology Today, " *Scientific American,* supplement, 1983.

Figure 42.—JaDanese Share of World Production of Consumer Electronics Products (1980)



SOURCES: Japan Electronics Industry Development Association; in Gene Adrian Gregory and Akio **Etori**, "Japanese Technology Today: The Electronic Revolution Continues," Scientific *American,* supplement, 19S4.

Recognizing the primacy of computers and telecommunications as growth sectors, as well as conforming to the trend towards more advanced technology production, Japanese industry has focused on a technology key to these areas-integrated circuits. As in the case of consumer electronics, Japan imported basic semiconductor technology and in the early **1970s** initiated the production of integrated circuits. Although exports were insignificant during the beginning production years, Japanese industry focused on lowering costs and improving quality. Integrated circuitry production has grown in value terms at approximately 25 percent per year. Figure 43 illustrates the growth in the Japanese information processing, computer, and integrated circuit industries between 1974-81. By 1976, Japan accounted for a 40 percent share of the world market for 16 K RAMs, and in 1978, Fujitsu Ltd. was the first to announce the commercial production of the 64 K RAM. Japanese companies as well as U.S. manufacturers are the first to produce 256 K RAMs which will be available in 1984-85. Figure 44 illustrates Japanese integrated circuit production relative to U.S. production.

Perhaps the most significant step in this technology development sequence is the recent introduction by Japanese firms of one of the fastest supercomputers worldwide. These new computers, manufactured by Fujitsu and Hitachi, represent a major step in Japan's government-sponsored national effort to build fifth-generation computers."

Government

The large percentage of private R&D funding would indicate the tremendous importance of Japanese industry in the Japanese success in world information technology markets. However, it is a mix of government support, a favorable and stable political structure, as well as freedom from national security expenditures, that have combined with the rather unique Japanese sociology to create a period of economic growth in the area of information technology. The nickname for the Japanese economy "Japan Inc., " which was given some years ago, may be said to be a realistic evaluation of the Japanese Government and private corporations during postwar Japan, when Japan sought to catchup with the industrially advanced nations. The term "Japan Inc. " is still used today but in most cases this word appears to reflect a misunderstanding of the relationship between the Japanese Government and industry.

The Japanese Government does not control industrial R&D through funding mechanisms or specific policies that must be adhered to, but rather there is a participatory partnership among different segments of government and industry, based on pragmatic decisions, mutual respect, working within a framework of common goals. The councils and industrial associations have long been proposing to the Japanese Government to increase its research

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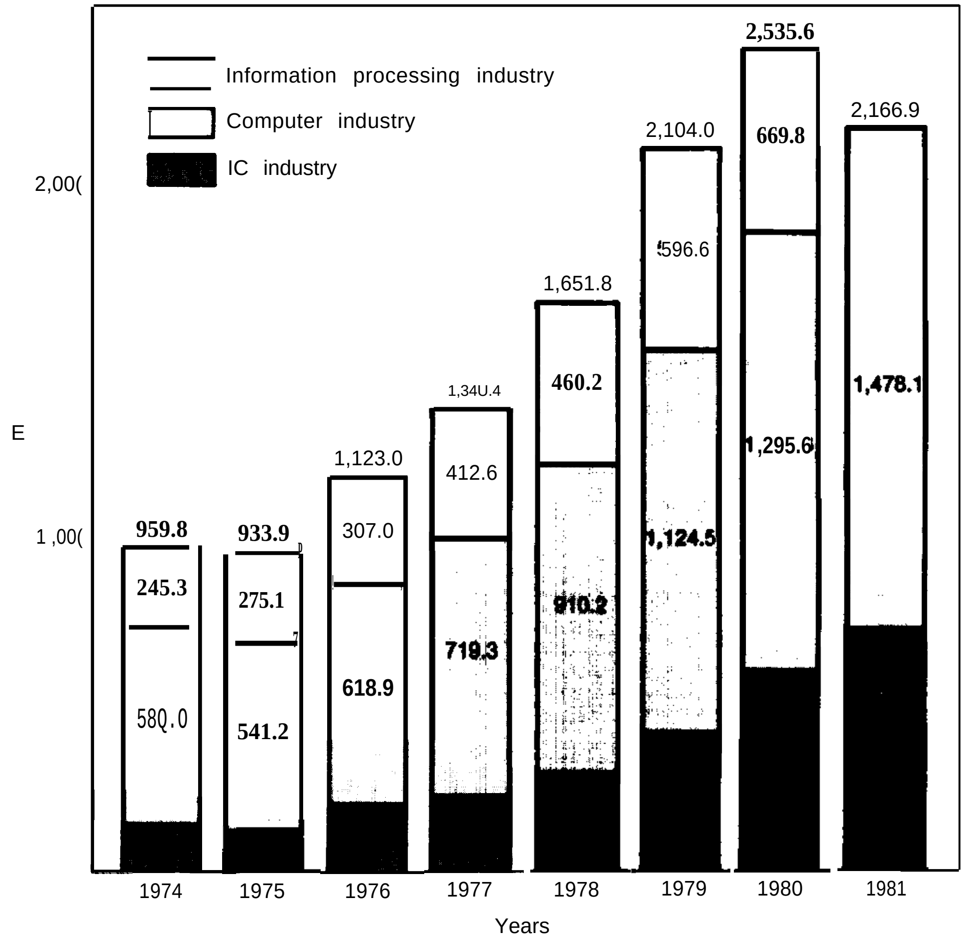
[47] **Phillip J. Hilts, "Japanese Firms Build Two Fastest Computers, "** *The **Washington** Post,* **Feb. 7,** 1984, **p. A,**1.

Figure 43.—Japanese Information Technology Industry Sales



NOTE: Information Processing Industry sales figures for 1981 not available.

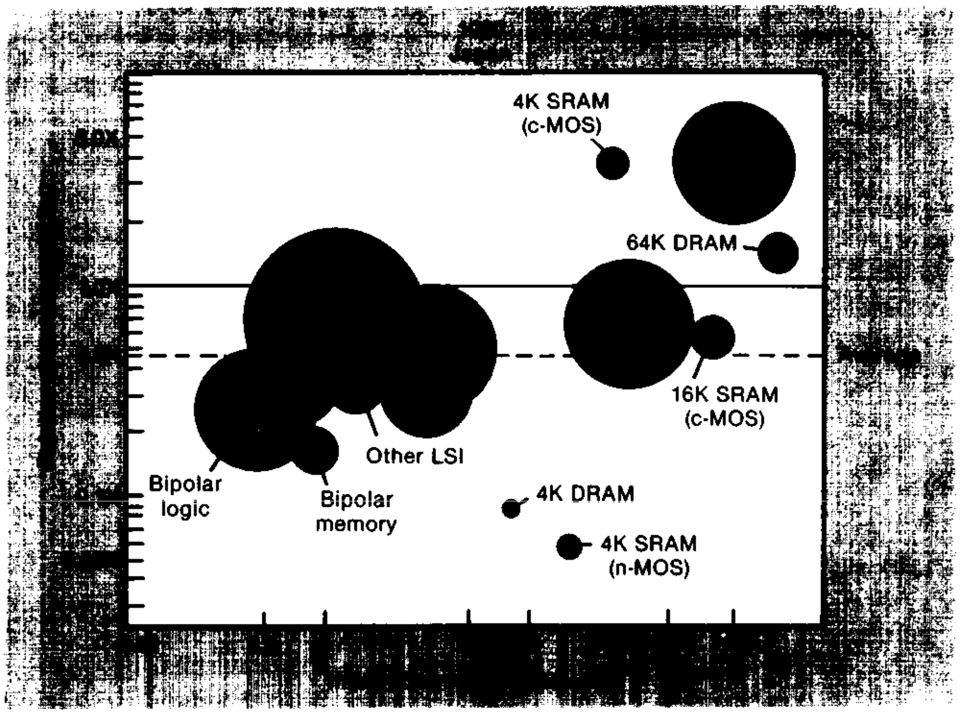
SOURCE: **MITI** Survey on Specified Services, **MITI** Production Statistics in Computer ***White Paper** 1982 **Edition**,* Japan Infer. **mation** Processing Center.

and development support, but government funding has only increased 1.4 percent annually over the past 10 years. Although the government does promote some industrial R&D, industry has always been a larger investor. Government-industry relations in Japan have been broadly discussed, and it is often misunderstood that such relations are largely due to the Japanese Government subsidy of industrial R&D.

Japan's information technology firms are fiercely competitive and the government's role is seen as a means for providing an orderly framework for coordinating private industrial development. But when any coordination or intervention is decided on, it is undertaken through the development of a consensus among private enterprise and government. This consensual decisionmaking process between industry and government, frequently accomplished informally as well as through formal institutional structures, is in many ways the most important factor affecting decisions on R&D projects and funding for information technology.

The major function of the Japanese Government is to select, or to guide the selection of technologies to be targeted, to reduce the economic risks normally associated with developing new technologies, and to assist companies

Figure 44.—integrated Circuit (IC) Relative Production Share



SOURCES: Electronics, **Dataquest**, newspaper articles; in James C. **Abeggien** and Akio **Etori**, "Japanese Technology Today," ***Scientific American***, supplement, 1982

to achieve large scale production. The direct financial support for R&D provided by the Japanese Government to targeted industries is in many instances less important than the fact that the industry has been singled out by the government as a "target" sector. There are tangible and intangible benefits which flow to such industries. A targeted sector gains prestige and public respect. Private banks are more willing to extend credit, customers and suppliers will tend to give preferred treatment, and government officials in various agencies are also likely to be more responsive to the particular needs of target-sector companies.

In addition to the informal consensual decisionmaking, targeting and funding of information technology R&D is accomplished through major formal government institutions: Ministry of International Trade and Industry (MITI), Science and Technology Agency (STA), Ministry of Education, Culture, and Science (MOE), Ministry of Posts and Telecommunications (MPT) which has nominal control over Nippon Telegraph and Telephone (NTT), and the Ministry of Finance **(FOC)** through the Japan Development Bank (JDB). The major Japanese Government organizations directly involved with information R&D are illustrated in figure 45.

Ministry of International Trade and Industry (MITI)

Perhaps the most misunderstood agency within the Japanese Government, the Ministry of International Trade and Industry (MITI) has been credited by many in the United States as being much more pervasive than it is in reality.[48] Taking into account the scale of the Japanese economy, the complexity of international markets and the rapid changes in technology, MITI alone cannot and does not completely control industry. A case in point is MITI's failed attempt during the 1970s to consolidate the Japanese automobile

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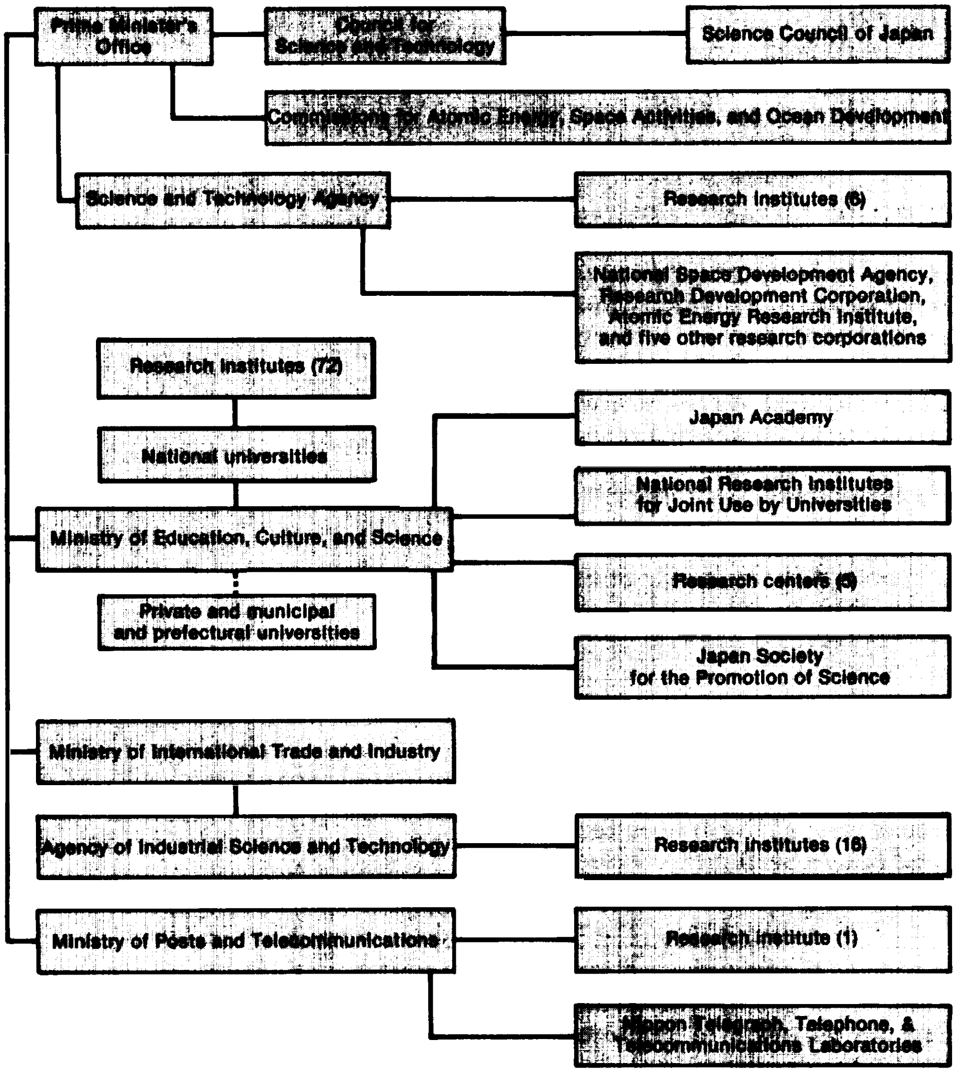
[48] **Toshimasa Tsuruta, "The Myth of Japan Inc.,"** ***Technology Review***, **July 1983, p. 43-48, and Robert C. Christopher, "Don't Overestimate Tokyo Industrial Aid,"** *The New York Times*, **Jan. 30,** 1984, p. **A,** 21.

Figure 45.—Japanese Government Organization for Information Technology Research and Development



SOURCE: "Science in Japan," *Nature,* Sept. 29, 1983.

industries into three large groups. Some have claimed that MITI is on paper at least no more influential than the Department of Commerce in the United States.[49]

MITI was established in 1949 with the broad charter of shaping the structure of Japanese industry, managing foreign trade and commercial relations, ensuring adequate raw materials and energy supplies, and managing relationships between particular business and technical industrial sectors and the government. Despite this broad legal mandate, the pervasive MITI practice of "administrative guidance" by which many policies are implemented depends on no statutory authority. Nevertheless, MITI does have the advantage of broad contacts across information technology industries and relies extensively on this informal practice to influence firms and whole industries in the direction it wants them to take.[50]

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[49] "Science in Japan," *Nature,* vol. 305, Sept. 29, 1983.

[50] Ira C. Magaziner and Thomas M. Hout, *Japanese Industry Policy* (Berkeley, CA: Institute of International Studies, 1980), pp. 40-41.

Within MITI's bureaucratic structure, the Industrial Policy Bureau has played the major role in guiding overall industrial development. This Bureau consults with representatives from all industrial sectors and through these informal and formal meetings sets Japanese industrial policy. The major MITI bureau involved with information technology is the Machinery and Information Industries Bureau. In general, this Bureau oversees and coordinates export, import, production, distribution and consumption of machinery and mechanical apparatus. In addition to information technology, aircraft, automobile, machine tools, as well as other industries, are within the Bureau's responsibilities. Within the Bureau there are several divisions which deal directly with information technology.

The most significant division involved with information technology is the Electronics Policy Division. Its responsibilities include: 1) planning comprehensive policies for electronics equipment industries; 2) the distribution of computers; 3) planning programs on the utilization of computers; 4) conducting surveys on the utilization of computers; 5) representing the Japanese Government at international organizations concerning information technology matters; and 6) overseeing the Data-Processing Promotion Council.

The Industrial Electronics Division is responsible for exports, imports, production, distribution, promotion of consumption, and improvement and adjustment of communications products. These products include computers, laser application devices, radar, electronic measuring instruments, telephone and telegraph equipment, switchboards, facsimile equipment, broadcasting equipment, fixed multiplex communication devices, and communication wire and cables.

Two other divisions, Data-Processing Promotion and Electrical Machinery and Consumer Electronics, also are directly involved with information technology. As its name suggests, the Data-Processing Promotion Division responsibilities include: 1) the examination and licensing of data processing technicians; 2) the cultivation and promotion of data processing service industries; and 3) the promotion of computer usage and applications programs development.

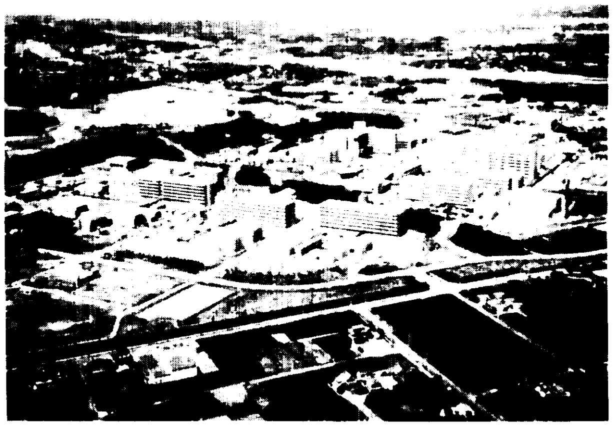
In addition to these major Bureaus and their respective divisions, MITI policies are influenced by several advisory councils, industry associations, and research associations. Perhaps the most unique aspect of MITI policymaking, these advisory groups are where industry and government officials develop a consensus on goals and policies for technological development. In these councils and associations members from government, academia, and industry discuss technology trends, market potential, and policy. Problems, ideas, and proposals are discussed, and if a general consensus is obtained, it is reflected in government and industrial R&D policies and practices. In addition to these formal channels, there are also a number of informal exchanges between government and industrial representatives.

Within MITI, the Agency for Industrial Science and Technology (AIST) is explicitly oriented toward research and development of technology with industrial applications. In addition to its responsibilities of planning and administering policies and programs for research and development, AIST operates 16 government laboratories, including the Electrotechnical Laboratory (ETL), the major MITI laboratory for information technology R&D. In conjunction with ETL, AIST also oversees collaborative research with affiliated laboratories and private companies-particularly for MITI's targeted national information technology R&D programs. The AIST also administers the industrial standards programs.

Directly under MITI's jurisdiction, the Electrotechnical Laboratory is the largest national research organization in Japan specializing in electronics research. The ETL, with an annual budget of $40 million, employs approximately 730 researchers. ETL's major areas of research include solid state physics and materials, information processing, energy, standards, and measurements. Similar to DOD facilities in the

United States, ETL has in addition to Its own internal research, responsibility for advising the government on technology options and monitoring industrial R&D programs. ETL, like other technology in-house research laboratories, does not attempt to compete with industry. As in many U.S. Government research labs, ETL concentrates on identifying research projects and directions (usually high risk) where it could supplement industrial research activities. ETL also oversees the industrial research efforts for MITI coordinated national R&D projects.[51]

As the Japanese Government began to move into more basic research activities and new state-of-the-art technologies, many of its policymakers felt that its institutions were ill--equipped (e.g., too constrained, rigid) for basic, pioneering research. Consequently, Tsukuba Science City, which was begun in 1966, was planned and built by the government for the purpose of centralizing research and educational activities. In terms of its concentration of high level personnel, it in many ways resembles Silicon Valley in the United States, although in terms of government organization, the North Carolina Research Triangle is perhaps a better comparison. Located within Tsukuba City are 30 of Japan's 98 national research institutes. These 30 research institutes account for approximately 40 percent of the total research budget and 40 percent of the total number of researchers in Japan. In addition to these 30 national research institutes, the Tsukuba Science City accommodates a total of 46 research organizations, including two national universities, six organizations belonging to government-funded special organizations, and eight organizations affiliated with other administrative entities. Approximately 27 research-oriented private corporations have also relocated to Tsukuba Science City.”



Phofo cred(f Embassy of Japan

Tsukuba Science City

National Research and Development Projects

Another effort to stimulate basic long-term research activities by coordinating industry and government research efforts was begun in 1966 with the initiation of National Research and Development Projects. Perhaps the most significant aspect that sets Japanese R&D efforts apart from U.S. R&D, these national projects are directed towards research that is in the Japanese national interest, long-term, high-risk, and precompetitive-research that is not directed towards any specific product, but technology that is useful for an entire industrial sector.

The initiation of a national R&D project is accomplished through a series of steps. First, through meetings with government, academic, and industrial representatives, usually within various councils and associations, MITI officials derive a consensus on areas for national R&D attention. MITI's “Vision of MITI Policies in the 1980s ” is an example of the consensuaI decisions reached among the representatives. Reflected in these “Visions of the 1980s” is Japan's basic national economic philosophy which states that Japan should seek to ensure its economic survival by becoming a technology-based nation and by making maximum use of brain power, which is its greatest resource to develop innovative technology.[53] More specifically, the report suggests

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“George E. Lindamood, “The Rise of the Japanese Computer Industry, ” *Scientific Bulletin,* **Department of the Navy, Office of Naval Research Far-East, vol. 7, No. 4, October-December 1982, p. 61, 62.**

‘*For a detailed discussion of Tsukuba **Science City see Justin L. Bloom and Shinsuke Asano, ‘‘**Tskuba **Science City: Japan Tries Planned Innovation, ”** *Science,* **vol.** 212, **June 12, 1981, pp. 1239-47 and “Science City in Japan-Tskuba, ”** *Science and Technology in Japan,* **January-March 1983, pp. 6-11.**

[53] **“The Vision of** MITI **Policies in the** 1980s, **” provisional translation, Ministry of International Trade and Industry, Tokyo, Japan, Mar. 17, 1980.**

that Japan should encourage development efforts and a switch-over to “forward-engineering” in the knowledge-intensive or information technologies.

By targeting specific information technology areas for national priority, MITI identifies those areas to receive a combination of direct and indirect project R&D support. This support system for national projects, often termed seed money because of its relatively small amount, initiates basic precompetitive research and leaves to industry detailed product-oriented decisions. Often this seed money is given to various information technology firms in the form of 50-50 matching grants.

Lastly, MITI forms company groups or research associations to work on a specific national project. Sometimes research associations have actually overseen R&D activities (as in the VLSI project); however, these research associations generally coordinate each member’s separate research efforts. Staff of these research associations usually include employees on detail from government and industry, as well as retired industry and government officials.

Between 1966 and 1979, the Japanese Government contributed approximately $400 million to 16 different national research projects.[54] A chronological history of Japanese Government support for national information technology research and development projects is presented in figure 46. Since the early projects, typical amounts committed to national research projects appear to be increasing and the scope of the projects is towards more basic research.

The VLSI development project exemplifies one of the better known national information technology R&D projects, largely because of the subsequent market success of the Japanese integrated circuit industry. Begun in 1976, the VLSI project involved the formation of a new VLSI research association with seven participating private companies in addition to Nippon Telephone and Telegraph and the MITI Electrotechnical Laboratory. The project was jointly funded at $150 million from government and $200 million from industry over a 4 year period. The VLSI Research Association and MITI laboratory efforts were largely generic and provided support for already existing industry R&D efforts. The net effect of these efforts was the worldwide introduction of the first 64 K RAM device. The resultant successes of the Japanese information technology industry may signify that efforts across public (MITI), quasi-public (NTT), and private (major corporations) sectors in pursuit of a common national technological goal is in fact one of the strengths of the Japanese national R&D projects system.[55]

The national information technology R&D project which has received the most attention recently is the Fifth-Generation Computer Systems Project. Begun in 1979, the project has become an impetus to the initiation of other major national information technology R&D projects in the United Kingdom, France, and Europe.

In light of the Japanese Government’s goal of stimulating basic research efforts, the objective of the fifth-generation computer project is to move Japan to a lead position in information technology areas related to office automation, computer-aided design, computer-aided engineering, robotics, and computer-aided instruction. Moreover, the intent is to direct information technology development in Japan to specific societal needs. These include: coping with an aging society; increasing activity in low productivity areas; increasing energy savings; and assisting the transformation of society into one in which information plays a key role. The goal of the fifth-generation project is to develop basic technology and prototype systems that can perform functions such as inference, association, and learning as well as non-numeric processing of speech, text, graphics, and patterns.

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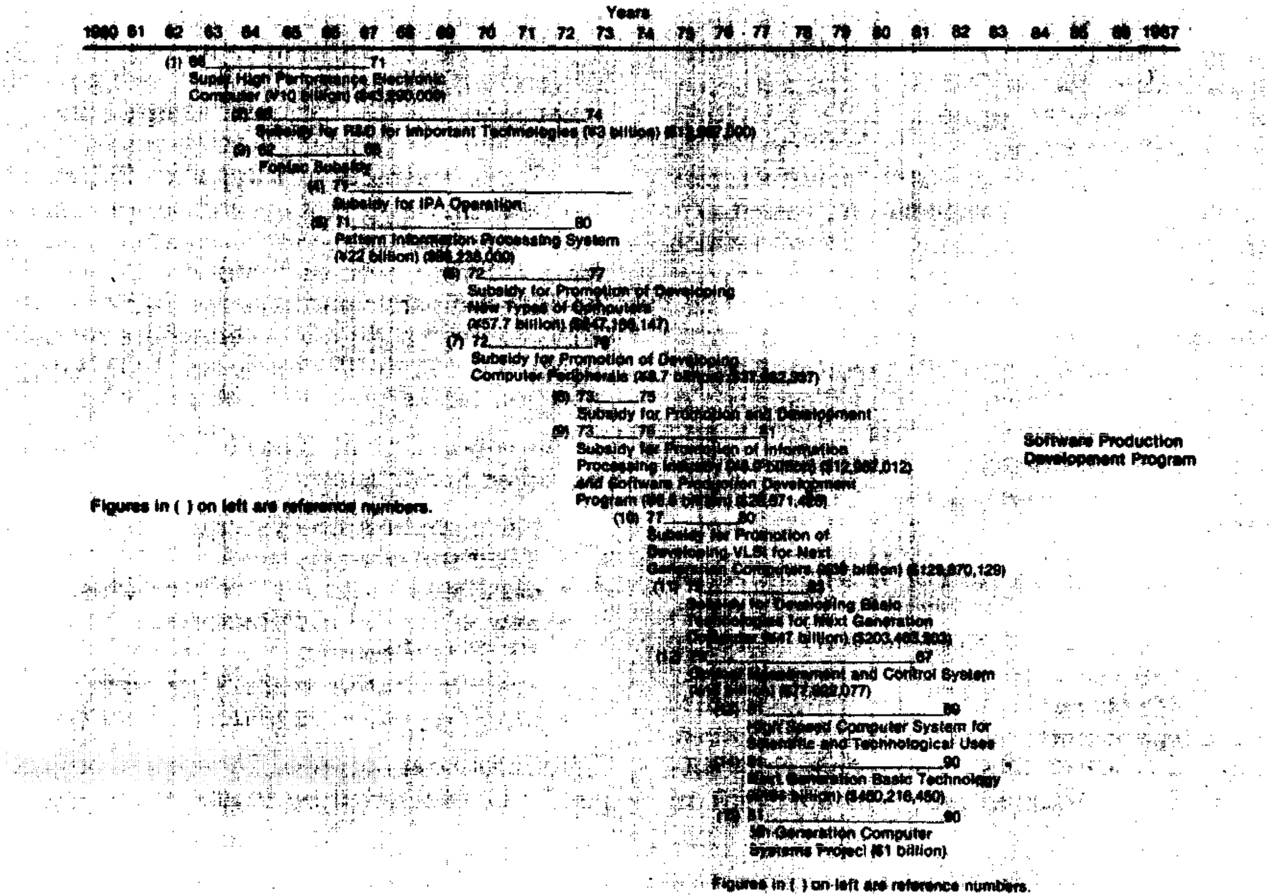
[64] Leonard Lynn, “Japanese Technology: Successes and Strategies,” *Current History,* November 1983, p. 370.

“For an in-depth analysis of the VLSI project, see Kiyanori Sakakibara, “From Imitation to Innovation: The Very Large Scale Integrated (VLSI) Semiconductor Project in Japan, ” Alfred P. Sloan School of Management, Massachusetts Institute of Technology, 1982-1983.

Figure 46.—Japanese Government Support for Information Technology



NOTES:

1 *Sponsors* AIST, Large Scale Project; MIT I *Funding* All government funding through consignment payments.

2 These are combined because (3) is a continuation of (1) *Sponsors* AIST, MITI *Funding* All government funding through consignment payments

3. FONTAC was aimed at developing a large size computer competitive with IBM systems. *Corporate participation* Fujitsu, OKI, NEC

4 The IPA was established by law in 1970 to encourage the development of software by direct and indirect financing IPA operations are reviewed by M(TI Three long term credit banks provide loans to software houses and data services through IPA's guarantee fund Total government support unclear, but subsidies totaled Y14.9 million for FY 1972.1980 (see text for additional material),

5 Continuation of (2) *Sponsors* AIST and Electrotechnical Laboratory *Corporate Participation* Toshiba, Hitachi, Fujitisu, NEC, Mitsubishi Electric, Sanyo. Matsushita Research Institute, Konishiroku and Hoya Glass

6. Subsidy aimed at developing a new series of computers competitive with IBM's 370 series *Funding* a 50 percent subsidy to three computer manufacturer groups *Corporate Participation* Fujitsu-Hitachi (produced M series), NEC.Toshiba (produced ACOM), and Mitsubishi-OKI (produced MELCOM)

7 *Sponsor* MITI; *Participation 31* companies, *Funding 50/50* (government/private); *Goal* develop high efficiency Input-output units and terminals

8 *Sponsor* MITI, *Participation* unclear, *Funding* 50/50 (government/private).

9. *Sponsors* Machinery and Information Bureau and Data Processing Division, MITI; *Corporate Participation:* 17 large Japanese software companies belonging to an I PA subsidiary, the Joint Systems Development Corp , in addition, a number of unspecified smaller firms, *Goal:* to Increase the production and use of software programs This constitutes IPA's most active software development program to date Results unclear

10 & 11, because 11 is seen as a continuation of (10), *Sponsors* Machinery & Information Bureau and Industrial Electronics Division, MITI; *Corporate Participation two* phases: (I) Fujitsu, Hitachi, Mitsubishi, NEC & Toshiba, OK I, Sharp, Matsushita; (II) above, plus NTT and AIST's Electrotechnical Laboratory staff, *Association formed* Phase I VLSI Research Association formed, Phase II Electronic Computer Basic Technology Research Association formed (July 1979). *Funding* (government) conditional loan, repayable if profits are generated from technologies; Phase 1: Y30 billion from the government, Y42 billion from the private sector Phase II Y22.5 billion from the government; Y24.5 billion from the private sector

12. *Sponsors* AIST, National Research and Development Program, MITI; *Corporate Participation* Fujitsu, Hitachi, NEC, Toshiba, Mitsubishi Denki, Matsushita Furukawa, OKI, Sumitomo Electric, *Association Formed* Engineering Research Association of Optoelectronics Applied Systems (January 1981); Laboratory Formed by Association: Optoelectronics Joint Research Laboratory within the Fujitsu Kawasaki Plant, *Funding* all government funding through consignment payments.

13. *Sponsors* AIST, National Research and Development Program, MITI; *Corporate Participation* Fujitsu, Hitachi, NEC, Toshiba, Mitsubishi Denki, OKI; *Government Laboratory Ass/s tance* Electrotechnical Laboratory, AIST; *Association Formed* the Association for the Development of High Speed Scientific Computers (December 1981), MITI's Electrotechnical Laboratory is also Involved, although majority of work will be conducted at companies' own research facilities; *Funding* all government funding through consignment payments.

14. *Sponsors. Next* Generation Baste Technology Planning Of fice, AIST, MITI; *Corporate Participation* 48 companies in 3 areas; numbers in ( ) Indicate number of firms, Area I: New Materials (33), Area II; Biotechnology (14), Area III: Semiconductor Function Elements (10), *Association Formed* five associations formed, 3 for Area 1, 1 for Area 11, and 1 for Area III; *Funding*: all government funding through consignment payments

15. *Sponsor"* Machinery and Information Bureau, MITI; *Corporate Part/c/pal/on* Fujitsu, Hitachi, NEC, Toshiba, Mitsubishi Denki, OKI; *Government Laboratory Ass/stance.* Electrotechnical Laboratory, AIST; *NTT Personnel Participation* primarily at preparatory stages; *Association Formed* The Institute for New Generation Computer Technology, an endowed research foundation (April 1982), *Funding* total funding yet to be determined

SOURCE Jimmy W Wheeler, Merit E Janow, Thomas Pepper, and Midori Yamamoto, "Japanese Industrial Development Policies in the 1980's: Implications for U.S. Trade and Investment, " Hudson Institute Inc , 1982, for the U.S Department of State.

The Japanese Government established the Institute for New Generation Computer Technology (ICOT) in April, 1982 as the center organization for coordinating the fifth-generation computer project R&D activities. Although the government is funding the initial 3 year R&D stage, eight manufacturers donated money to establish and run ICOT. The consortium of eight manufacturers which equally support ICOT and share in the research results are: Fujitsu Ltd., Hitachi Ltd., Matsushita Electrical Industrial Co., Mitsubishi Electric Co., NEC Corp., Oki Electric Industry Co., Sharp Co., and Toshiba Co. These companies, in addition to NTT and MITI's Electrotechnical Laboratory, have sent 42 researchers to the ICOT research center.

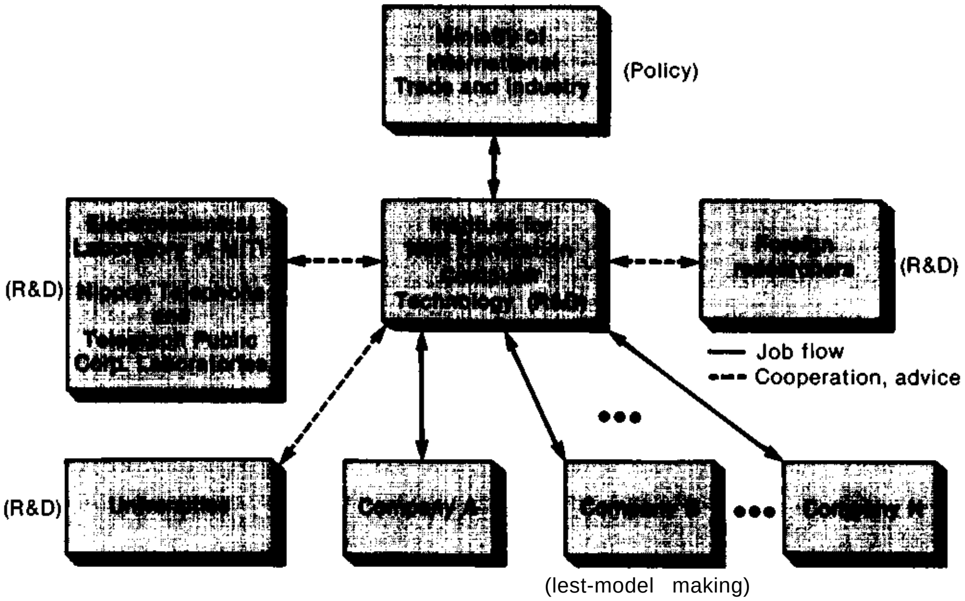
Beginning with a staff of 52 and a planned budget of $450 million over the first 5 years, the overall research program is scheduled to last for 10 years. In addition to its relatively long-term research, ICOT is unusual because it is a separate neutral organization with a centralized research laboratory. This contrasts with the traditional Japanese approach in which each of the participating research institutions and companies conducts its own research work. In addition to its own internal research, I COT cooperates with two government laboratories, various Japanese universities, and independent foreign researchers. ICOT also contracts with Japanese industries to make and test prototype software and hardware. The specific universities and companies involved vary with each individual research project and participation is not limited to the consortium of eight major companies sponsoring ICOT. Figure 47 illustrates ICOT's organization for various research projects.

The research plans of the ICOT center focus on seven major areas:

- basic application systems,
- basic software systems,
- distributed function architectures,
- new advanced architectures,
- VLSI technology,
- systematization technology, and
- development supporting technology.

Within these seven areas, 26 research projects are to be conducted by teams of university,

Figure 47.—Cooperation Between Research Participants for the Fifth-Generation Computer Systems Project



SOURCE: Trudy E. Bell, "Tomorrow's Computers—The Quest," IEIEE *Spectrum,* November 19S3.

industry, and government researchers. The 10 year span for these 26 projects is divided into three phases. Begun in 1982, the initial phase involves reviewing and evaluating research on knowledge processing and developing basic technology for the second phase. Hardware and software subsystems such as simulators, prototypes for language processing, and experimental natural language processing systems are being constructed for several experimental systems. The intermediate phase will attempt to develop subsystems for hardware and software as well as algorithms and basic architecture. The final stage will attempt to integrate software subsystems, hardware subsystems, and applications software in order to develop the first fifth-generation computer prototypes. These three phases of research within the seven different areas are illustrated in figure 48.[56]

Science and Technology Agency (STA)

The Science and Technology Agency (STA) is responsible for the overall coordination of social needs-oriented science and technology policy and expenditure in Japan. It is responsible for the planning, formulating and promotion of basic policies pertaining to science and technology, and for coordination of these policies and activities throughout the various

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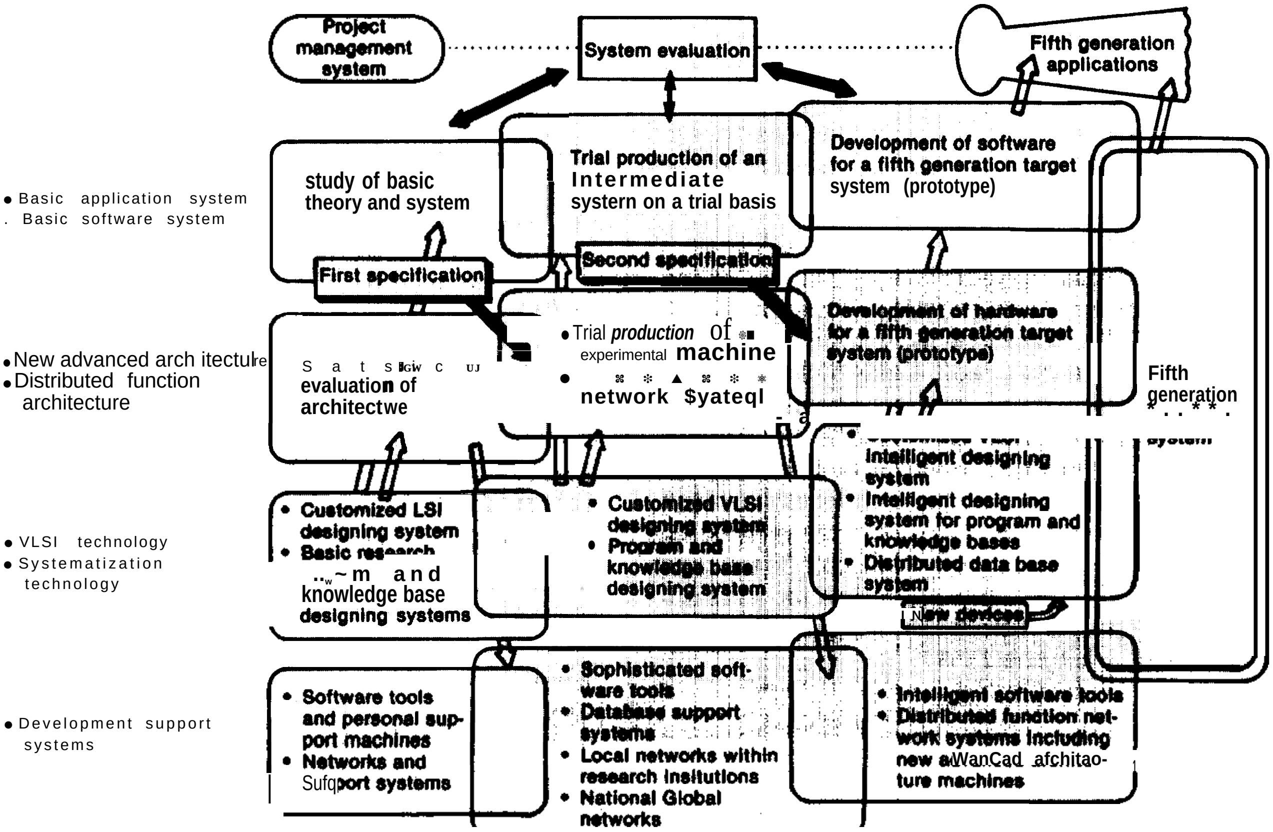
[56] See Richard Dolen, "Japan's Fifth-Generation Computer Project," *Scientific Bulletin*, U.S. Department of the Navy, vol. 7, No. 3, July-September 1982, pp. 63-97, and "Research and Development Plans for Fifth Generation Computer Systems," Japanese Embassy, April 1982.

Figure 48.—Concept Diagram Showing How Research and Development Are to Progress in the Fifth Generation Computer Systems Project



SOURCE" Fifth Generation Computer Systems Conference, Japanese Ministry of Trade and Industry, Tokyo, Japan, Oct. 19-22, 1961 government ministries. STA has jurisdiction over councils, research institutes and development agencies which mainly concentrate on technological developments in nuclear energy, space and ocean development, aviation technology, and laser technology. Practically none of STA'S budget directly supports industrial R&D; therefore, information technology R&D which is categorized as an industrial area, is not widely influenced by STA. However, approximately half of the STA budget indirectly supports information technology R&D through procurement of information and communication technology equipment and facilities for its agencies' activities.

Information Technology Promotion Agency (IPA)

Another government organization aimed at developing and disseminating information and computer systems is the Information Technology Promotion Agency (IPA), which was established in 1970 under the Information Technology Promotion Agency law. Its goal is to promote the use of computers, encourage the development and use of programs, and help software firms. It is the only national organization in the field of software promotion in Japan.

Financing for the I PA comes from government subsidies, private corporations, three long-term credit banks (the Industrial Bank of Japan, the Japanese Development Bank, and the Long-term Credit Bank of Japan), and from revenues earned by the association itself. One of the more important of IPA's activities is its credit guarantee programs. Information processing firms and software houses are often in need of funds to develop software programs, but have limited property that can be used as collateral. The I PA has a system for guaranteeing such obligations, as long as they are registered with the IPA.[57]

Japan Electronic Computer CO. (JECC) and Japan Robot Leasing Co. (JAROL)

Assistance is also provided by the Japan Electronic Computer Co. (JECC), which borrows money from the Japan Development Bank (JDB) and also from private banks. It is a jointly owned firm that purchases computers from participating manufacturers and leases them to customers. In 1980, the Japan Development Bank provided $263 million to the JECC, $218 million in 1981, and approximately $100 million in 1982. When the JECC was first established, it provided major support for the Japanese computer industry; however, as the financial resources of these companies increases, the Japanese computer companies have become less dependent on government subsidy and are establishing their own leasing operations.

The Japanese Government also helped toestablish the Japan Robot Lease Co. (JAROL) which is made up of 24 members of the Japan Industrial Robot Association and 10 insurance companies. JAROL'S objective is the encouragement of the development and use of robots in small and medium businesses. Like the JECC, JAROL buys robots from manufacturers and leases them at low prices to small businessmen. JAROL also receives most of its funds from the JDB and is therefore able to lease its robots at low prices. Similar to the JECC, JAROL aims to create a mass market for robot technology while encouraging production.

Ministry of Posts and Telecommunications (MPT): Nippon Telegraph and Telephone (NTT)

The Ministry of Posts and Telecommunications (MPT) indirectly influences information technology research and development because of its administrative guidance over Nippon Telegraph and Telephone (NTT).[58] NTT's

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[57] An IPA-style credit guarantee system is not uncommon in the United States. However, the American credit guarantee systems tend to be aimed at broad industries, such as housing, rather than at narrowly targeted sectors.

[58] There is Some contention over whether NTT should be classified as a nongovernmental or governmental entity. Because NTT receives no direct funding from the Japanese Government some argue that Nil' is not a government entity. On the other hand, the U.S. Government has encouraged NTT to open up its procurements to foreign suppliers on the grounds that NTT is a government entity and therefore is subject to the GATT government code.

budget, services, tariffs, and overall policies, as well as appointments of top officials, are subject to MPT's review and approval. However, NTT has not received a government subsidy for over 30 years; in fact, over the last 3 years NTT has returned to the Japanese Government on request approximately $2 billion. This contrasts sharply with the idea that the Japanese Government heavily subsidizes information technology R&D.

NTT is the domestic public telecommunications monopoly in Japan, although it does not have any manufacturing capability within the organization. NTT, as the owner of virtually all the telephone lines in Japan, remains the most powerful single entity in Japanese telecommunications. NTT accounts for about three-quarters of the Japanese market for telecommunications and data communications, equipment, and services. As a result, NTT with its demands for new equipment and services has a powerful influence on Japanese information technology research and development—more so than MITI.

Typically, new communications products destined for NTT use are initiated in one of its four Electrical Communications Laboratories (ECL). NTT spends approximately 2 percent of its revenue on R&D (which amounted to more than $350 million in 1980), mainly at ECL labs. This system of labs corresponds to Bell Labs although it is approximately one-fifth of the size of its U.S. counterpart. ECL tends to do more developmental R&D rather than the basic research for which Bell Labs has been so widely acclaimed. Much of the research carried out at NTT's labs is devoted to achieving the extremely detailed and demanding specifications that the company requires when it issues R&D contracts to private firms.

More often, NTT launches research in collaboration with one or more of the four major Japanese electronics firms (NEC, Fujitsu, Hitachi, and Oki Electric), which actually send staff to the NTT labs. The subsidized joint research normally results in NTI's appointment of a preferred supplier from among the researchers when the time comes to purchase the product. Because NTT is one of the largest information technology and telecommunications markets in Japan, most electronics firms cooperate with NTT. Competition often develops between these firms in efforts to be selected as partners in new technologies and systems developments.

NTT divides its procurement procedures practices into three tiers or "tracks" which have been agreed to in the General Agreement on Trade and Tariffs (GATT) and other bilateral trade agreements:[59]

> Track 1 (competitive bidding) is applied to products to be procured based on the Government Procurement Code agreed to by the General Agreement on Trade and Tariffs (GATT). These procurements usually include off-the-shelf products such as PBXS, data terminals, modems, computers, peripherals, facsimile machines, measurement instruments, etc.
>
> Track II is applied to equipment that is not available in the marketplace and which requires some research and development. This track generally refers to products for which a limited amount of collaboration between the supplier and NTT is necessary to tailor applications to NTT's specifications. Track II contracts are normally single-company contracts.
>
> Track III is applied to equipment not available in the marketplace and which requires extensive R&D for NTT use. These are the most highly prized contracts and the most difficult for foreign or small companies to penetrate. NTT seeks a supplier with sufficient research ability to develop a product, or to develop one according to an NTT prototype.
>
> In addition, there are Tracks 11A and 111A that allow for new producers to take over expired Track II and III contracts.

U.S. and other foreign telecommunications equipment manufacturers have suggested that NTY'S close collaborative R&D activities with several Japanese companies prevent them from penetrating the Japanese telecommuni-

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[59] Jack Osborn, outgoing telegram from the U.S. Embassy in Tokyo, Japan, Oct. 21, 1983, 7 pages.

cations market. With a 20:1 trade deficit in telecommunications equipment and a substantial Japanese penetration of certain U.S. market niches, many U.S. companies would like to balance some of these telecommunications trade deficits.[60] Moreover, other motivations for insisting on participating in the Japanese market relate to the changing balance in American and Japanese research and development. Just as the Japanese presence in the American market has a dual purpose-exports and the transfer of technology-so might American participation in Japanese markets and R&D activities serve two functions.

The issue of NTT's procurement policy can be best viewed within the framework of the plans for liberalization of the entire Japanese telecommunications monopoly. Because a large amount of NTT'S profits (last year's profit was $1.6 billion) goes to the Japanese Government ($600 million) which needs revenue in the face of its continuing deficits, NTT cannot make a large profit. Another fiscal constraint is the rapidly decreasing rate of growth in the number of telephone users. More than 90 percent of Japanese households now have telephones, which means that the traditional market (revenue) has leveled off. In addition, NTT is in the process of testing and eventually implementing its ambitious 20-year all-digital Information Network System (INS) program, which is expected to cost up to $120 billion by 1990.

To solve these financial problems, Prime Minister Nakasone is supporting a major four step reform plan recommended last year by a special study group commissioned to study the Japanese Government. The plan, now under discussion, would first convert NTT to an incorporated government-owned entity. NTT would then be free, however, to set its own management and personnel policies. Under the proposed plan, many operations, such as data communications services, would be delegated to spin-off companies operating at a regional level-somewhat like the pattern of the AT&T divestiture in the United States.

Hisashi Shinto, the new chairman of NTT, believes that transforming the massive bureaucratic Japanese telecommunications monopoly into a partly private company will be more profitable, while encouraging greater competition and innovation in the telecommunications and information technologies industries. It is believed that more Japanese companies will be encouraged to vie both for NTT's business and for the private telecommunications market previously controlled by NTT and its selected family of suppliers.

Kokusai Denshin Denwa Ltd. (KDD)

The KDD operates Japan's international telephone, telegraph, and other related communications services.[61] Divided from NTT in 1953, it is 90 percent privately owned, with 10 percent of its stock held by NTT. At the time of the inauguration of KDD, the international telecommunications research group of the Electrical Communication Laboratories of NTT was transferred from NTT and reorganized as KDD's Research Department. By 1969, a development center was created and the department was renamed Research and Development Laboratories. The laboratories, located in Meguro, Tokyo, employ more than 120 R&D personnel and are composed of 12 special purpose laboratories and three divisions.

A new laboratory being built in the Nerima suburb of Tokyo, will be completed in 1985. This R&D reinforcement will permit further research and development concentration in such fields as switching for integrated digital networks, fiber-optic submarine cable transmission, satellite digital transmission, optical-memory disks, system conversion techniques, wideband video, etc. To help in this effort, KDD expects to add 50 more engineers to its R&D staff by 1988.

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[60] In 1982 the Japanese exported more than $408 million in telecommunications equipment to the United States. During this same period, Japan imported less than $88 million of this same equipment from the United States. Peter J. Harm, "Data Communications in Japan, " Data *Communications,* **August 1983, p. 56.**

[61] Yasuo Makino, "Telecommunications in Japan: Changing Policies in a Changing World, " ***Telecommunications,*** **October 1983, pp. 139-145.**

Defense Agency

Because of Japan's small national market for defense equipment, Japanese defense research and development activities are fairly limited. Overall, Japanese procurement of defense equipment accounts for less than four-tenths of 1 percent of total Japanese industrial production.

Within the Defense Technical Research Institute there are very small-scale development projects on electronics equipment (radar, etc.) with a budget of ¥ 1.3 billion ($5.6 million) in fiscal year 1982, ¥ 0.6 billion ($2.6 million) in fiscal year 1983, and ¥ 3.8 billion ($16.5 million) in fiscal year 1984. These projects are done in cooperation with private firms. In addition, the Defense Agency indirectly supports information technology R&D by purchasing hardware for testing purposes from private electronics firms.

As a result of economic trends in both the United States and Japan, as well as a changing international security environment, there have been growing tensions over trade and defense issues. In general, some Americans believe that the low level of Japanese military expenditures frees funds for civilian research and investment while requiring higher taxes and absorbing resources in the United States which in turn provides defense.[62] As a result, the U.S. Government believes that Japan should increase its military strength as well as information technology R&D expenditures for military applications. Moreover, U.S. companies argue that an inequality exists between United States and Japanese trade: no manufactured U.S. civilian product (with the single exception of airplanes) has captured as much as 10 percent of the Japanese market, while approximately 14 percent of Japanese defense equipment is purchased by the United States.[63]

Japan Development Bank (JDB)

The Japan Development Bank (JDB) is another government financial intermediary used to target industrial development. The Japanese Government's Trust Fund Bureau (which is the main organization in its Fiscal Investment Loan Program) provides JDB with its main source of capital, though it can also raise funds by issuing certain types of bonds. JDB's principal responsibility has been the extension of long term, low interest loans for capital investment in new industries. In the years immediately after its formation, JDB concentrated on loans for the reconstruction of basic manufacturing industries.

As a result of the consensus to increase the support for "knowledge-intensive' industries, the JDB began to target support for what it terms "development of technology." The funding categories in area of development of technology are illustrated in table 43. Most of the computer funds, as a matter of policy, have gone to the JECC, although some software firms have also received funding. For the other funding areas for technology development, there are two general JDB loan programs. Both of these loan programs, which resemble MITI's seed money grants, attempt to stimulate private investment in specific areas of information technology R&D. The first loan program, set up under a 1978 law, amounted to ¥ 10 billion ($43.3 million) in 1981. Loans from this program must be directed toward specific project areas designated by cabinet order. Should a designated project area be oversubscribed (as happened with semiconductors), JDB can force larger firms that have better access to private financial markets to utilize those markets, while JDB loans are preserved for the smaller firms.

The other technology development loan program was established by the bank itself and not designated by specific laws, though it still falls within the broad policy guidelines of the government. This part of the JDB budget totaled ¥ 44 billion ($190.5 million) in 1981.

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[62] David Denon, ''Japan and the U.S.—The Security Agenda, " *Current History,* November 1983, p. 355,

[63] Stephen J. Solarz, "A Search for Balance," Foreign *Affairs,* p. 75.

Table 43.—Japan Development Bank Loans for Development of Technology (in billions of yen)

	Fiscal year 1977	Fiscal year 1978	Fiscal year 1979	Fiscal year 1980	
New **loans**	¥71.2	¥129.0	¥108.5	¥96.4	$457”
Development of electronic computers	38.2	55.3	47.1	55.4	262
Domestically-manufactured computers	35.5	53.5	45.0	54.0	256
Computer manufacturing plants	0.4	0.2	0.4	0.6	3
Data processing systems	2.3	1.6	1.7	0.8	3
Use of high technology in certain electronic and machinery industries	8.3	7.8	10.2	14.5	69
Electronic industry	3.8	2.1	7.0	12.0	57
Machinery industry	4.5	5.7	3,2	2.5	12
Development of domestic technology	24.7	65.9	51.2	26.5	126
Development of new technology	20.4	57.4	40.9	22.6	107
Trial manufacturing for commercial use	0.9	4.0	1.2	0.3	2
Development of heavy machine	3.4	4.5	9.1	3.6	17

[a]In millions of dollars.

SOURCES: *U.S. **Facts and** Figures **About the Japan Development Bank,*** Japan Development Bank, 1981, p. 28; and Jimmy W. Wheeler, Merit **E**. Janow, Thomas Pepper, and **Midori Yamamato,** “Japanese Industrial Development Policies in the 1980’s: Implications for U.S. Trade and Investment,” Hudson Institute **Inc.**, 1982, for the U.S. Department of State.

These loans are devoted to new domestic technologies and initial manufacturing efforts for commercialization of these new technologies. Firms that believe that they have developed a process or technology falling within the broad parameters established by the cabinet must apply in order to be considered for loans; JDB does not solicit customers. The firm’s proposal is submitted to a council of scientific advisors, which evaluates the proposal. If the technology is approved, the applicant then faces an evaluation of credit worthiness and of the financial characteristics of its loan application. If the applicant is a large company with well established financial links, it must concurrently seek private financing, because JDB will provide only partial funding. If the applicant is small, and has relatively weak financial links, or if the project is large-scale or viewed as a high priority for the nation, then the JDB may take a lead role in putting together a consortium to finance the project. Finally, by general agreement, the JDB only finances the first plant in a new area. Its role is to help launch new technology, not to provide low cost financing for the expansion of industry.

The small size of the JDB loans indicates that the importance of government’s financial mediary role “stems not from outright control or from overall size, but rather from socializing risks, coordinating private investments, and processing information.”[64]

University

The Ministry of Education, Culture, and Science (MOE) funds research at three research institutes, six National Institutes (for joint use by universities), and 93 national universities.

Among the various national universities in Japan, the big seven are the universities of Tokyo, Kyoto, Osaka, Tohoku, Hokkaido, Nagoya, and Kyushu. In the area of information technology, Tokyo University has activities in several departments: information science (in the Faculty of Science), information engineering and precision engineering (in the Faculty of Engineering), as well as a large central computer center. In most of the other universities, there is just one department (usually in the Faculty of Engineering), as well as a sizeable central computer center. Kyoto University claims to have the oldest information engineering department and is considered a close rival to the University of Tokyo. Other national universities that have significant

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[64] Eisuke Sakakibara, Robert Feldman, and Yuzo Harada, “The Japanese Financial System in Comparative Perspective,” a study prepared for the use of the Joint Economic Committee (Washington, DC: U.S. Congress, U.S. Government Printing Office, Mar. 12, 1982), p. 11.

computer science departments include Tsukuba University and the Tokyo Institute of Technology. Among private institutions, only Keio University and Waseda University are considered to have sizeable computer science programs.

Higher education has become an important social investment in Japan. Between 1960 and 1975, the numbers of students in higher education multiplied by more than three times (to 2.2 million), including students in Japan's junior colleges (post high-school institutions concerned with teacher training, technical education, etc.). Of the 1.73 million undergraduates enrolled at Japanese universities in 1981, approximately 334,000 were enrolled in engineering studies (exactly six times as many students in the natural sciences, including mathematics). Many universities have no science faculty, only engineering departments. These large numbers of engineering students indicate the heavy emphasis placed on engineering in Japan. Consequently, Japan continues to maintain a large engineering manpower base. However, a small percentage of these engineering students continue on to graduate study where they could contribute to basic university research. For instance, in Japan, the proportion of graduate research students to the entire undergraduate student population is 3 percent. In the United Kingdom the proportion is over 19 percent; in France 22 percent; and in the United States 12 percent.[65] Although Japan has more undergraduate students enrolled in electrical and electronics engineering programs than the United States, Japan has approximately one-fourth as many electrical and electronic engineering graduate students as the United States. Because students at the graduate level make a large contribution to basic R&Din university environments, the low number of Japanese graduate engineering and science students has been cited as one reason for such a small amount of university research in Japan. In this context it is also worth noting that Japanese companies, which prefer to train their own development engineers, like to recruit young inexperienced persons-recruiting them before they go on to postgraduate work.

Recently, there has been concern that the environment for information technology basic research has generally not been adequate at Japanese universities. In addition to the inadequate number of graduate students, two other causes for the small amount of information technology basic research activities in Japanese universities have also been cited.

Some researchers believe that the heavy emphasis on rote learning in Japanese schools has helped to suppress creativity in the learning process. Moreover, the importance of severe university entrance examinations has been seen as a deterrence to specially talented or creative students.

Researchers usually cite two indices of success in originality and successful basic research-the number of Nobel Prize winners and the frequency with which scientists' work is cited by other researchers. Japan has had four Nobel Prize winners. The citation index devised by the Institute of Scientific Information in the United States includes 19 Japanese researchers (and roughly half of those worked in American laboratories) among the 1,000 international scientists accredited with the most frequent citations in the scientific literature.[66]

A second major factor affecting basic research in university environments is the level of government funding. More than 98.8 percent of R&D expenditures at national and public universities was funded by the government and only 1.2 percent by private industry.[67] In 1979, universities spent approximately $3.69 milion for R&D: national and public universities spent $2.459 million, and private universities spent $1.15 million. The funds for research are distributed by the Ministry of

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“The Economist, **Aug.** 6, 1983, p. 65.

[66] The citation system **however, does not take** into **account the fact that very few Western scientists are able to read the Japanese scientific literature that is published in Japanese. See March 1984 hearings held by the House Science and Technology Committee on Japanese science and technology information.**

[67] **Michiyuki Venohara, Nippon Electric Company, Ltd., “Japanese Social System for Technological Development-Its Merits and Demerits, ” presented on Dec. 8, 1982 in Endohoven, Netherlands, p. 21.**

Education in the form of formula support and project research grants.

Through formula support the government provides each Department Chairman with three posts, two assistant professors and one research assistant or vice versa. In each engineering or information science department or other related department, the chairman is given approximately ¥ 7 million ($28,000) to spend on research. Half of these funds maybe kept by the university to cover administration costs. As a result, many departments are left with approximately ¥ 2 million ($8,000).

The research project grants, totaling ¥ 40,000 million ($160 million), also appear to be insufficient because of their short term and small amount. A limitation is that the funds cannot be used for recruiting short-term assistance because most researchers (as well as most Japanese workers) enjoy life-time employment. The Japanese Government began in 1982 to award 3 or 4-year support for research projects, each costing approximately $1 million.

Although funding levels for basic research are sometimes perceived as being inadequate, the equipment in university laboratories has been described as adequate by one recent American visitor to the University of Tokyo labs:

> In general, both in the industrial as well as in the university laboratories, the impression I got was of a lot of equipment, some old, some new, mixed in a somewhat random fashion. In the university laboratories, in particular, space seems to be at a premium. There does not, however, appear to be any shortage of new equipment.[G8]

Research and Development Links Between Universities and Industry

Direct cooperation between universities and industries in basic and applied R&D has been relatively limited. Japanese companies do not encourage students to obtain work experience in private industry. Furthermore, most Japanese firms do not generally look to universities for innovative ideas; the larger, more important firms prefer to carry out their own basic research. Some university professors in Japan have accused Japanese firms of suffering from a "not invented here syndrome" and this has caused a great mistrust between industry and university faculty. A further factor is that the Ministry of Education, which is the direct employer of university staff, actively discourages direct links between academics and companies. Professors at state universities are forbidden to consult for private firms because it could lead to nepotism in obtaining appointments.

The most effective channel for university-industry collaboration in Japan is through informal personal links. In comparison with other countries Japanese graduates remain in close contact with each other throughout their professional careers. This leads to valuable cooperation between academics and industrialists, particularly in research. This is reinforced by the role university professors play (as employees of the Ministry of Education) in the establishment and implementation of national research programs, such as the VLSI project and the Fifth-Generation Computer Systems Project. The presence of academics in the controlling bodies of these projects helps to exchange research results between companies and universities more effectively.

Other cases of informal collaboration include exchanges of researchers between companies and industries. For example, the Electronics Department at the University of Tokyo currently has five visiting researchers from well known Japanese electronics companies for periods of 1 or 2 years. Also the department receives grants from at least 10 companies to be used for purchasing equipment. The arrangement for visiting researchers from industry has some similarity to the U.K.'S Teaching Company Scheme, but the emphasis seems to be on the industrialist working in the universities rather than on the academic working in industry environments.

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[68] Derek L. Lile, "Japanese Laboratory Visits," *Scientific Bulletin*, Department of the Navy, Office of Naval Research, Far East, January-May 1983, p. 48.

Collaboration between companies and university departments is also aided by the practice of using universities as "shop windows" for new equipment that is often given or sold to them at very low prices. Through university use of new equipment, firms receive feedback on the operation of new equipment and often valuable suggestions for modifications and extensions. Instances of this practice can be found in the areas of computers (Fujitsu) and telecommunication receivers (NEC).

Another recent government incentive for industry-university R&D collaboration concerns patents. As government employees, university staff in Japan were not allowed to profit from the commercial exploitation of their ideas. This has created a disincentive to patenting, while promoting dissemination of results through open publications. Currently academic researchers are being encouraged to apply for patents and at least two universities have set up special offices to facilitate the patent application process (Tokyo Institute of Technology and Tohoku University). This could be to make research results more attractive to private firms, which can in turn apply for licenses in order to market the technology.

As the technological level of Japanese industries approaches that of other advanced nations and the innovation of original technologies is more widely demanded by domestic as well as foreign markets, the need has been voiced by Japanese industrial and government circles for much closer cooperation between industry and university researchers. As a result, the Japanese Government is also encouraging closer research links between universities, industrial firms, and government institutions through the development of research parks, such as Tsukuba Science City.

Industry

To compete in global markets, Japanese information technology industries, in general, are large-scale organizations in order to assure maximum economies of scale and to sustain the large amounts of capital necessary for continued innovation. Although there are many smaller electronic firms in Japan, most of them subcontract small-scale production or fill special niches (some in global markets) which require custom or batch labor intensive production technologies. In general, however, major information technology firms are more diversified and highly integrated than other competitor nations' industries. For example, Japanese firms competing in the semiconductor markets are significantly larger in total sales and assets than their U.S. counterparts-approximately two to four times larger than Texas Instruments and Motorola, and much larger than National Semiconductor, Fairchild, and Intel.[69]

In addition to large-scale operations, many of the major Japanese information technology firms are vertically integrated. For example, most computer manufacturers produce semiconductors and several of them are major semiconductor suppliers in the world market. This sharply contrasts with the United States where, although most computer manufacturers have at least some in-house semiconductor development and production capability, only a few firms market both semiconductor chips and computers, and most of them do not

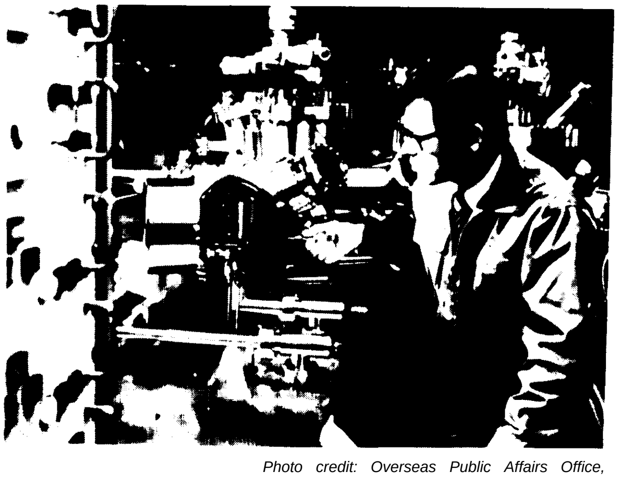

Photo credit: Overseas Public Affairs Office, Electronic Industries Association of Japan

Semiconductor research

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[69] **Gene Adrian Gregory, and Akio Etori, "Japanese Technology Today, the Electronic Revolution Continues, "** *Scientific American supplement, 1983,* **p. J,** 22.

sell the large range of products that are available from Japanese companies.

Another type of structural integration that is believed to give the Japanese a competitive advantage is in the area of consumer products. Compared to many American computer manufacturers that specialize in their production capabilities, Japanese firms which manufacture computers are also large producers of consumer electronics products. Because consumer electronics products usually have a large market and generate large sales revenues, Japanese firms can utilize these large profits to fund research and development projects in other information technology areas.

As a result of structural integration, namely, production and development of computers in conjunction with telecommunications equipment, and consumer products coupled with integrated semiconductor development and production capabilities, the Japanese information technology firms may have a strong technological base from which to continue their innovation process. Moreover, because of their vertical integration, Japanese information technology firms can draw on cash flow generated by consumer electronics sales to sustain large capital investments and research and development costs of basic research.

Japanese information technology firms also participate in cooperative joint R&D programs. Because there is relatively low technology transfer between Japanese firms (due to lifetime employment of engineers and fierce competition between firms), they often undertake identical research projects. The efforts of limited numbers of research engineers in each company are therefore spread out across many different areas, making it difficult to concentrate on basic research. In response to these difficulties, the Japanese Government created research associations so that industries could collaborate on research projects centered on different technology areas.[70]

Because of the highly competitive nature of the electronics firms, industrial researchers were at first extremely skeptical about these research associations. However, the area of cooperation is limited to very basic research, and development efforts are still necessary to develop commercial products. The basic research efforts generally leave many possible avenues for future product development and allow firms to compete with one another. Because of their wide acceptance and heavy industry participation, these joint R&D programs have been useful to Japanese industry.

NEC Corp.

NEC Corp. is Japan's largest manufacturer of communications equipment with fiscal 1982 sales totaling $4.98 billion and a pretax profit of $204 million. In 1982 sales to NTT and the Japanese Government agencies accounted for $888 million, or 19 percent of NEC'S revenues, of which a significant portion was for data communications. Foreign purchasers accounted for 30 percent of NEC'S sales. NEC has a strong position in the world market (including several plants in the United States), and it markets over 14,000 products in over 100 countries worldwide. NEC has also produced the distributed information-processing network architecture (DIMA) on which 60 to 70 percent of all networks in Japan are now based. NEC'S success in part can be attributed to the fact that it is a vertically integrated supplier with strong shares of the Japanese computer, communications, and semiconductor markets. Internationally, NEC is known for having installed over half of all satellite earth stations and for its microwave technology. NEC'S vertical integration activities are best summed up by Michiyuki Uenohara:

> Combining computers and communications (C + C) was conceived as a form of business best suited for our expansion into new areas, making the most of technological resources we have as a company that started out as a communications equipment maker. It was in 1975 that the concept was put into practical business programs, and in 1977, we

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[70] **See the section on MITI for a description of the industrial participation in the research associations.**

> came up with a clear-cut expression of C + C. First of all, we achieved the ability to put on the market a digital switching system which can serve as a link between communications and computer networks. Digital switching has made the combination of computers and communications not only possible, but natural.[71]

NEC'S central research laboratory, located just outside Tokyo in the city of Kawasaki, houses approximately 700 scientists involved in research on a wide variety of subjects related to computers and communications. Specific research includes projects on GaAs circuit development and semiconductor surface treatment.

Fujitsu Ltd.

Fujitsu is Japan's largest mainframe vendor, and ranks second to NEC in telecommunications equipment sales. Fujitsu is now ranked sixth in the world, ahead of Honeywell (U.S.), CII-Honeywell Bull (France), ICL (U.K.), and Siemens (West Germany). With fiscal 1982 sales of about $3.36 billion, telecommunications equipment accounted for $638 million of Fujitsu's total sales. Sales to NTT accounted for 37 percent and sales to the Japanese commercial market were 27 percent of Fujitsu's total sales. Similar to NEC, Fujitsu is well established in the world information technology market, with a solid history of sales in the United States. Currently, Fujitsu is manufacturing and marketing digital PBXs in a joint venture with American Telecommunications Corp., and microcomputers and terminals in a joint venture with TRW, Inc. Other joint venture partners include Canadian, West German, and Spanish companies. Although Fujitsu ranks second to NEC in microwave equipment, carrier transmission, and automated office equipment, it is a leader in Japan's fiber optics and optoelectronics research.

The "tsu" in the title Fujitsu means communications and this was the basis of the Fujitsu laboratories. However, because of a perceived saturation of the communications field, Fujitsu decided to diversify and as a result, communications equipment now occupies a minor part of Fujitsu's research operations. Approximately 60 percent of the research activities is currently devoted to computer and computer-related research. The Fujitsu Laboratories, also located in Kawasaki, employ approximately 800 people. The semiconductor division consists of 190 people divided into three main subgroups: GaAs devices and circuits, silicon integration, and materials. Because its research is well advanced in the semiconductor division, Fujitsu is expected to play an important role in the Japanese supercomputer project.

Hitachi Ltd.

Hitachi is Japan's third largest company (after Nippon Steel Corp. and Toyota Ltd.). It entered the computer market in the late 1950s and was one of the first Japanese companies to enter into a technology exchange agreement with a U.S. computer manufacturer (RCA in 1961). Since then, Hitachi has made agreements with Intel. During 1978-80, Hitachi also completed marketing arrangements for its computer systems in Europe with BASF (West Germany), Olivetti (Italy), and St. Gobain (France).

Hitachi generated more than $3.3 billion in fiscal 1982 (out of total sales of $15 billion) from information and communications systems and other electronics devices. Although Hitachi has in the past maintained a strong position in the consumer electronics market, the company is placing more emphasis on industrial electronic equipment. As a result, Hitachi is attempting to evolve into an integrated office systems supplier in the United States. Hitachi is concentrating some of its efforts on the development and marketing of PBXs.

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[71] Gene Adrian Gregory and Akio Etori, "Japanese Technology Today, The Electronic Revolution Continues, " *Scientific Amen"can, Special Supplement, 1984,* p. J, 44.

Photo credit: Overseas *Public Affairs Office, Electronlc Industries Association of Japan*

A Hitachi engineer feeds a glass plate into an electron beam lithography device which produces a photomask by drawing LSI patterns on the plate with a sharply focused electron beam under high-precision computer control. The device is also capable of directly writing patterns on silicon wafers.

Hitachi has rapidly increased research and development expenditures. Hitachi's Central Research Laboratory at Kokubunji is one of the five Hitachi research labs and is devoted to the development of new materials and devices as well as *new* measurement equipment, medical engineering equipment, and communications and information processing systems. The laboratory, established in 1942, employs approximately 1,200 research and support personnel. Their principal integrated circuit research project is aimed at developing a 1K bit static RAM for use in the central processing unit (CPU) and main memory of large computers. Other projects that are also currently underway include the development of GaAs, analog circuits for automobile telephones, and semiconductor material research. There is also research taking place in lasers, light-emitting diodes (LEDs) and light detectors, and some preliminary work in electro-optic integration.

Oki Electric Industry Corp.

Oki Electric Industry Corp. was one of Japan's first entrants into the computer market with its transistorized OKITAC 6020 in 1959. Oki-Univac Company Ltd. was formed in September 1963 to manufacture various Univac-based machines in Japan. Since that time, Oki has not engaged in the development of large computers. However, it remains strong in peripherals and terminals. In 1972, Oki established subsidiaries in the United States to pro duce and market communications equipment and computer peripherals, terminals, and components, and has subsequently set up similar operations in Germany and Brazil.

Oki Electric Industry Corp. had fiscal 1982 sales of $1.03 billion, of which telecommunications sales to NTT totaled $185 million and those to government entities another $94 million. Oki also exported approximately $120 million in equipment, mainly digital printers, to the United States. In July, the company announced that it will build a plant in Atlanta, Ga., to produce mobile cellular radio telephones for a subsidiary of AT&T. The facility is expected to produce 1.5 million units a year eventually.

France

Introduction

The historically agrarian society of France has changed with tremendous speed since World War II. In 1945 over half of the French population was dependent on agriculture for its income; by 1970 that dependency had been reduced to between 7 and 8 percent.[72] Information technology, particularly telecommunications, has been a major component of this

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[72] Pierre Aigrain, "Seminar on High Technology in France," Center for Strategic and International Studies, Georgetown University, Feb. 9, 1983.

change. French efforts to expand advanced information technology research and production have been directed toward two major goals: strengthening France's international competitiveness and the development of an information technology-based infrastructure for the preservation and continued development of French culture and society. Coupled with historic French governmental involvement in industry,[73] the comparatively small size of French participation in the world market for information technology, and the unique French social and political contexts for technology, these goals have shaped French information technology research and development into a pattern quite unlike that in the United States.

French information technology research and development activities occur in government laboratories, in industrial settings, and in academic environments. The structure, organization, and direction of R&D activities within these communities are all dissimilar, however, from the American experience. The pervasiveness of government intervention in industrial and academic sectors makes it difficult to differentiate the three areas, but for ease of comparison with the American experience, French government, university, and industry information technology research and development environments are discussed separately below. Before discussing these environments, it is important to understand the size of French participation in information technology, and the social and recent political environments for the conduct of information technology research and development.

The Size of French Participation in Information Technology Markets

In 1982 the French estimated that they controlled about 5 percent of the world market in information technology. This compares with a United States share of 48 percent in 1982. Moreover, if one were to compute the French share of the world market using information technology goods and services produced exclusively by French-controlled corporations, the share would decline to 4 percent.[74]

Photo credit' Scientific Mission, Embassy of France and Ministere des PTT, French Government

Videotex terminal "Minitel"

Slightly over one-half of the French information market is served by foreign suppliers; the United States holds about 22 percent of the market, Japan and West Germany 7 percent each. The Netherlands holds 6 percent

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[73] **The French Government has traditionally played a large role in the coordination, funding, and direction of the French economy since Jean Baptiste Colbert founded the Academy of Sciences in 1666. French Governments since have changed the scope and nature of that involvement, but the traditional mechanisms used by government in industry, including those of the present French Government, have changed very little.**

[74] **"French telecommunications and Electronics Council,** *The Electronics Industry: U.S.A./France 1982,* **pp. 10-18.**

and Italy, the United Kingdom, Austria and others hold the remainder. Several major subsectors of the French market such as mainframe computers are nearly dominated by U.S. manufacturers. In areas of French strength within the French market (e.g., in telephone terminal and switching equipment, in which the French control about 91 percent of their market), French participation in the United States and/or world markets is often very small. For example, France has less than one-tenth of 1 percent of the U.S. market in telephone terminal and switching equipment. This situation may be more due to the structure of the U.S. telecommunications industry than any French inadequacy. In addition, the future French position in the U.S. telecommunications market may improve as both CIT Alcatel and Thomson CSF have recently established U.S. subsidiaries.”

The size of French participation in the markets for information technology affects the level of funds available for R&D. French industrial funding of information technology research and development was reported as $2.2 billion in 1982, some significant portion of which was funded by the government. In addition to information technology research and development in industrial settings, the civilian French governmental funding of information technology conducted in public laboratories was reported to be $0.6 billion in 1982.[76]

The Political Environment for French Information Technology Research and Development

It would be difficult to describe French information technology research and development activities without first considering the context of the present French Government's policy. The last French presidential election (1981) marked the first time science and technology were used as apolitical issues.” Indeed, all candidates had some increased R&D funding planks in their platforms. Before losing to Mr. Mitterrand, Mr. d'Estaing had designed a plan for increasing real government R&D funding 8 percent per year for 5 years beginning in 1980. When Mr. Mitterrand was elected, he more than doubled that goal.

Mr. Mitterrand's emphasis on increasing R&D spending was part of a larger industrial policy for France which included companion employment and education policies as well as planned market programs in several areas of high technology.[78] The overall government policy, designed around the Socialists' principles of decentralization, democratization, humanism, and volunteerism, included several elements.

The first element of the French Government's general policy was the declaration of information technology development as a national priority. Thus a major objective was to bring together universities, government laboratories, and industry to enhance national efforts in technological development.[79] The second element was to convince the French people of the importance of industry, a particularly necessary action in a country that has not yet completely integrated industrial activity among its values and culture. The third element of the French Government's policy was to create conditions for people to accept more readily changes in their work environment and social structure (caused by the introduction of new technologies), basically through a renewed social participation. This was viewed as a necessity for the continuous introduction of new technology. The fourth element consisted of the introduction of mechanisms to increase industrial investment. One of the major mechanisms for attracting investment in major industries has been the nationalization of major French industrial firms.

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[75] Interview with Mr. Chavance, CIT Alcatel director, June 1983 and *Telephony,* July 25, 1983, p. 24.

[76] *A.F.P. Sciences, No. 325,* Oct. 7, 1982, p. 30.

[77] Pierre Aigrain, "The French Experience in High Technology, " Center for Strategic and International Studies, Georgetown University, p. 2.

[78] "French Technology Preparing for the 21st Century," *Scientific American,* November 1982, p. F3.

[79] Robert Chabbal, "The New Investment in Science and Technology in France, " in Thomas Langfitt, Sheldon Hackney, Alfred Fishnay, Albert Glowaske (eds.), *Partners in the Research Enterprise, University-Corporate Relations in Science and Technology* (Philadelphia University of Pennsylvania Press), 1983, p. 138.

The first step taken by the Mitterand government was to establish a ministerial department for research and technology. One year later, the three ministries of research and technology, industry, and energy were combined to create one very large ministry called the Ministere de la Recherche et de l'Industrie. This ministry was created in part to stimulate interactions and exchanges between government and industry.

Another measure taken by the French Government was the nationalization of major industrial firms and most of the banking sector. Nationalism was viewed as a means of controlling investment and ensuring that the government could exert economic leverage to achieve its goals of: expanding employment; transforming the workplace environment; enhancing French productivity and competition; directing research and development into areas of government priority; and recapturing the domestic market by replacing imports with domystically produced products.[80] Moreover, government ownership was seen as means to enable those companies to receive ample funding for innovative, relatively high risk research and development.[81] Nationalization was also viewed as a mechanism to increase cooperation and technology transfer between industry and government.

The nationalization program was implemented in several stages over a period of 2 years.[82] **Following** several delays, the nationalization program was approved on February 11, 1984, giving the government control of 5 industrial groups, 39 banks, and 2 financial organizations.[83] In the information technology sector, almost every major company has been reorganized to reflect a majority of government ownership. For example, the government took over the central organizations (but not necessarily all the subsidiaries) of the Compagnie Generale d'Electricity, Saint Gobain Pont-a-Mousson, Pechiney-Ugine-Kuhlman, Rhone-Poulnec, and Thomson-Brandt. The government also acquired majority shares in Dassult and Matra, and later negotiated controlling or full ownership of three foreign-owned companies in France, Roussel-Uclaf, Cii-Honeywell-Bull, and I.T.T. France.

The actual effects of nationalization on the information technology industry and on the French economy as a whole are still uncertain. This uncertainty is created in part by the dominant role the French Government has played in the French economy throughout all of the postwar period, and in part by the confusion in the transition to Socialist industrial policy. Moreover, the effects of nationalization have also been obscured by France's economic decline in the first 2% years of the Socialist government, which in turn has ultimately weakened the nationalization efforts to reshape or control the activities of specific firms or certain sectors of the economy.Nationalization efforts have also been complicated by changes in three different ministers of the Ministere de la Recherche et de l'Industrie within a 2 year period.

Most significant to the general Mitterand strategy for the development of technology was the enactment of the legislation, Law for Programming and Orientation for Research, which established scientific and technological research and development as national priorities. Moreover, the law ensured funding for long-term scientific efforts by stipulating both quantitative and qualitative objectives for the following 5 years. The law stated that between 1981 and 1985 the percentage of the Gross National Product (GNP) devoted to research and development will increase from 1.8 to 2.5 percent, thereby increasing by 40 percent the spending for technological development in 5 years.[85] This process began in 1980 and there

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[80] **Michael H. Harrison, "France Under the Socialists, "** *Current History,* **April 1984, p. 155.**

[81] **"Pitfalls in France's Vast R&D Plan, "** *Business Week, Nov. 23, 1981,* p. *94.*

[82] **Companies were actually nationalized on Feb. 11,** 1982 (Law 82-155); **however, the reorganization plans were not in effect until January 1983,**

[83] **Michael H. Harrison, "France Under the Socialists, "** *Current History,* **April 1984, p. 155.**

[84] Ibid.

[85] **Robert Chabbal, "The New Investment in Science and Technology in France, " in Thomas Langfitt, Sheldon Hackney, Alfred Fishnay, Albert Glowaske (eds.),** *Partners in the Research Enterprise, University—Corporate Relations in Science and Technology* **(Philadelphia: University of Pennsylvania Press), 1983, p. 140,**

have been 12 percent annual increases in each of the three successive budgets.[86] The French Government's contribution will be matched by industry, which calls for industry to increase its expenditure for research and development by 40 percent in the next 5 years.[87]

In addition to meeting broadly the scientific and development needs, these increased expenditures are also for financing national mobilizing programs that are focused on industrial and government targeted priorities, such as information technology. Although there are major programs in biotechnology, new sources of energy, machine tools, etc., the information technology program is perhaps the most ambitious. La Filiere Electronique, implemented by the Mitterand government in 1983, is designed to coordinate and stimulate government, university, and industry information technology research and development efforts in order to move France into the forefront of advanced information technology R&D and production.[88] Figure 49 illustrates some of the coordination efforts between industry and government for La Filiere Electronique program. The 5-year infusion of f 140 billion (approximately $18.7 billion) for R&D is expected to accelerate the production of information technology products by 3 to 9 percent each year, produce a surplus trade balance in information technology products, and create 80,000 new jobs.

Fourteen national projects for research and development are outlined in La Filiere Electronique program:

- large scientific and industrial French computer,
- building blocks of mini- and micro-computing,
- consumer electronics systems,
- display technology,
- ergonomics of computerization,
- computer-assisted instruction,
- multiservice communications,
- widebank communications network,
- design and production assisted by very large scale integrated circuits,
- computer-assisted engineering design and production,
- voice-processing module,
- electrophotographic module,
- electronic editing, and
- computer-aided translation.

In addition to these projects and programs, the plan sets forth mechanisms for state/industrial cooperation and outlines efforts which are aimed at alleviating other constraints on information technology research and development not related to direct R&D funding. These include manpower programs to correct a perceived shortage of engineers and technicians and government-sponsored market promotion efforts.[89]

Because of economic difficulties, there have been some funding problems for the Mitterand government. Consequently, the plans for an overall increase of 4.5 percent funding for research activities have suffered significantly. For most areas of research, this reduction in funding means that the 1984 research spending will remain at the same level as in 1983. However, the government has stressed that it will maintain its commitment to increase funds for high priority areas, including information technology.[90] Other impediments to La Filiere Electronique program and to French information technology research and develop-

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[86] This increase occurred after 10 years of decreasing spending for scientific equipment and, therefore, the need was extremely acute.

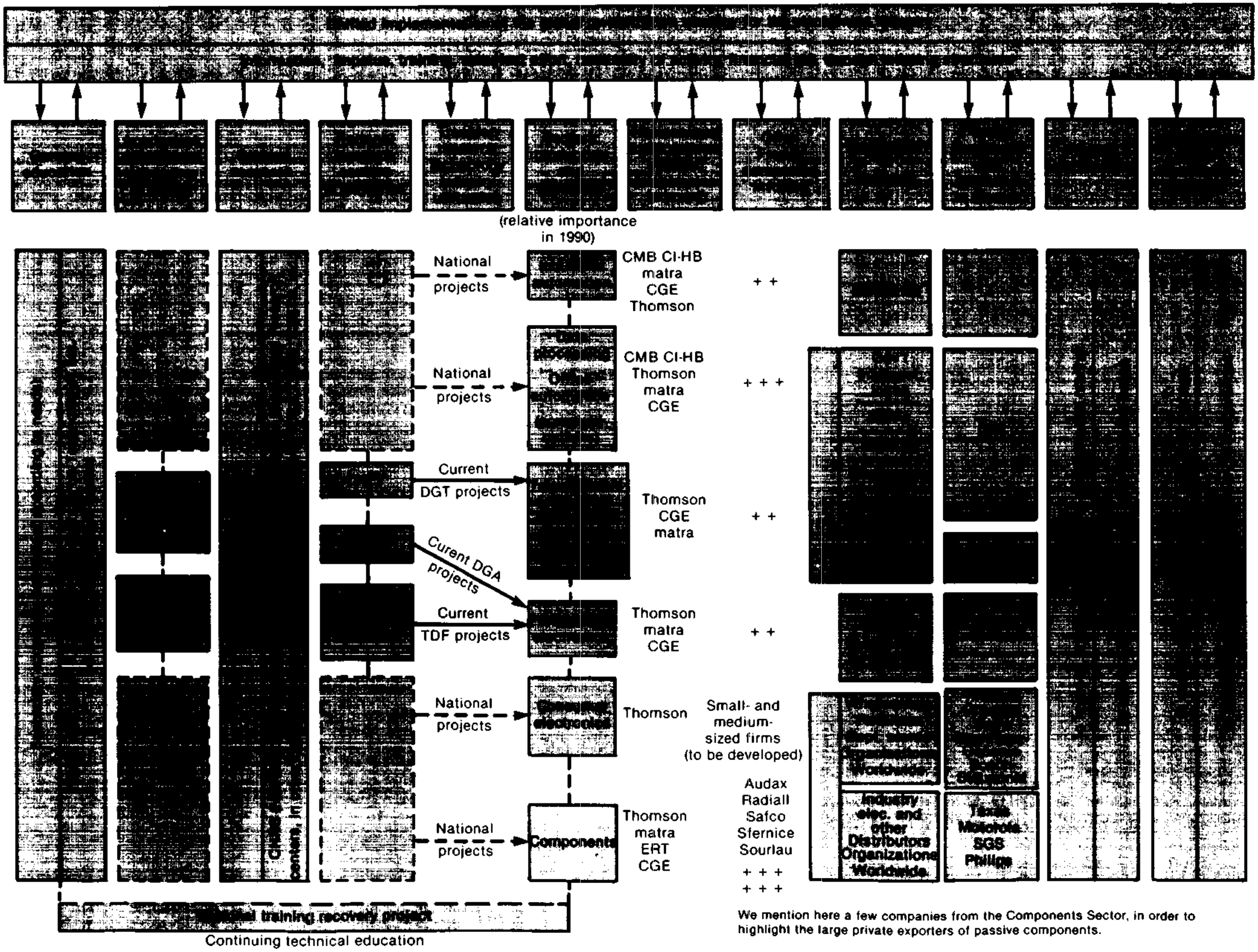
[87] Robert Chabbal, “The New Investment in Science and Technology in France,” in Thomas Langfitt, Sheldon Hackney, Alfred Fishnay, Albert Glowaske (eds.), Partners *in the Research Enterprise, University and Corporate Relations in Science and Technology* (Philadelphia: University of Pennsylvania Press, 1983) p. 140.

[88] A “filiere” in France is a targeted industry grouping or other goal around which a government plan for funding, production, investment, education and dissemination assistance has been developed, There are currently six filieres in France today: robotics, electronics, energy, biotechnology, work environments, and cooperation with developing countries.

[89] For example, the number of people with Level 1 qualifications in information technology (a French Masters degree, approximately equal to an American Ph. D.) is expected to fall short of needs by 70,000 for the period 1981-1990 in France. In the French context, this number is quite large; in 1979 it was estimated that 105,000 scientists and engineers were actively involved in all aspects of French science (energy, pharmaceuticals, mechanics, aeronautics agriculture etc., as well as information technology). Jean-Pierre Letouzey, Scientific Mission, Embassy of France, *Statement for the American Association for the Advancement of* Sciences, Mar. 24, 1983, p. 9 (unnumbered).

‘David Dickson, “Hard Times Force France to Cut Back Ambitious Plans to Support Science,” *Chronicle of Higher Education*, Apr. 21, 1984, p. 10.

Figure 49.—Recommended French Government/Industry/University Cooperation Relationships for Information Technology R&D



We mention here a few companies from the Components Sector, in order to highlight the large private exporters of passive components.

SOURCE: French Government, 1983.

ment may also stem from the proliferation of new projects which may in turn dilute available funds to inconsequential levels.

Social Environment for French Information Technology Research and Development

The French Government's desire to push France into a technologically based future has encouraged information technology research efforts in office automation, microcomputers, consumer electronics, and telephone terminal equipment. In addition, each of these research areas has included a major effort in the human factors aspects of design and interaction, perhaps in recognition of the difficulty expected with the assimilation of these technologies into French society. The emphasis placed upon human factors engineering has given rise to French prototypes and products that are generally esthetically pleasing and easy to use. Many French designs have been adapted else where. For example, it was a French study that suggested amber on black CRT screens were the most pleasing and produced the least eye strain.

Three French characteristics stand out as important with respect to information technology research and development. Risk taking in the French industrial sector does not appear with the frequency or at the level considered commonplace in the United States. One indication of this is the small number of venture capitalists in France and the unwillingness of the traditional banking industry to fund entrepreneurs. However, there are efforts on the part of government and industry to increase the use of venture capital.

For the conduct of information technology research and development, the French risk-avoidance characteristic may be translated into the general lack of leading-edge, often high-risk, technological research. Another possible consequence for information technology research and development is the prevalence of large organizational environments for the conduct of R&D. It is difficult to judge what implications this has for French information technology research and development. It can only be contrasted to the fact that one of the strong aspects of U.S. information technology research and development has been considered to be the infusion of small, innovative firms into the research community.

The second French characteristic which appears to affect the conduct of information technology research and development is the frequency of what might be termed reengineering. Reengineering, or the production from scratch, of French versions of an existing product is very common in French information technology. Reengineering efforts maybe attributed to the French attempt to develop domestic production capabilities in order to mitigate United States and Japanese dominance in some niches of the French information technology market.

The French attention to reengineering is quite possibly related to a third French characteristic, strong national loyalty to French-made products. This adherence to French products occasionally provides a serious handicap to French information technology research and development. Because the French do not manufacture all types of state-of-the-art instrumentation, French scientists and engineers (who in some cases maybe restricted to purchasing French instrumentation) may be limited in their research activities.

Government

There are a variety of French Government organizations involved in information technology research and development. A few were newly created with the advent of the Mitterand government, but most have been operating for decades. Although the nationalization of industries and the government provision of research and development under Mitterrand are often thought of as socialist government actions, the link between French politics and French research has been longstanding. Traditionally, France has closely overseen both basic and applied science research through government mechanisms.

Centre National de la Recherche Scientifique (CNRS)

The largest and oldest French Government-funded research organization is the Centre National de La Recherche Scientifique (CNRS), founded in 1939. CNRS supports basic research in chemistry, physics, earth, atmospheric and ocean sciences, life sciences, engineering, social sciences, mathematics, and humanities. In 1984, CNRS had a budget of *f* 7,735 million (almost 24 percent of the public civil research budget), and employed approximately 25,000 people in 1,350 laboratories or within universities, other government agencies, and industry. CNRS has seven laboratories devoted to basic research in some aspect of information technology. The portion of the 1984 budget applicable to information technology research and development is *f* 225.2 million, an increase of 13 percent over the 1983 budget. This increase in the budget for the information technology research (in contrast to other CNRS research areas which received less or no increases) is significant and is largely the result of the recognition of the importance of information technology to the French economy and society.[91]

In line with France's new efforts in strengthening its information technology industry, CNRS information technology activities are currently coordinated with the Filiere Electronique program and are becoming largely de voted to applied, industrial research. There are efforts in software development and programming techniques, speech recognition and synthesis, artificial intelligence, and robotics. CNRS draws heavily from the French university system for its personnel, unlike industry or most other government agencies, where the grandes ecoles supply the researchers and administrators.[92]

In the past, CNRS ties with industry have been relatively weak. However, as CNRS increases its applied research activities, ties with industry have also grown. Closer ties between CNRS and industry seem to be important to the Directeur General of CNRS who has recently established several agreements between CNRS and industry.[93]

CNRS has exchange programs and scientific accords with 30 countries, including agreements with the National Science Foundation, the National Institute of Health, Massachusetts Institute of Technology, the University of Chicago, and others.

Ministere des Postes, Telecommunications, et Telediffusion (PTT)

The French Ministere des Postes, Telecommunications, et Telediffusion (PTT), through the Ministere de la Recherche et de l'Industrie, is responsible for the provision of all telecommunications services and equipment, network maintenance, standards development, telecommunications policy, technical assistance to former French colonies and other foreign entities, and research and development. The PTT's jurisdiction over telecommunications policy has resulted in increased PTT involvement in information technology R&D. The PTT often joins the Ministere de la Recherche et de l'lndustrie and others in the funding of projects that cross the technological boundaries between telecommunications and computers.[94]

The reach of the PTT through the Ministere de la Rechereche et de l'Industrie into the information technology research and development communities is extensive. The PTT funds the Centre National d'Etudes Telecommunications (CNET) much in the same manner that AT&T funds Bell Labs. The PTT also funds the Institut National des Telecommunications (INT), a portion of the Agence de l'Informatique (ADI), and all of the Ecole Nationale Superieure des Telecommunications

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[91] Discussion of CNRS based on "French Technology Preparing for the 21st Century," *Scientific American,* November 1982, pp. F4, F11.

[92] Interview with Charles Garriques, President, Agence de l'Informatique, June 24, 1983.

[93] For example, agreements have been signed with Saint-Gobain, Renault, and Roussel-Uclaf. "French Technology Preparing for the 21st Century," Scientific *American,* November 1982, pp. F4-F11.

[94] For example, le Project Pilote NADIR (exploration of new uses of Telecom 1 for data and voice transmission) is funded 50/50 by the PTT and the Ministere de la Recherche et de l'Industrie.

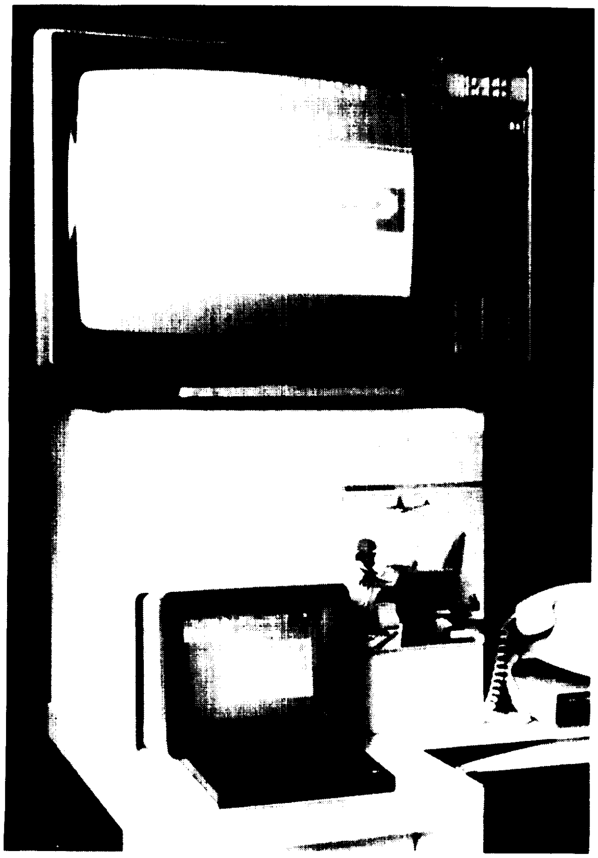

Photo credit: Scientific Mission, Embassy of France and Ministere des PTT, French Government

Videotex terminal “Minitel” with CCP card reader.

(ENST). The PTT’s terminal equipment, switching and transmission needs are supplied through contracts with CIT Alcatel, Thomson CSF, the French Cable Co., and a host of others. The R&D for the products manufactured by these firms for PTT use is funded by the PTT, generally through cooperative efforts between the industrial entity and the CNET.

The current government-sponsored push in information technology research and development follows upon a recent similar effort in telecommunications implemented by the PTT. By most accounts, the research, development, and implementation programs designed in 1974 and 1975 to transform the French telecommunications system into a technologically advanced network on par with the United States has been a success.[95] In 1974, France averaged 12 main telephone lines per 100 inhabitants; in 1981 the figure was 33.[96] The number of lines in the national network grew from 7 million in 1975 to 20 million in 1982. In 1975 electronic exchanges were virtually nonexistent in France; in 1981, 70 percent of newly installed switching capacity was electronic.[97]

As a result of the recent modernization of the French telephone network, the French have a greater percentage of digital equipment than any other country.[98] This, in turn, has spawned the provision of many sophisticated services such as Transpac (public data packet switching network), Transmic (dedicated data transmission), Teletel, and Videophone (video conferencing). These technological possibilities have pushed PTT-sponsored telecommunications and computer research and development in several directions. The three main directions have been satellite technology (the French launched Telecom 1 in the summer of 1983), an integrated services digital network (ISDN), and optical fibers (a wideband, multiservice optical subscriber network experiment is taking place in 1,500 homes in Biarritz). The major research efforts in all of these areas have taken place at the Centre National d’Etudes des Telecommunications (CNET).

Centre National d’Etudes Telecommunications (CNET)

The CNET was formed in 1944 to provide scientific research and technical assistance to the PTT.[99] The CNET is active in applied mathematics, computer science, solid-state physics, and earth sciences. The total budget in 1982 was about *f* 1 billion (about $133 million); approximately 55 percent is spent on net-

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[95] “No Hang Ups for French Phones, ” *Telecom France*, June 1982, p. 10.

[96] Conseil Economique et Social, La *Telematique et L ’Amenagement du Territoire*, Apr. 21, 1983, p. 35.

[97] PTT Telecommunications, *Biarritz, The Lightwave Communications World of the Future*, p. 1.

[98] Ibid.

[99] Discussion based on the group of brochures and pamphlets included in the CNET *Dossier Presse*.

work and service engineering, 25 percent on components engineering and 20 percent on basic research.

In 1982 2,600 scientists and engineers worked in six laboratories. Two of the groups are located in Paris. Paris A performs long-term network planning and administers the other five centers. Paris B is the center of basic research for the CNET. Materials and geophysical research are the primary efforts. Applied work in components, transmission, marine cables, and satellites is also performed.

The two centers at Lannion work on local area networks, ISDN, software, human-machine interface, and acoustics (Lannion A) and digital transmission, optical communications, and components (Lannion B). The center at Grenoble is devoted to microelectronics research, while the laboratory at Rennes is shared with the Centre Commun d'Etudes de Television et Telecommunications and studies future telecommunications services and their integration with broadcasting technologies.

Since the advent of the Mitterrand government, the CNET has assumed a significant role in the French national industrial development strategy. Under the plan for the electronics sector (La Filiere Electronique), the CNET laboratory at Grenoble has undertaken projects in CMOS technology for very large scale integrated circuits, gallium arsenide, computer-aided design, and artificial intelligence.

In conjunction with La Filiere Electronique research effort, CNET has introduced a program to improve its transfer of technology to the industrial sector. The CNET owns over 550 patents which it licenses to French and other companies. The licensing is done virtually without regard to the royalty potential; CNET'S 550 patents provide approximately *f* 20 million in revenue per year.

L'Institut National de Recherche en Informatique et Automatique (INRIA)

L'Institut National de Recherche en Informatique et Automatique (INRIA) is one of the newest French Government information technology research agency. It was formed in December 1979 under the d'Estaing Ministry of Industry. INRIA remains under the jurisdiction of the Ministere de la Reserche et de l'Industrie in the Mitterrand government. The name of this ministry has had several evolutions of late. With the advent of the Mitterand government the Ministere de l'Industrie was changed to the Ministere de la Recherche et de l'Industrie. Currently, the organization is titled the Ministere de l'Industrie et de la Recherche. The first change effected by the Mitterrand government was an effort to combine the mission of the Ministry of Industry with that of the Ministry of Research and Technology. The second change appears to be one of emphasis. INRIA is considered the leading research institute in computer science in France. It has several locations. The main research center is in Rocquencourt (just outside of Paris); another smaller center is located in Sophia-Antipolis. INRIA shares facilities with the CNET at Rennes and Grenoble and has a small group in Toulouse. In 1982, INRIA's budget was *f* 146 million (about $19.5 million) which funded 409 people, 225 of whom were scientists and engineers. In 1983, the budget was expected to be *f* 200 million for funding of INRIA contracts with industry.[100]

INRIA has a three part mission: the conduct of research on experimental computer systems; international scientific relations; and the transfer of technology. Each of the missions is guided by industrial needs, at least insofar as those needs are articulated by the Ministere de la Recherche et de l'Industrie. Consequently, the research performed by INRIA is applied and the bulk of the work can be characterized as product development.

INRIA has eight research programs in areas such as system architecture, languages, algorithms, automation, and man-machine interface. Each program conducts three to five projects. In addition INRIA is responsible for four of six pilot projects to be undertaken in connection with La Filiere Electronique program. Those pilot projects are KAYAK (office

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[100] **INRIA,** *Dossier Presse.*

automation), NADIR (applications of Telecom 1 satellite capability), SIRIUS (distributed systems), and SOL (portable software).

Each pilot project has a different configuration of funding, personnel, and industry participation. For example, NADIR is financed 50/50 by the PTT and the Ministere de la Recherche et de l'Industrie. The project administrative responsibility is shared between the Agence de l'Informatique (ADI) and the Direction des Affaires Industrielles et Internationales, a division of the Direction Generale des Telecommunications within the PTT. The actual research is conducted at INRIA with a mixture of INRIA and CNET personnel. Industry personnel are not research team members, although several industrial representatives are participating through provision of user specifications.[101]

SIRIUS is an older project, and as such, its original funding sources and location have changed. Currently, the project is administered by ADI. The research team includes INRIA, the University of Nancy, several smaller divisions of the Ministere de la Recherche et de l'Industrie and 15 industrial companies including CAP-Sogeti, Cii Honeywell Bull, and SNCF (the French national railroad).[102]

The organization of INRIA is quite different from the CNET and in many aspects provides complementary research support. Unlike the CNET which draws heavily from the grandes ecoles system for its researchers, INRIA recruits from the French university system. Many project directors at INRIA are French university professors who come to INRIA for the duration of a project.

Also unlike the CNET, whose mission is to be the research arm of the state telephone network, INRIA is not responsible to one centrally defined set of research requirements. Rather, the institution generally must respond to a more diffuse set of requirements from industry. The coordination of research projects is nominally the job of the Ministere de la Recherche et de l'Industrie, but most often, such coordination is effected by INRIA research staff members who take ideas forward to the Ministry for funding.

Agence de l'Informatique (ADI)

Like INRIA, the Agence de l'Informatique (ADI) was recently formed. Funded by the Ministere de la Recherche et de l'Industrie (75 percent) and the PTT (25 percent), ADI's 1981 budget was F 300 million ($40 million). Funding in 1982 was F 320 million as was the 1983 budget. A 20 percent cut is expected for 1984. ADI was originally designed to be self sustaining though royalties from its research-derived patents and the sale of its published studies, but as yet, those items account for less than 1 percent of ADI's revenue. ADI has three major areas of activity: research and experimentation, application development and dissemination, and training and education. It also has three support activities: regional programs, international affairs, and economic and legal studies. Sixty professionals manage these programs.[103]

The goal of ADI's training and education program is to produce more computer science graduates and to improve the quality and availability of science and engineering education. Included in the program is a project to put computers in the secondary schools. The application development and dissemination programs provide a forum for users and producers of information products to exchange ideas and develop computer applications tailored to the specific requirements of various business sectors.

ADI's research program funds efforts in computer science in a manner analogous to that of the National Science Foundation; that is, ADI funds but does not conduct the research. This program has approximately F 100 million ($13 million). In addition to the four pilot projects ADI helps fund at INRIA,

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[101] The Pilot Project NADIR, English Language bulletin, May 1983.

[102] INRIA, *Dossier Presse*, Le Project Pilote SIRIUS.

[103] Agence de l'Informatique, English language brochure, and interview with Charles Garriques, President, ADI, June 24, 1983.

partial funding is provided for the RHIN (system interconnection) and SURF (functional security) projects. These six pilot projects were originally to be undertaken as only a portion of ADI research mission. Longer-term projects in new architectures, languages and programming, human-machine interface, design aids, automation, computer-aided translation, security, and translation are also planned. Recent budget cuts, however, have limited these research endeavors.

Centre d'Etudes des Systemes et des Technologies Advancees (CESTA)

The Centre d'Etudes des Systemes et des Technologies Advancees (CESTA) is the newest French agency involved in information technology. Founded in January 1982, it is one of two completely new agencies formed by the Mitterrand government in information technology. Under the jurisdiction of the Ministere de la Recherche et de l'Industrie, CESTA'S 40 employees have two missions: technology forecasting and identification of employment impacts due to technological advance. The technological scope of CESTA goes beyond information technology (e.g., there are programs in biotechnology) but the majority of its work involves various aspects of information technology. CESTA'S forecasting responsibility takes the form of evaluations of market, cultural, and social acceptance of technologically advanced products. When employment impacts can be identified, retraining programs are developed by CESTA personnel. CESTA'S major activities undertaken to further these goals are the conduct of seminars and the commission of studies and papers on topics of interest.[104]

Although CESTA resides under the auspices of the Ministere de la Recherche et de l'Industrie, the director described his agency as independent, not administration-linked and drew an analogy between CESTA and the Tennessee Valley Authority. He saw this independence as a necessary ingredient to his ability to gather groups representing divergent interests.

Centre Mondial Informatique et Ressource Humaine

The Centre Mondial Informatique et Ressource Humaine is the other information technology agency created by the Mitterand government. The original mandate of the Center was threefold: research in those areas of information technology applicable to microcomputers; social experimentation in France; and Third World pilot projects designed to explore computer applications for the dissemination of medical and education information.[105] However, the Center's role in information technology research and development has not always been clear. Since its inception in November, 1981, the Center has been racked with political struggles. Exactly what role the Center plays or may play in French information technology research and development, however, still remains uncertain.[106]

University

Two parallel systems of higher education exist in France; one is found in the universities, the other in the grandes ecoles. Both systems produce scientists, engineers and administrators with relatively little training in the applied sciences and/or the business aspects of research such as marketing, management finance, or accounting. Beyond this similarity, the systems have few parallels.

In general, French university training does not usually prepare individuals for careers in government or in the higher levels of industry. University trained scientists are occasionally found in industry and in government research laboratories in instances where the

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[104] CESTA, *CESTA*, December 1982, and interview with Yves Stourdze, Directeur CESTA, June 20, 1983.

[105] Centre Mondial Informatique et Ressource Humaine, *Fiches D'Information, Statuts et Organisation.*

[106] See for example, Dray and Menosky, "Computers and a New World Order, " *Technology Review,* May/June 1983, and Walsh, "Computer Expert Signs Off From World Center, " *Science, vol.* 218, Dec. 3, 1982.

work is decidedly theoretical or, as in computer science, the discipline is so new that a grande ecole exclusively for the subject is nonexistent. Although computer science is taught in several of the grandes ecoles, computer scientists, particularly software engineers, in France have emerged from the university community. As a result, several French universities such as the university of Grenoble, have recently become sites for information technology research and development activities around which industry has begun to collect. This may eventually change the nature of French research and development which traditionally has been institutionally split into three components. In general, the universities (and some government organizations) have conducted France's basic research, the government and the grandes ecoles have been the sites of applied research, and industry has been the environment for development activities. Although these various institutions have certainly funded activities in each of the other components, cooperation among them has been minimal.

The highly respected grandes ecoles system, which produces the French cadre of government officials and industrial managers, was formed by Napolean to develop an elite group of French intellectuals who would be responsible for guiding France's cultural, social, economic, and political futures. Today there are about 150 grandes ecoles in France of which approximately 10 produce state engineers. The others produce administrators, economists, sociologists, artists, and a host of other professionals in the sciences, liberal arts, and humanities. All grandes ecoles have entry requirements. One must take a competitive exam which requires between 2 and 3 years of study preparation. Typically, the French high school graduate will prepare for this exam at the university, within the high school setting, or in private preparatory institutions. Based on their test scores, students are generally assigned to specific grandes ecoles.

The Ecole Polytechnique has traditionally produced the highest level of government officials in France. As the name suggests, the curriculum at Ecole Polytechnique is based on a theoretical education in a variety of scientific disciplines. In addition, students who wish to specialize in an area often enter one of the other grandes ecoles for additional training after graduation.

The Ecole Nationale Superieure des Telecommunications (ENST) is the primary grande ecole for the production of researchers and engineers in information technology. The ENST is funded by the Ministere des Postes, Telecommunications, et Telediffusion (PTT), and its curriculum is overseen by the PTT. The school is considered to rank among the top ten of the 150 grandes ecoles in France. The school accepts 70 first year students annually, based on performance on the competitive exam. More students are added during the second and third years of the school's program. Entry into the second year at ENST can be obtained after completion of another grandes ecoles education and/or after graduation with a maitrise (roughly equivalent to a U.S. bachelor of science degree) from the university. These additions result in a total student population of about 540 and the award of 220 degrees annually. ’07

The first and second years of study at ENST involve mathematics, physics, electronics, computer science, economics, foreign language, and humanities. During the third year, a student chooses from eight areas of specialty to study for half of the year. Three months are spent in a work-study project in industry or government or in a foreign study program. These work-study projects are a unique opportunity for students to gain applied or industrial experience. As a result of ENST'S emphasis on applied engineering, the proportion of graduates who work in industry is quite high in comparison to other grandes ecoles. Approximately 60 percent of the graduates of ENST go to industry, and the remainder find jobs in the PTT.

The ENST has four laboratories where instructional research is conducted: systems and communications, computer science, electronics

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‘°’ Ministere des PTT, *ENST*.

and physics, image and sound, and life sciences. Occasionally research is conducted in collaboration with government research centers and industry; however, the main purpose of the research is to provide student instruction, not to further the state-of-the-art.[108]

The highly theoretical nature of the grandes ecoles training does not always prepare government officials to direct and conduct research for purposes of French industrial growth. Experience in the industrial community does not appear to be an alternative method of developing such preparation for government officials, as the transfer of people from careers in industry to careers in government (or vise versa) is quite rare. However, in conjunction with its goal of strengthening the links between industrial and government research and development, the Mitterand government has implemented several new programs. These include increasing the number of commercially oriented grandes ecoles, the teaching of marketing, accounting, and finance throughout the grandes ecoles system, and encouraging more work-study programs.

Industry

The industrial component of French information technology research and development, just as in the United States, has many members. Similar to the situation in both Japan and the United Kingdom, a few large information technology firms are responsible for the major proportion of research and development efforts. Cii Honeywell Bull, Thomson CSF, CIT Alcatel, and Sogitec, representatives of the spectrum of French industrial experience in information technology research and development, are described below.

Cii Honeywell Bull

When nationalization became operational at Cii Honeywell Bull in January 1983, the firm was completely reorganized. It took on several divisions of Thomson and Alcatel and rearranged its internal divisions into four groups: Bull Systems manufactures mainframes; Bull Sems (purchased from Thomson CSF) manufactures minicomputers; Bull Peripheriques makes disks and printers; Bull Transac (purchased from Alcatel) produces microcomputers and office automation products. The collection of groups is now called Bull. The transfer of the company to state ownership has not only changed the structure of divisions, and their personnel, it has changed the relationships between management and worker to reflect socialist principles. The work week has been shortened, salary differentials between men and women have been eliminated, and the number of upper management personnel and their salaries have been reduced.[109]

Research at Bull has been reorganized into six working groups, each with 30 scientists and engineers: advanced systems research; integrated circuits research and technology; custom design of integrated circuits; standard integrated circuits; interfaces for technology use; and discrete components and subsystems. The integrated circuits research and technology group is mandated to "be a proponent of technology alternatives to our partners" and to [provide] updated competence for the best choices in integrated circuit technology at the Bull group level. " Similarly, the custom integrated circuits group is to "establish know-how in design of custom VLSI" and "provide support and expertise in our choices of new technologies available outside the company. " In addition to the six research groups, additional studies to determine the feasibility of research in languages, artificial intelligence, vector processing, and distributed architecture are underway.[110]

Bull's future position in information technology research and development is unclear. It is important to note, however, that should it not improve, the French efforts in information technology research and development, and indeed in other advanced technology

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[108] Ibid.

[109] Cii Honey-well Bull, *Bilan Social d'Entreprise, Exercise 1982* and "Avis du Comite Central d'Entreprise sur le Bilan Social, 1982, "

[110] Bull, *Corporate Technology*, June 17, 1983.

areas, may be diminished. Much of France's technological future is dependent on the availability of a wide range of sophisticated computers and computer peripherals. As long as the French rely on Bull for these products, a very important link in the information technology research and development chain may remain uncertain.

Thomson CSF

Thomson CSF produces a variety of aeronautic electronics equipment, telecommunications equipment for the public telephone network, medical devices, electronic components, and office automation products. Thomson CSF is partially controlled (40 percent) by Thomson-Brandt, a producer of durable consumer goods, electromechanical capital goods, lamps and lighting fixtures, and engineering and financial services.[111] Thomson CSF produces, sells, and distributes its products through a network of almost 60 domestic and foreign subsidiaries and holding and associated companies.[112] Its revenues are dominated by the sale of electronic equipment followed by telecommunications and medical devices.[113]

In 1981, Thomson CSF spent over F 4 billion ($530 million), approximately 10 percent of Thomson CSF and Thomson-Brandt combined revenues, on research and development. Seventy-five percent of the effort was internally financed. Thomson CSF performs R&D for both Thomson CSF and Thomson-Brandt, and its spending represents 25 percent of all R&D spending in France. The vast majority (95 percent) of the research is product-related and takes place throughout the company's subsidiary structures. Basic research takes place in the Laboratoire Central de Recherches.[114]

Basic research at Thomson CSF includes programs in gallium arsenide, molecular beam epitaxy, single mode fiber optics, and machine level languages. The basic research effort, while small, is extremely important to Thomson CSF. The basic research effort provides Thomson with entree into the basic research community in France and abroad (Massachusetts Institute of Technology, Stanford University, CNRS and several French universities were mentioned as important research collaborators). Moreover, a credible basic research effort helps with the recruitment of scientists and engineers. Because of the excellent reputation of Thomson CSF'S basic research function and the small portion of corporate funds it represents, nationalization is not expected to change the nature of the activities and may even increase funding.

Like Bull, Thomson-Brandt, was nationalized with the passage of legislation in February 1982. The effect on R&D activities at Thomson CSF has been minimal in comparison with the changes at Bull. Product-oriented research has been modified slightly to meet some specifications of La Filiere Electronique program and state management has caused some difficulties, but personnel and directional changes for the company have caused almost insignificant disruption.

CIT Alcatel

CIT Alcatel is a subsidiary of the Compagnie Generale d'Electricity (CGE), the fifth largest company in France. CIT Alcatel (through its 8 French and foreign subsidiaries and affiliates) represents the public telecommunications division of CGE. Another 11 Alcatel Group members produce office automation and professional electronics products and provide computer services. Nationalization has not changed the personnel or the conduct of research at CIT Alcatel. It is anticipated that state ownership will improve the relationships between academia and industrial research and development, although results are not expected for another 10 years.[115]

CIT Alcatel's research and development activities are scattered throughout the company's subsidiaries. In addition, some research

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[111] Thomson-Brandt, *Principales Filiales et Participations Francaises et Etrangers.*

[112] Ibid.

[113] Thomson-CSF, *Rapport Annual des Activities en 1981,*

[114] Ibid.

[115] Alcatel, *The Alcatel Group.*

activities take place in association with CGE, CNET, and CNRS, and in conjunction with other French (e.g., Thomson CSF) and U.S. companies (e.g., SEMI Processes, Inc.). The company's director estimated that between 10 and 12 percent of the employees (some 17,065 in 1981) were involved in R&D[116]

Each product division within the CIT Alcatel companies funds the R&D activities it deems needed. Like Thomson CSF, the basic research at CIT Alcatel is performed at a central laboratory that is shared with all members of the CGE Group. Approximately 6 to 8 percent of CIT Alcatel's total research budget is devoted to this central laboratory.[117]

Sogitec, S.A.

Unlike the majority of French information technology firms, Sogitec is not a state-owned corporation and is representative of a small information technology firm. Founded in 1964 by its president, Christian Mons, Sogitec has grown to employ about 550 people in three locations: Paris, Rennes, and Lakewood, California. Sogitec also has sales offices in New York and Washington, D.C. Its sales growth has been impressive; 1978 revenues were doubled by 1979. Customers include General Electric, McDonnell Douglas, Ford, Daussalt, and others in the aircraft, shipbuilding, and automobile industries.[118]

Sogitec has two divisions that are designed to meet individual user needs. The data processing services division provides software packages and the related hardware for full text documentation, storage, and retrieval. The other Sogitec division produces real-time simulators and simulation packages for aircraft, helicopters, land vehicles, and ships. The French military has purchased Sogitec products for combat pilot training in the French Mirage fighter bombers. In addition, Sogitec's simulation expertise is currently being adapted for film production, television commercials, and animation.

Some notion of Sogitec's research intensity can be seen in its distribution of personnel. Over 250 of Sogitec's 550 employees are scientists or engineers involved in research and development (50 are located in the United States). Eighty percent of the researchers come from the grandes ecoles system, the remainder from French universities.[119]

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[116] Ibid.

[117] Ibid.

[118] Department of State, "WTDR on Sogitec (SIC) Data Systems," Oct. 10, 1983, p. 3.

[119] Ibid.

The United Kingdom

Historically, the United Kingdom has heavily relied upon industrial manufacturing for its economic well-being. As the post-industrial society arrives with the decline of manufacturing as a primary economic activity, the British economy has suffered.[120] The United Kingdom's share of world trade in manufactured goods in the decade 1963-73 fell from 15 to 9 percent. For the first time in history the United Kingdom now appears to be approaching a trade deficit in manufactured products. Moreover, the U.K. 'S needs for various information technology products are completely or substantially met by imports. As a result of the importance of exports to the U.K. economy and the increasing importance of information technology to the world economy, both the U.K. Government and industry have concluded:

> Our basic economic situation dictates that we must become a net exporter of high technology, high value-added products; information technology is a prime example of this.

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[120] Daniel Bell, *The Coming of Post-Industrial Society* (New York: BASIC Books, Inc., 1976).

> Moreover, unless our [the United Kingdom] information technology industry achieves a strong world competitive position, then the efficiency of our other industries in the manufacturing services will suffer. Their capacity to be advanced users of information technology has a close synergy with the level of the information technology industry itself.[121]

Traditionally, the United Kingdom has been one of the world's leaders in basic scientific research, particularly in the physical and biological sciences. Britain holds the highest per capita ratio of Nobel Prize winners in the sciences which is more than double those for any of the other industralized nations. Although the United Kingdom has in the past had the largest R&D expenditure percentage of gross national product (GNP) outside of the United States, the United Kingdom has been traditionally weak in converting and applying its basic research efforts to the production and marketing of new products and services.

This difficulty of transferring scientific knowledge to commercial applications has consequently created serious problems in the industrial sector and in the international competitiveness of British-made goods. This failure to capitalize on basic research efforts is documented in a recent publication of the Central Office of Information, London, "British Achievements in Science and Technology":

> . . . there have been an array of 'firsts' that apply to the information technology area, including radio navigation, computers, optical fibers, liquid crystal displays, and flat screen televisions, yet in none of these areas is a British manufacturer a principal supplier. '22

Thus the current challenge in the United Kingdom is to bridge the gap between the creative basic research in information technologies and the relatively weak state of industrial application of these technologies in order to create an environment which is more innovative in pursuing both domestic and international markets. This is particularly important in the area of information technology where the development of user applications of the technologies for the provision of new and innovative services is vital to the marketing of information technology.

Reflecting the need to increase applied research activities, the current U.K. Government has taken measures in the opposite direction of the traditional high level of government intervention in both industry and social programs. The more conservative government's efforts include privatizing the economy and restoring entrepreneurial initiatives, thus attempting to make industry more independent of government and reducing government involvement in the marketplace. Government strategies include privileged credit, deregulation measures, and tax benefits to encourage the growth of small and medium businesses.

Privatization measures also entail exposing state-run monopolies to outside competition. A major example of this introduction of competition is the termination of the monopoly of British Telecom (BT) by granting a license to a major competitor to operate an alternative national telecommunications network. It is hoped that this recently introduced competition into the provision of telecommunications services will stimulate demand for advanced technology transmission and exchange equipment. In conjunction with the privatization measures in the field of information technology, the U.K. Government is also promoting the marketing or applied aspects of research and development by shifting some of its R&D expenditure from government research establishments to the private sector. In Cambridge for example, where a preference for basic research has long prevailed, anew view towards research is emerging:

> What has changed is the idea that money is dirty and that one must do pure science. Now, as in Cambridge, Mass., or in California, people are not adverse to doing research that could be put to commercial use. This change in the work ethic has helped us.[123]

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[121] The Department of Trade and Industry, "A Prograrnme for Advanced Information Technology, " the Report of the Alvey Committee (London: Her Majesty's Stationary Office, 1982), p. 14.

[122] Central Office of Information, London, *British Achievements in Science and Technology,* April 1981, No. 11 1/RP/81.

[123] Phillip LeFournier, "Is Britain Reviving?" *World Press Review,* September 1983, p. 31.

Because of radical changes in government policy over the past decades in the United Kingdom, the continuity of policy which has, for example, aided Japan in its post-war recovery, has not been there to support industry in its efforts to expand. This complicates any simple characterization of the U.K. Government role in industrial policy and suggests a dynamic situation currently regarding U.K. Government initiatives in information technology. Consequently, it is difficult at times to disassociate government, industry, and university roles in information technology R&D. However for purposes of comparison with United States, Japanese, and French R&D efforts, government, university, and industry R&D environments are described separately below. Before discussing these environments, it is important to understand the size of the U.K. participation in information technology markets.

The Size of U.K. Participation in Information Technology Markets

While the United States and Japan are net information technology exporters, the United Kingdom is a net importer of information technology products by F 300 million ($420 million) annually.[124] In 1980, the U.K. industry captured approximately 50 percent of its own F 2.1 billion ($2.94 billion) information technology market. Moreover, the U.K. information technology industry captured 3.8 percent of the world information technology market in 1980.[125]

Because of the relatively small size of its national markets, the U.K. information industry has been somewhat inhibited. Moreover, it has had difficulty in generating significant export markets for its information technology products to balance its heavy imports. For example, of the 19 top semiconductor companies in the world, which account for approximately 75 percent of the world market, not one is from the United Kingdom.

Government

The U.K. Government officially recognized the importance of the development of information technology to the British society, industry, and economy by requesting the Advisory Council on Applied Research and Development (ACARD),[126] which advises the Prime Minister and the Cabinet Office on important developments in advanced technology, to address the following questions:

- Should development and application of information technology in the United Kingdom be stimulated?
- Are there constraints on British industry which supplies and applies information technology equipment, software, and systems?

The resultant 1980 ACARD report "Information Technology" has contributed to present policy formulation in relation to information technology, with an emphasis on the application of information technology as a key element in the future industrial and commercial success of the United Kingdom as well as on the potential significance of information technology for both society and individuals.

The ACARD report recommended the following:

1. One minister and one government department should be wholly responsible for information technology.
2. One government department should be responsible for the regulation of communications and broadcasting.
3. There should be a government commitment to information technology.
4. The government should actively promote and publicize British information technology.

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[124] All U.K. pound figures are converted into U.S. dollars according to foreign exchange rates as of Aug. 1, 1984, where L 1 = $1.4.

[125] "A Strategy for Information Technology," National Enterprise Board, 1981, p. 19.

[126] Probably the nearest United States counterpart to ACARD is the Committee of Advisors, recently created by Dr. Keyworth in the Office of Science and Technology Policy in the White House. ACARD, whose members are experts drawn from industry, government, and academia, offers specific recommendations for government action.

5. Central government, local government, and the nationalized industries should apply information technology vigorously.
6. The Post Office should provide a worldwide network.
7. Education, training, and guidance should be accentuated in information technology.
8. Links between users and suppliers of information technology equipment should be improved.
9. Strong British teams should participate in international fora on regulations and standards.
10. Legislation should be introduced to provide for better protection of data, and other legal reforms will be required.
11. The Post Office monopoly on use of its services should be ended.
12. Public purchasing should be used to "pull through" development of equipment.
13. The Science and Engineering Research Council and the Department of Industry should promote research and development in information technology.
14. All publicly funded information technology research and development should be coordinated. This would involve Department of Trade and Industry, Ministry of Defense, the Post Office, and the Science and Engineering Research Council.

The United Kingdom has taken a wide-scope approach to encourage the development and application of information technology in British industry and society. In response to the ACARD report, Mrs. Thatcher's government has developed an overall strategy for information technology. The main objectives of the U.K. Government's policy for information technology are:

1. The development of a statutory regulatory framework favoring the growth of information technology products and services.
2. The development of new products and techniques through direct research and development support and enlightened public purchasing.
3. Action to make individuals more aware of what information technology offers and so enable them to take advantage of the new information technology products and services.
4. The provision of a national telecommunications network capable of stimulating, and meeting, demands for new services.

For implementation of these goals, 1982 was designated as IT Year in the United Kingdom. A wide range of promotional aids was used to increase the awareness of the general public, industry, and schools, and main procurement agencies. The major force in IT Year, in addition to the information technology awareness campaign, was a major and intensive government-industry initiative to encourage research, development, and application of information technology in order to help strengthen the overall U.K. economy.

Also during 1982, the British Government acknowledged the need to address the field of information technology in a coherent manner and subsequently made significant changes in its policymaking structures. A minister with special responsibilities for information technology was appointed, the first such appointment in any nation. The Minister for Industry and Information Technology has responsibility, under the Secretary of State for Trade and Industry, for all the Department of Trade and Industry's activities concerned with information technology, including those related to research and development. More specifically, the Minister has responsibilities for information technology, telecommunications, computer systems, microelectronics, electronics applications, robotics, and space. He oversees British Telecom and the Post Office public purchasing, research and development (including the industrial research establishments) and the British Technology Group. He is also responsible for sponsorship of the chemical, mechanical and electrical engineering, and paper industries; and for distribution and service trade industries; newspapers, printing and publishing; and for standards and quality assurance and firms. Although the responsibilities of the Minister of Industry and Information Technology are central to the promotion of information technology in the United Kingdom, at times the press coverage of ministry activity tends to be exaggerated.

Department of Trade and Industry (DTI)

As a result of the 1980 ACARD recommendations which suggested increasing coordination between industry and government, the Department of Trade and Industry (DTI) has become the major focus for U.K. initiatives in areas related to information technology. In recent years there has been a shift in U.K. Government support from its own research establishments (which still account for a substantial part of the nation's scientific resource) to the private sector. The DTI total expenditure in 1982-83 was approximately F 230 million ($322 million), of which approximately two-thirds was spent in the private sector. DTI allocated approximately F 80 million ($112 million) for information technology R&D in 1979-80.'[127] This trend is greatly supported by the U.K. Government because it locates research closer to the point of application (which some feel is vital in the area of information technology) and encourages private sector initiatives.

The DTI's decisions on funding priorities for research and development rely on the advice of five Research Requirements Boards (RRBs). Each RRB is chaired by a Senior Industrialist and consists of industrialists, scientists, and government representatives. The RRB's are seen as an effective system for monitoring and developing strategies to ensure that research support priorities match the demands of changing technologies and future industrial needs. The DTI, therefore, works closely with industry through the Research Requirement Boards to ensure that research in the national laboratories is directed towards industrial needs. Three of the Research Requirements Boards, Computers, Systems, and Electronics; Mechanical and Engineering; and Metrology and Standards, are involved with information technology R&D support. The Computers, Systems, and Electronics RRB is the major supporter of information technology R&D with 1980-81 expenditures of F 6 million ($8.4 million).[128]

In keeping with the current U.K. Government policy, which aims to achieve a profitable, competitive, and adaptable private sector, the DTI has recently implemented a variety of programs that are intended to supplement direct R&D support. Because of the recent recession that has inhibited U.K. companies from investing large resources in R&D activities, these programs are intended to encourage the private sector to research, develop, and use information technology. The DTI's support programs generally comprise three elements:

1. An *awareness* program to stimulate interest in the potential of the new technology.
2. **Consultancy** to explain how a particular technology can be applied to a particular company's needs.
3. **Support** for ensuing projects.

These DTI R&D support programs, categorized by the various applications of information technology, are presented in table 44.

THE ALVEY PROGRAMME FOR ADVANCED 1NFORMATION TECHNOLOGY

In addition to industrial R&D support schemes, the DTI recently initiated a collaborative national information technology R&D program. One of the catalysts to the formation of the Alvey Programme was the announcement of the plans for Japan's Fifth-Generation Computer Systems Project and Japan's invitation to other countries, including the United Kingdom, to discuss participation in the program. The scale and cohesiveness of this and other Japanese programs were seen by the U.K. representatives to the Japanese conference as a major competitive threat. The British also believed that the U.S. industry's

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[127] John K. Thompson, " 'IT' in Britain, " speech given at the British Embassy to the Potomac Chapter of the American Society of Information Scientists, June 9, 1982.

[128] Statement of Kenneth Baker, before the U.K. House of Commons, Dec. 21, 1982.

Table 44.—Department of Trade and Industry R&D Programs

CAD/CAM	— The Computer-aided Design and Computer-aided Manufacture program is designed to promote and accelerate the acceptance and application of CAD/CAM primarily in the mechanical and electrical engineering industries.	- 6 million ($8.4 million) (over 3 years from 1981)
CAD/MAT	— The Computer-aided Design Manufacture and Test Program is designed to encourage the use of CAD/MAT for design testing and production in the electronics industries.	- 9 million ($12.6 million) (over 3 years from 1982)
FMS	— The Flexible Manufacturing Systems Scheme is designed to encourage fiirms to install flexible manufacturing systems.	- 60 million ($84 million) (over 3 years from 1982)
FOS	— The Fiber Optics and Opto-Electronics Scheme is designed to encourage the development, production, and application of fiber optics and opto-electronics.	-25 million ($35 million) (over 5 years from 1981)
MAP	— The Microelectronics Application Project is designed to encourage the application of microelectronics in products and processes in manufacturing industries.	-55 million ($77 million) (commenced 1978)
MISP	— The Microelectronics Industry Support Program is designed to promote the microelectronics components industry, particularly for the manufacture of silicon integrated circuits.	-55 million ($77 million) (commenced 1978)
ROBOTICS	— The Industrial Robotics Scheme is designed to encourage the development and application of robots in manufacturing industries.	+ 10 million ($14 million) (over 3 years from 1981)
SPS	— The Software Products Scheme is designed to encourage the development and application of software products and packages.	
Awareness programs, demonstration projects and other promotional activities		+80 million ($1 12 million) (over 4 years commencing 1981)

SOURCE: Office of Technology Assessment.

reaction to the Japanese Fifth Generation Computer Systems Project could also cause an equal if not greater degree of competition for the U.K. industry.

In the light of these factors, the U.K. delegation called for an urgent study into the feasibility for a collaborative R&D program geared to particular strengths and requirements. This study, completed by the Alvey Committee, outlined plans for a national information technology R&D effort to improve the United Kingdom's competitive position in world information technology markets.[129] John Alvey, Chairman of the Committee, comments on the coordination aspects of the program:

> This is the first time in our history that we shall be embarking on a collaborative research project on anything like this scale. Industry, academic researchers, and government will be coming together to achieve major advances in technology which none could achieve on their own. The involvement of industry will ensure that the results as they emerge are fully exploited here in Britain to the advantage of our economy. Information technology is one of the most important industries of the future and therefore one upon which hundreds of thousands of jobs in the future will depend. Collaboration will ensure that the results of the research are widely disseminated particularly to smaller firms which have such an important contribution to make to the industry. No one can guarantee success, but the government is convinced that this program will ensure for British industry secure access to the new technology and to the products and processes on which our future prosperity depends.

The Alvey Program for Advanced Information Technology is a 5 year program funded by three government ministries and industry. Total funding for the program will be approximately $525 million over a 5 year period. The

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[129] See "A Programme for Advanced Information Technology, The Report of the Alvey Committee, " Department of Industry, Her Majesty's Stationary Office, 1982.

Department of Education and Science (DES) through the Science and Education Research Council (SERC) will fund approximately 50 million ($70 million) for promoting advanced research in academic institutions and the training of necessary manpower. The Ministry of Defense (MOD) will fund approximately %40 million ($56 million) for research believed to be important to the defense industry and will contribute its experience in the field of integrated circuits. The Department of Trade and Industry will provide the major portion of the government's funds, approximately L 110 million ($154 million), and will have the overall responsibility for management of the program. Industry will fund the remaining L 150 ($210 million) in the form of 50 percent matching funds for each R&D project.

The Alvey Program R&D projects are concentrated in four technical areas, known as "enabling technologies. " These enabling technologies, seen as crucial to the development and application of information technology in the United Kingdom, include:

- *very* large scale Integration (VLSI) silicon integrated circuits,
- software engineering,
- intelligent knowledge based systems (IKBS), and
- man/machine interface.

The research projects in these four technical areas will be managed by the Alvey Directorate consisting of staff from industry, DTI, MOD, and SERC. Each of the four technology areas has its own director in addition to a director in charge of networks and communications among the various R&D projects. Each of the research teams will generally be organized in small consortia—e.g., two information technology firms, together with a government research establishment team, and a university team. Unlike the Japanese approach of creating a center for research, research teams will rely on a data network and electronic mailbox service that will allow interactive communication among the R&D program participants.

The United Kingdom will also be a major participant in the European Strategic Program for Research in Information Technology (ESPRIT). Currently, U.K. companies are involved in more than half of ESPRIT's pilot projects. The Alvey program is also designed to complement the ESPRIT program with interl.inking communications networks and common parallel research strategies.

THE DEPARTMENT OF TRADE AND INDUSTRY'S NATIONAL LABORATORY FACILITIES

The U.K. national research establishments involved with information technology R&D are the National Physical Laboratory, the National Engineering Laboratory, and the Computed-Aided Design Centre.[130]

The National Physical Laboratory (NPL) has a long distinguished history in computer technology. In 1981-82, NPL R&D expenditures were approximately L 22 million ($30 million). Currently, R&D projects are focused on data networks, data security, special input devices, and microprocessor applications. The Laboratory also is developing standard network protocols and evaluating cryptographic methods for data protection. NPL also develops software for solving engineering problems.

The National Engineering Laboratory (NEL) carries out research, development, design, consulting, and testing in automated manufacturing. The 1982 Information Technology Year campaign highlighted the Laboratory's involvement in robotics and automated production systems. NEL R&D expenditures were approximately L 16 million ($22.4 million) in 1981-82. Key areas of NEL research include automated assembly, control and optimization of production systems, the development of an advanced turning cell, and other flexible manufacturing systems.

Computer-Aided Design Centre (CADCENTRE) is the primary center in the United Kingdom

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[130] Discussion **of the U.K. National Research Labs, based on "Research and Development Report, 1981 -82," Department of Industry, 1982.**

for the development of computer techniques in design and engineering. In 1981-82 the CADCENTRE R&D expenditures were approximately L 4 million ($5.6 million). The center offers approximately 30 computer software packages in CAD/CAM and provides a comprehensive range of services including software development, consultancy, production services and the provision of hands-on experience in CAD/CAM techniques. Because private sector initiatives were encouraged in DTI sponsored R&D, the DTI agreed to sell the Cambridge-based CADCENTRE to a U.K. consortium led by the U.K. computer firm International Computers, Ltd. (ICL) for approximately L 1 million ($1.4 million). The newly privatized CADCENTRE employs ICL staff and DTI management staff. In addition, the DTI has agreed to provide some financial support in order to ease the transition from a government research establishment to a commercially run company. The DTI will be entitled to a royalty based on the CADCENTRE'S turnover.[131]

The Ministry of Defense (MOD)

The Ministry of Defense (MOD) is also a major supporter of applied R&D. Almost half of the United Kingdom's R&D budget has been devoted to defense. In the 1970s, defense R&D remained relatively constant although all other areas of R&D decreased by almost 50 percent. In 1978, the Ministry of Defense expenditures for electronics research and development were approximately $900 million.[132]

Beyond the direct support from industrial research funds, the defense sector has potentially the greatest possibility for contributing to civil information technology. There has been a recent shift in emphasis within the MOD away from aircraft and towards electronics research and development. Because the overseas defense electronics market is fairly strong, it is difficult to predict what the long-term consequences of this shift maybe. If the market grows for defense electronics, there could be a positive effect on the U.K. supplier industry. On the other hand, because the spin-off effect of U.K. military R&D to commercial products has not been particularly significant, any increase in attention to military needs by the limited U.K. electronics industry might have the effect of further reducing their civilian-oriented work and reducing their market competitiveness.

Department of Education and Science (DES)

Under the advice of the Advisory Board for Research Councils (ABRC), the Department of Education and Science (DES) allocates the science budget to five Research Councils. The Science and Engineering Research Council **(SERC)** has the primary responsibility for information technology R&D. The SERC budget allocated to information technology R&D was L 5 million ($7 million) in 1979-80, L 8.5 million ($11.9 million) in 1980-81, and L 11 million ($15.4 million) in 1981-82.*[33]

SERC, analogous to the U.S. National Science Foundation, accepts competitive bids from universities for special projects. Unlike NSF, SERC provides only half the funds for sponsored projects. The rest of the funding must come from industry, charitable foundations, or other government departments. SERC also provides research establishments with central computing support. The Engineering Board of SERC is most involved with information technology, with funding areas in:

- device-related research,
- skilled manpower training,
- software technology, database utilization, and system reliability,
- distributed computing systems.

SERC operates the Rutherford Appleton Laboratory (RAL). The lab itself has a considerable research program in information technol-

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[131] Under the royalty arrangements, the U.K. Government will be repaid and could receive a further net amount of L 4.5 mil-ion over a 10-year period, assuming forecast revenue levels are achieved by the company.

[132] J. Thyme, "Information Technology in the U. K.: Government Policy, " in G.P. Sweeney (cd.), *Information and the Transformation of Society,* North-Holland Publishing Co., 1982, p. 261.

[133] John Thompson, " 'IT' in Britain," speech given at the British Embassy to the Potomac Chapter of the American Society of Information Scientists, June 9, 1982.

ogy, with efforts in distributed computing systems, industrial robotics, computing applications in engineering, electron-beam lithography, and image processing.

British Technology Group (BTG)

The British Technology Group is an independent public corporation established to promote the development and application of new technology. The British Technology Group was formed in 1981 and includes the former National Research Development Council (NRDC) and the National Enterprise Board (NEB).

BTG provides funds for technological innovation through:

- joint venture finance under which BTG can provide 50 percent of the funds required for the business in return for a levy on sales of the resulting product or process;
- recirculating loans, which are a form of working capital loan, through which BTG can help a company to meet specific orders for innovative products; and
- equity and loan finance on venture capital terms where a company is set up for the purpose of developing and marketing an invention or new technology; equity may also be provided in the form of redeemable preference shares.

Projects from all sectors of industry are eligible for consideration. The primary consideration for BTG support is that the proposal project must be based on a new invention or a genuine technical innovation.

University

Basic research is supported primarily at the university level (approximately 22 percent of government R&D spending) both by discipline oriented committees of the Science and Engineering Research Council (SERC) and the University Grants Committee (UGC). Recent cuts in university funding have been substantial—15 percent over the last 4 years. In addition, lowered enrollment has caused the universities to become top-heavy with senior, relatively expensive faculty. The steadily rising cost of research equipment has also affected the available funds for university research. Together, these three factors have resulted in substantially less spending for university R&D.[134]

Although university research funding has been decreasing over the last few years there have been marked changes in the distribution of funds—away from basic research towards engineering and applied R&D. This trend towards greater emphasis on industrial application of research results is exemplified in several recently initiated schemes. These schemes, designed to promote high quality research in fields of applied science, are cosponsored by SERC and DTI. In one of the more successful joint SERC/DTI initiatives, the Teaching Company Scheme, DTI pays for engineers to do postgraduate work in industry. Students work on product development, design, and manufacturing processes, but with close attention and support of academic staff who supervise the innovative aspects of the graduates' work. The program so far has attracted great interest from industry, and many firms such as General Electric Co., British Aerospace, Ferranti, and IBM are participating.

Another program aimed at promoting industrial training is the introduction of approximately 150 information technology centers (ITEC centers) throughout the United Kingdom. Funded by DTI, Manpower Services Commission, and industry grants, these centers collaborate with local industries to provide computer training for unemployed high-school age youths. Approximately 70 percent of the students upon leaving the centers find employment in a computer-related field. Other programs that offer technical training include Computers in Schools, through which DTI funds 50 percent of the cost of up to two microcomputers in each U.K. school, and a Manpow-

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[194] Robin B. Nicholson, "Science and Technology Policy in the United Kingdom, " address given at the Nineteenth Annual Meeting of the National Academy of Engineering, Nov. 2-3, 1983.

er Services Commission Program that funds information technology training in computer-related subjects. Approximately half of all the programmers training in the United Kingdom is provided by these programs.

In addition to industrial training programs, the U.K. Government has encouraged greater industrial participation in R&D as well as closer industry-university ties through the initiation of science parks. Similar to the Japanese and U.S. science parks, the U.K. science parks provide an opportunity for industry to locate in the proximity of major research universities.

Industry

Since the late 1960s, the U.K. Government has played an important role in supporting the U.K. computer industry. For example, in 1968 the government encouraged a series of mergers that led to the establishment of International Computers Ltd. (ICL) and then provided funds amounting to approximately $12 million annually until 1976. Moreover, the government encouraged ICL'S growth through preferential procurement policies that guaranteed almost all large central government contracts to ICL. ICL became the largest European computer company, with a wide customer base in the United Kingdom as well as overseas, including the United States. ICL became so successful that government assistance was withdrawn in 1976, and in late 1979 the government sold its 25 percent share in the company. However, by 1981, ICL was heavily in debt, and the government (although it encouraged private funding and joint research programs) arranged L 270 million ($378 million) in loans for ICL.

In an effort to become profitable again, ICL is currently exploring joint activities with non-U.K. firms. In 1982, ICL and Fujitsu reached a collaborative agreement. The arrangement provides for special access to Fujitsu's advanced microelectronics technology, and provides for purchases of semiconductor chips developed by Fujitsu. ICL will in turn market large Fujitsu computers in Western Europe, thus broadening the ICL product line into more powerful computers. It is hoped to extend this collaboration at a later date to other technology areas, including communications technology. ICL also recently reached an agreement with a small U.S. company, Three Rivers, to manufacture and market worldwide a microcomputer designed by Three Rivers.

In 1979, the U.K. Government also invested $100 million for the creation of a national semiconductor firm, Inmos. Operating as an independent producer, Inmos was established to manufacture a limited range of products (principally high-capacity semiconductor memory chips) to sell to large electrical goods manufacturers. Also, to assure indigenous production of semiconductors, the U.K. Government has convinced several U.S. semiconductor companies to setup production in the United Kingdom by offering them grants up to 33% percent for R&D costs, under the Support for Innovation Program (SFI).

Currently, more than half of the U.K. industrial electronics R&D expenditure is funded by government. The funding may be in the form of cost-sharing grants, procurements, or any of the multitude of funding schemes. Moreover, the pervasive influence of the U.K. Government is exemplified in the original Alvey proposal which called for the government to fund 90 percent of industrial R&D activities. The proposal, however, was finally amended to the current commitment of 50 percent only after considerable debate, on the grounds that industry would not be committed if it only was required to invest 10 percent of its own resources.

The historically low industrial funding for information technology R&D has been attributed to the U.K. information technology industry's focus on highly specialized markets. Because the U.K. information technology industry in some instances fills small but important market niches, it usually does not capture mass markets; consequently, the U.K. information technology industry has not always had adequate resources for R&D funding.

A case in point is the British semiconductor chip industry. The leading U.K. information technology firms have concentrated on producing specialized chips known as “specials” where the demand is low and the market relatively small. For example, world sales in 1980 of custom-built special chips came to only L 100,000 ($140,000) almost one-twentieth of the comparable figure for standard chips.[135] Although the leading British electronic firms’ demand for these standard chips are extremely high, U.K. industry has left the manufacturing of these types of chips mainly to companies from the United States and Japan, which together capture approximately 75 percent of the world market. However, the United Kingdom’s leading firms—Ferranti, Plessey, and GEC—all plan to expand their manufacturing capability of standard chips for domestic use. This pattern has also been repeated in other information technologies; for example, few British companies produce hardware that directly serves the semiconductor and electronics industry (i.e., for testing and production needs).

There is some indication that U.K. industry may be reassessing its investment policies. Current estimates suggest, for example, that the volume of R&D has been maintained through the recession on a selective basis with substantial advances in areas such as microelectronics and corresponding decreases in metals and traditional engineering. For example, industrial electronics R&D expenditures increased form L 279 million ($390.6 million) in 1975 to L 442 million ($618.8 million) in 1978.[136]

Similar to the situation in France and Japan, a few large firms are responsible for a large proportion of information technology R&D expenditure in the United Kingdom. Several of these major firms are described below.

Plessey

In 1983, Plessey invested approximately $225 million in R&D, 15 percent of its sales. Approximately $22 million of the R&D expenditures were allocated to basic research activities. Of the 320 researchers in the main Plessey laboratory working on microelectronics, 170 people are working on gallium arsenide and related materials and 150 are working on silicon. Plessey’s silicon research is geared towards speciality or custom circuits.

Plessey relies heavily on outside contracts, and approximately 45 percent of its research is done for the MOD and British Telecom. Of the remaining 55 percent, half is conducted for the Plessey operating divisions and half is conducted for the head office. Currently, Plessey is attempting to reduce its reliance on outside R&D funding in favor of more operating division work.[137]

General Electric Co. (GEC)

In 1983, the General Electric Co. (GEC) invested approximately $900 million in research and development, approximately 10 percent of its sales. Unlike Plessey, only 25 percent of GEC’s research is for the MOD and British Telecom. Fifty percent of the research is for GEC’s 120 operating companies, and 25 percent is for basic, speculative research. Because a large percentage of its R&D is supported by its operating companies, GEC’s research activities are more oriented towards commercial product development. GEC’s key areas of research include microelectronics, fiber optic devices, software engineering, and custom chip design.[138]

British Telecom (BT)

Previously a public monopoly, the U.K. Government has recently privitized British Telecom (BT). Moreover, the U.K. Government has permitted the licensing of other competitors

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[135] **Peter Marsh, “Britain Faces Up to Information Technology, ”** *New Scientist,* **Dec. 23, 1982, p. 637.**

[136] **Robin Nicholson, “Science and Technology Policy in the United Kingdom, ” address given at the Nineteenth Annual Meeting of National Academy of Engineering, Nov. 2-3, 1983.**

[137] **“Profile: GEC and Plessey: Two Approaches to R& D,”** *The Economist, Nov. 20, 1982.*

[138] **Ibid.**

to provide telecommunications services. It is hoped that the introduction of competition into the provision of telecommunications services will stimulate new demand and provision of a vast array of new services. Consequently, U.K. companies with advanced products are expected to be well placed to take advantage of market development and to use the United Kingdom as a springboard for capturing European and other world information technology markets.

The privatization efforts, however, have caused some speculation about the future of BT laboratories in much the same way that divestiture has caused speculation about the future of Bell Labs. Currently, BT Labs research expenditure is approximately L 100 million ($140 million) annually. BT has traditionally had strong research programs in four major areas:

- advanced technology (e.g., CAD in large scale integrated circuit design, optical communications systems, gallium arsenide, high speed logic);
- transmission (e.g., digital transmission in LANs, small earth station satellites);
- customer service/apparatus (e.g., Prestel and Viewdata);
- advanced systems (e.g., microprocessor software development ISDN local connection).

European Strategic Program for Research in Information Technology (ESPRIT)

In an attempt to reverse the decline of Europe's competitiveness, to ensure a stronger technological base, and ultimately to ensure economic and political independence, the Commission of European Communities proposed the European Strategic Program for Research in Information Technology (ESPRIT).[139] Although EEC members hope that ESPRIT will succeed in strengthening Europe's technological base and international competitiveness, there are concerns as to whether research can be effectively undertaken and shared among potential international competitors.

ESPRIT is designed to address three major difficulties that currently face the European information technology industry as it attempts to develop new state-of-the-art technologies: the problem of raising adequate funds for long-term research and development during a period of economic recession and falling sales; a domestic market which, unlike those of the United States and Japan, is fragmented into a number of relatively small national units; and reluctance by some within individual countries to subsidize other nations who have historically been economic and political rivals.[140] Consequently, the ESPRIT program seeks to: increase the size of research teams, optimize the use of human and financial resources, and initiate definition and adoption of European standards for information technology products.[141]

ESPRIT attempts to address the problem of the fragmentation of the European market, as well as the divided efforts of the individual member nations' national R&D support programs, by linking a significant proportion of key European engineers and scientists from government, industry, and universities. In this respect, ESPRIT is similar to other national research and development programs such as Japan's Fifth-Generation Computer Project, the United Kingdom's Programme for Advanced Information Technology, and the U.S. Semiconductor Research Corporation (SRC), which are also partnerships among various companies, academic research laboratories,

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[139] **In 1975, the European Community had a trade surplus in information technology products; however, by 1980, the trade deficit in information technology products reached $5 billion and reached approximately $10 billion in 1982. At present, Europe represents one-third of the world information technology market but accounts for only 10 percent of world information technology production. For example, in the European domestic market, 2 out of every 5 information technology products sold are European; 8 out of 10 personal computers sold in Europe are imported from the United States; 9 out of 10 videotape recorders sold in Europe come from Japan. ESPRIT Proposal, COM(83) 258 final, Commission of the European Communities, June 2, 1983, p. 8.**

[140] **David Dickson, "Europe Seeks Joint Computer Research Effort," Science, Jan. 6, 1984, p. 28.**

[141] **ESPRIT Proposal, COM(83) 258 final, Commission of the European Communities, June 2, 1983, p. 9.**

and government agencies. However, unlike these other research and development programs, ESPRIT also represents an international institutional arrangement.

Unlike the MITI program in Japan, the ESPRIT program is limited to precompetitive research; it does not intend to develop a commercial product as does the Japanese fifth-generation computer effort. At any point in the research, however, the participating companies are free to take the technical results gained from the ESPRIT projects and develop commercial products on their own. Therefore, ESPRIT is not seen to be in competition with national research and development programs or individual companies, but as a reinforcement to make them more effective.

Funding for ESPRIT is approximately $1.3 billion for the next 5 years and approximately 2,000 researchers will take part in research activities.[142] The funding be equally shared among 12 principle corporate partners and other participating companies with the Commission of European Communities. The 12 main corporations participating in ESPRIT include: General Electric Co. (United Kingdom), Plessey plc. (United Kingdom), International Computers Ltd. (United Kingdom), Compagnie General de L'Electricity (France), CIT-Alcatel (France), Cii Honeywell Bull, (France), Thomson-Brandt (France), AEG-Telefunken AG (West Germany), Nixdorf Computer AG (West Germany), NmbH Phillips Gloeilampenfabrieken (Netherlands), Olivetti SPA (Italy), and Societa Torinese Esercizi Telefoncini (Italy).

The ESPRIT program consists of five major research areas: advanced microelectronics, software technology, advanced information processing, office automation, and computer integrated manufacturing. The EEC has chosen these five areas of information technology because of their perceived importance for future European industrial competitiveness. The first three of these research areas were selected in part to develop better enabling or core technologies. Office automation and computer integration were selected as specific applications areas where information technology is expected to have a large economic and social impact–automation of the office and the factory.

The advanced microelectronics project's major goal is to develop smaller, more reliable, and more powerful integrated circuit technology so that devices can perform more functions or operations than circuits available today. More specifically, the goal of the advanced microelectronics project is to improve the current state-of-the-art process, which is based on three-to-five micrometer structures, to processes that are based on structures smaller than one micrometer. The Europeans are hopeful that this advanced microelectronics project will improve Europe's current integrated circuit trade deficit.[143]

The major emphasis of the advanced information processing project is on information and knowledge engineering, information storage and usage, signal processing, and external interfaces. The research project's overall goal is to develop technological capabilities that underlie machine intelligence. Advances in the new types of information processing will also entail breakthroughs in advanced computer architecture, further miniaturization in microelectronics, and higher reliability.

The goal of the software technology project is to improve software engineering techniques. More specifically, the project's goals include establishing standardized software interfaces, automating the software engineering process, and disseminating and centralizing software research results in a common database so that individual modules of software programs can be reused where similar functions are required.

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[142] Actual funding for ESPRIT is 1,500 million European currency units (ECU). Approximately 1 AU equals 1 U.S. dollar. Of the total European Community countries' research and development expenditures, 1.7 percent is for EEC research and development activities. Nine percent of the EEC R&D budget is reserved for industry of which 20 percent is for ESPRIT funding.

[143] Currently, Europe absorbs 20 percent of the world's integrated circuit market, although Europe produces only 6 percent of the world's integrated circuits.

The office automation project, one of the two specific applications projects, is directed at developing a multimedia interface for all office communication needs, and at developing efficient electronic filing systems for unstructured information (text, voice, graphics, images, etc.). The project will also examine the cross-cultural interaction of human factors, educational, sociological, and industrial effects of office automation systems. Moreover, research on machine translation (which is of great importance to the European Community) and aspects of machine-user interfaces, such as integrated image test speech communication, document creation, and distribution will also be conducted.

The goal of the computer integrated manufacturing project is to develop improved systems for automated factories. These systems will integrate in a common data base computer-aided design, computer-aided manufacturing, computer-aided testing and repair, and assembly. Such integration will require further developments in integrated systems architecture, advanced components, real-time based imaging, and integrated control subsystems mounted on semiconductor chips.

Experts from the 12 main industry partners as well as outside consultants have developed a work plan of specific projects in the five project areas. As these specific projects have been defined, proposals are solicited. Proposals may be submitted by research teams from any industry or university, although the team must be composed of nationals from two or more EEC countries. This arrangement is meant to encourage international cooperation between nations and industries, and therefore prevent duplication of research efforts and make optimal use of limited financial and human resources. The main criteria for evaluating proposals include: technical soundness; contribution to industrial strategy in light of ESPRIT objectives; European Community usefulness; technical, scientific, and managerial capability to undertake the proposed project; and proposed activities that will facilitate the dissemination of research results.

The Commission and the advisory board, which consists of industry representatives (mainly from the 12 contributing industries), review research proposals and approve grants. Two broad types of proposals are considered for the different technical projects. Type A, which represents the strategic long-term research activities of ESPRIT, involves large research establishments and large commitments of resources, both human and financial, as well as clear long-term strategic plans to ensure continuity of research and long-term benefits. Type A projects receive 50 percent funding from the European Community, and the research participant is expected to provide the remaining funds. Type B proposals require relatively smaller resources and account for a significant share of the overall efforts under ESPRIT. Type B projects could range from very long-term, very speculative R&D to shorter-term and more specific R&D. Type B projects receive at least 50 percent of their R&D funds from the European Community, or more if the applicant is from an academic institution or smaller business with limited available finance.

One of the first ESPRIT research proposals to be funded is a project to develop advanced interconnection between very-large-scale integrated circuits. The research project is a joint effort between Plessy and GEC in the United Kingdom, Thomson CSF in France, and Telefunken in West Germany. Another initial project, jointly shared between the Polytechnic in London and the University of Amsterdam, is focusing on the development of 11 different aspects of tools and methods for developing machine intelligence.

The Future of ESPRIT

The initial response to the ESPRIT pilot phase has been favorable; the 1 year pilot phase of ESPRIT, launched in mid-1983 with a budget of $20 million and funded 50 percent by the European Community and 50 percent by industry, attracted over 200 research proposals. However, only 36 could be selected to receive EEC matching funds. EEC officials were quite surprised not only at the scale of response, but also at the apparent willingness of companies to permit their scientists to work together with few restrictions.[144]

Currently, however, there is still some doubt as to whether ESPRIT will further achieve its stated goals. In the past, the EEC has had some difficulties with other joint projects. In the 1960s, Pierre Aigrain, then President Pompidou's chief scientist, proposed a European project to strengthen the technological base of the computer and communications industry. However, the project was never launched because of resistance from the European telecommunications monopolies to the suggestion that their own research was insufficient and the lack of a plan to suggest how a cooperative research program supported by established companies and nationalized industries could be beneficial to all the participants.[145] Moreover, in the early 1970s, Dutch, German, and French computer manufacturers formed a joint venture, Unidata. Each company sent their top engineers to a joint research and development facility. However, the project had many difficulties and some of the participants eventually withdrew from the project.[146]

As in past joint European research efforts, the future of ESPRIT depends as much on the results of political struggles around the restructuring of Europe's economic and industrial base as it does on any judgment of its technical and scientific merits.[147] This is illustrated by the first few unsuccessful attempts in early 1984 for EEC endorsement of ESPRIT, which became intermingled with broader economic issues ranging from the efficiency of French farming practices to the EEC's budget procedures. Moreover, it is still unclear as to how the national information technology research programs will mesh with ESPRIT projects. Consequently, there are debates in each country over whether the results of information technology research and development, as an important key to future political and economic strength, should be shared with potential competitors.

International rivalry is also a large industry concern. The lack of an established legal framework in which companies will be allowed to collaborate may cause difficulties for European information technology industries. Because ESPRIT is concerned primarily with long-term precompetitive research, there may not be any conflict with the EEC antitrust laws which are intended to apply primarily to marketing strategies, rather than product development. However, some companies believe that as the gap between scientific discovery or basic research and commercial application narrows, collaborative precompetitive research will be extremely difficult.[148] It is for this reason that three of Europe's largest mainframe computer manufacturers (Siemens, ICL, and Bull) have established the European Computer Industry Research Center. The Research Center discourages open collaboration by initially excluding participation by other companies because:

> **If you recognize the fact that you are in a competitive market, in which companies are fighting against each other, then you must accept that it is not in the interest to offer all research results to everyone who might be interested in them, and that at least some projects will be of character that will forbid the open publication of research results from the beginning. . . . We do abstract research on an international basis where the balance of cooperation and competition should be determined by the rules of international commerce, and market-like research on a national basis, where individual companies can adopt the most appropriate strategies for their domestic and political environment.**[149]

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[144] David Dickson, "Europe Seeks Joint Computer Research Effort," *Science*, Jan. 6, 1984, p. 28.

[145] "What Hope for ESPRIT?" *Nature*, Feb. 16, 1984, p. 582.

[146] Beth Karlin and George Anders, "Europe Looks Abroad for High Technology It Lags in Developing," *The Wall Street Journal*, Oct. 5, 1983, p. 1.

[147] David Dickson, "Europe Seeks Joint Research Effort," Science, Jan. 6, 1984, p. 28.

[148] This problem maybe particularly acute in research projects such as office automation and computer-aided manufacturing.

[149] Statement by Mr. Heimann of Siemens, David Dickson, "Europe Seeks Joint Computer Research Effort," *Science*, Jan. 6, 1984, p. 29.

Despite the preliminary difficulties in achieving agreement on the funding for ESPRIT, the establishment of the controversial Siemens-ICL-Bull Research Center, and other underlying political and economic rivalry, ESPRIT may succeed in overcoming these impediments. If ESPRIT does succeed, it is likely to be used as a model for similar cooperative European Community projects in other fields, such as telecommunications and biotechnology.