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Government-Promoted Collective Research and Development in Japan - Analyses of the Organization Through Case Studies

G. J. Hane

June 1990

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
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GOVERNMENT-PROMOTED COLLECTIVE RESEARCH AND DEVELOPMENT IN JAPAN - ANALYSES OF THE ORGANIZATION THROUGH CASE STUDIES

G. J. Hane

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Pacific Northwest Laboratory
Richland, Washington 99352

SUMMARY

A study was commissioned by the Energy Conservation and Utilization Technologies (ECUT) Program of the U.S. Department of Energy (DOE) to better understand the strategies used for cooperative and joint-venture research and development (R&D) overseas. The study evaluates the organization and management of several different types of cooperative R&D programs in Japan that are sponsored under the Ministry of International Trade and Industry (MITI) Program, Exploratory Research for Advanced Technology (ERATO) Program, and the Key Technology Center (KTC) Program.

The oldest program, MITI, was created during Japan's rapid industrial growth following World War II. Its first projects focused on polymer materials technology and high-grade alcohol production. Two commonly used forms of cooperative R&D arrangements used by MITI are the multiparticipant groups, which are largely funded by the government, and multiparticipant joint R&D arrangements, where costs are shared between government and industry. Two projects that represent the two forms of private section management are reviewed.

The ERATO Program grew out of a concern over revising the government's approach to supporting research and technology development. The program was initiated to address what was regarded as a lack of creativity in areas at the forefront of science. The program recruits young researchers and allows them flexibility to explore multi-disciplinary areas at the forefront of science. It has been organized to allow for individual creativity but at the same time to benefit from the combined knowledge of an assembly of researchers. Because the plan is such a radical departure from conventional Japanese philosophy, it has met with certain bureaucratic obstacles. Visits to four ERATO projects are described.

The third program, the KTC Program, focuses on getting private firms to venture into risky areas of advanced technology to pave the way for future industries. Its goal is to encourage a shift of resources in the private

sector toward areas that are considered essential for the competitive development of future industries. The principal philosophy behind the KTC is that the private sector is in the best position to identify promising technical challenges and to weigh their commercial potential against research uncertainties. Three KTC research joint ventures are briefly described.

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The science advisory staff of the U.S. Embassy in Tokyo and the DOE representative, Robert Jackson, were of great assistance in identifying contacts and providing introductions.

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1.0 INTRODUCTION

In the search for strategies to accelerate the advancement of technology and to enhance international competitiveness, cooperative research and development (R&D) are receiving increasing attention. This cooperative pooling of resources and skills offers advantages that are becoming more attractive as capital requirements exceed the resources of single firms, as technical demands require multidisciplinary expertise, and as vertically integrating the stages of R&D becomes increasingly important.

The United States has had very little experience with cooperative research activities. By contrast, governments and institutions in other countries have experience with various cooperative R&D programs. In particular, Japan is perceived to be very effective in exploiting the advantages of cooperative R&D, providing industry with the skills and technology that have rapidly enhanced its position in international technology. In the past several years, the Japanese government has launched several new and different forms of cooperative research to meet the advancing needs of technology and industrial development.

To better understand the strategies for cooperative and joint-venture R&D being used in other highly developed countries such as Japan, this study was commissioned by the Energy Conservation and Utilization Technologies (ECUT) Program of the U.S. Department of Energy (DOE). Pacific Northwest Laboratory (PNL)[a] compiled this report at the request of DOE.

The purpose of this study was to evaluate the organization and management of several different forms of cooperative R&D arrangements in Japan. Three programs are reviewed. The oldest program, the Ministry of International Trade and Industry (MITI) Program, was authorized by the Japanese government in response to the country's need to "catch up" in technological areas following World War II. The second program, the Exploratory Research of Advanced Technologies (ERATO) Program, focuses on instilling creativity in young researchers in areas at the forefront of science. This program was

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initiated in 1981 in response to a general opinion that Japanese science lacked creativity and that this lack would be a handicap in the future. The third program, the Key Technology Center (KTC) Program, focuses on getting private firms to venture into risky areas of advanced technology to pave the way for future industries. The KTC Program was initiated in 1985 and is aimed at encouraging sectoral shifts in technology.

The field of advanced materials is examined in this report because the Japanese government consistently stresses it as a high priority. Also, MITI, ERATO, and KTC support advanced materials research. The ECUT also has an active area of advanced materials research. However, the study focuses on organization and management, not technical state-of-the-art issues.

The types of organizational issues addressed in this report include the following:

- How were the R&D projects conceived? How were the plans drawn?
- How is the activity funded?
- What are the organizational structure and system of management?
- What are the roles of participants? What is the role of cooperation?
- How are the projects terminated? How are the results assigned?

This overview of cooperative R&D programs in Japan was compiled from reviews of available Japanese and English language literature and from visits to various Japanese companies in August 1987. These visits included interviews with R&D program administrators and project directors. The study covers FY 1985 and FY 1986, although some figures show research projections beyond that time. The study's focus is on organization and management, not technical state-of-the-art issues. However, as noted below, any technical information obtained during the study is contained in the appendixes.

Chapter 2.0 of this report presents an overview of Japanese government programs in cooperative R&D. Chapters 3.0, 4.0, and 5.0 describe the management and organization of the MITI Program, the ERATO Program, and the KTC Program, respectively. Appendix A provides more detail on MITI projects, and Appendix B provides more detail on KTC projects.

2.0 OVERVIEW OF JAPANESE GOVERNMENT PROGRAMS IN COOPERATIVE R&D

This chapter presents overviews of the three programs examined in this study: the Ministry of International Trade and Industry (MITI) Program, the Exploratory Research for Advanced Technologies (ERATO) Program, and the Key Technology Center (KTC) Program. The chapter then discusses one of the primary advantages of collective R&D associations: providing firms from several industries the opportunity to participate in and take advantage of a new field.

2.1 PROGRAM DESCRIPTIONS

The following subsections provide background information on the formation of the three programs addressed in this study.

2.1.1 The Ministry of International Trade and Industry Program

The MITI Program has been the principal sponsor of large cooperative research programs promoted by the Japanese government in the post-World War II period. The Mining and Manufacturing Industries Technological Cooperatives Law authorized MITI to organize these cooperative research programs in 1961.

The first projects created under this law were the Engineering Research Associations (ERAs), which are claimed to be modeled after the European Research Associations, created in Britain in 1921 (Oshima and Kodama 1988). The first ERA was formed in October 1961 and focused on polymer materials technology. In November 1961, another ERA was formed to address high-grade alcohol production. In 1962, six more ERAs were created, addressing topics that included creep research, industrial optics, high-grade polishing, electronic computers, and wool and cotton manufacturing.

By law, ERAs were entitled to several tax advantages, including the following:

- All funds used in operating the associations and in purchasing equipment could be calculated as losses; expenses as low as 1 yen would qualify.

- Three-fourths of the cost of experimental facilities and equipment could be written off in 3 years.

By May 1988, 107 ERAs had been formed, and 66 were still operating (Shirai and Kodama 1989). Most (94) of these ERAs were formed under MITI; 14 were formed under the Ministry of Agriculture, Forestry and Fisheries (MAFF); and 2 were created under the Ministry of Transportation (MOT). The activity under MAFF is recent and reflects a growing interest in biotechnologies. The ERAs are listed in Table A.1 in Appendix A.

No ERAs were formed between 1965 and 1969. During this time, MITI established the first of its largely government-promoted R&D programs, the Large-Scale National Project System. As modified ERAs, large-scale projects were to be funded 100% (nominally) by the government, and national laboratories were to participate in the projects. The large-scale national projects were expected to be MITI's flagship program and, at the time, the ERAs were expected to be folded into this new program.

In the first year of the Large-Scale National Project System, projects were established to address fuel desulfurization processes and high performance on electric computer technology. Projects included such varied themes as seawater desalinization, electric vehicles, jet engine technology, robotics, and an earth resources satellite. Current projects are listed in Table 2.1, and completed projects are listed in Table A.2, Appendix A. None of the projects in the first 6 years involved ERAs. By 1973 it was decided that the two systems would coexist, so ERAs were re-established under the old form and also incorporated into the Large-Scale National Project System. The organizational effectiveness and convenience of ERAs have made them a continuing and central feature of MITI's multiparticipant R&D strategy.

Building on the experience of the large-scale national projects, MITI initiated two other large cooperative research programs in the mid-1970s to address the pressing concern of the decade, energy development and conservation. In 1974, the Sunshine Program was created to support R&D in coal, solar energy, wind, and various alternative fuels. In 1978, MITI created the Moonlight Program to support research in energy conservation technologies.

TABLE 2.1. Current Projects Under the Large-Scale National Project System (Agency of Industrial Science and Technology 1989)

Project Name	R&D Period (FY)	Total R&D Expenditure (mil. yen)	Budget for FY 1989 (mil. yen)
Manganese nodule mining system	1981 - 1991	20,000	1,096
High-speed computing system for scientific and technological uses	1981 - 1989	23,000	2,431
Automated sewing system	1982 - 1990	10,000	978
Advanced robot technology	1983 - 1990	20,000	2,676
New water treatment system	1985 - 1990	11,800	2,528
Interoperable database system	1985 - 1991	15,000	1,423
Advanced material processing and machining system	1986 - 1993	15,000	2,329
Fine chemicals from marine organisms	1988 - 1996	15,000	275
Super/hyper sonic transport propulsion system	1989 -	undecided	30
Underground space development technology	1989 -	undecided	30

In 1980, management of both the Sunshine and Moonlight Programs was placed in a newly created New Energy Development Organization (NEDO). NEDO is a wholly public corporation staffed about equally by bureaucrats on short assignments from their home ministries, by industry representatives on temporary assignments from their companies, and by permanent staff. The purpose of NEDO was to provide a body that could deal more closely with the day-to-day management concerns of the R&D projects, thus freeing MITI for general administrative and financial matters.

The late 1970s was a period of debate in Japan about the future of its industries. There was a growing recognition that the catch-up strategy used so effectively in the 1960s and 1970s was becoming less effective as many Japanese industries neared the forefront of technologies. In May 1977, Japan's Council for Science and Technology submitted to the Prime Minister a report titled On The Long-Range Science and Technology Policy for the Next Decade. Among the goals highlighted in this report were the promotion of 1) science, 2) advanced technologies, and 3) international cooperation and competitiveness. The debate over the best way to achieve these goals has progressively heightened with the assumption that advances in many of the new "high technology" areas would benefit significantly from stronger capabilities in generic areas of research and from enhanced creativity.

In 1981, two programs emerged from these concerns. To address the concern over enhanced technology basic research, MITI established the Basic Technologies for Future Industries Program (Next Generation Program). The Next Generation Program initially selected three general areas of science and technology for research support: 1) advanced materials, 2) biotechnology, and 3) advanced electronic devices. Each program was planned to operate over about a 10-year period, terminating around 1990.

The organization of the Next Generation Program largely mirrors the Large-Scale National Project System. Research associations or research foundations were formed in three areas: fine ceramics, composites, and biotechnology. These projects were directly administered by MITI until 1988, when the activities were transferred to NEDO, now renamed the New Industry and Energy Development Organization. All projects involve industry, national laboratories, and universities, with the latter primarily acting in an advisory role. [This will be described in more detail in Chapter 3.0.] To address the concern over enhancing the creativity of some of the nation's bright young minds, and to advance frontier areas of science, the Science and Technology Agency established the ERATO Program.

2.1.2 The Exploratory Research for Advanced Technologies Program

The ERATO Program was an new venture, and in some ways, was an experiment in promoting individual creativity and the frontiers of science. The underlying premise of its formation is revealed in the following statement by the president of the Research and Development Corporation of Japan (JRDC), which administers ERATO within the Science and Technology Agency, Shoto Kurachi (ERATO 1986):

> . . . It is a puzzle and a source of embarrassment to the Japanese why the Japanese people, who are capable of mass producing many high quality goods at low cost, have not been able to create radically new technology. It is an inevitable fact that Japanese economy must be supported by advanced science and technology, and therefore, it is imperative that the Japanese people themselves must strive to create and nurture original and basic scientific and technological innovations.

An important departure of ERATO with past government programs is the emphasis on the individual rather than the organization. The program recruits young researchers and allows them flexibility to explore multidisciplinary areas that are at the frontiers of science. The organization reflects carefully planned disorganization, which is designed to foster more room for individual expression. The program is intended to develop free spirited "scientific explorers" who will catalyze innovations in fundamental science.

The ERATO Program was initiated with four research projects, all in areas related to advanced materials. By FY 1987 eleven more projects had been added, with topics extending to biochemistry and other areas of advanced materials development.

2.1.3 The Key Technology Center Program

The final major addition to the government's cooperative R&D programs began to take shape in the early 1980s; the programs had less to do with a pressing need for another program, than with the availability of cash.

During the 1980s, the government has slowly spun-off some of its very profitable public corporations to the private sector. Two of the more significant spinoffs have been Nippon Telephone and Telegraph (NTT) and the Japan Tobacco Company. The sales of these organizations have yielded substantial revenue, which the government holds in its supplementary budget accounts (not the general operating budget), which provided the government with a source of funds to use to look for good ideas.

The sale of NTT in particular made a substantial pool of money available to the Japanese government. However, NTT was under the jurisdiction of the Ministry of Posts and Telecommunications (MPT), and thus had little experience supporting major research projects outside NTT laboratories. In contrast, MITI had extensive experience administering major R&D projects, but no previous tie to NTT. As a result of very heated political negotiations, described by Johnson (1989), MPT and MITI agreed to jointly support a separate center for promoting research on important future technologies, or "key technologies."

Consequently, a bill was introduced into the Diet (Japanese Parliament) in February 1985 specifically to allow for government investment in private-sector joint R&D ventures. The Law for the Facilitation of Research in Fundamental Technologies," passed in May 1985, led to the formation of the KTC in October 1985.

The primary operative goal of the KTC is to encourage a shift of resources in the private sector toward areas that are considered essential for the competitive development of future industries. The principal philosophy behind the KTC is that the private sector is in the best position to identify promising technical challenges and to weigh their commercial potential against the research uncertainties. As will be illustrated later in this report, the KTC's organization reflects this philosophy.

Under the KTC, most of the initiative for forming projects is left to the private sector. This approach appears to reflect an understanding that Japanese industries are positioned at many frontiers in science and technologies, where the next step is increasingly uncertain and the selection of winners by the government increasingly difficult.

2.1.4 Summary of Programs

A summary of these programs prepared by Shirai and Kodama (1989) is presented in Table 2.2. Examples of cooperative R&D projects are selected from the most recent programs: the Next Generation Program (MITI), the ERATO program, and the Key Technology Center Program. These programs were selected because they represent different approaches taken to address the common concern of accelerating development of capabilities in the forefront of science and technology.

TABLE 2.2. Summary of Major Cooperative R&D Programs (Shirai and Kodama 1989)

Support	Principal Promoter	Cooperative R&D System[a]	Purpose	Comments
Nominal Government-Support 100%	Government	Large-Scale National Projects (1966, MITI) (Contracting to the Private Sector)	To improve the overall level of the industry; improve international competitiveness; rationalize the development of natural resources. Emphasis on protecting the environment from industrial pollution; needed promotion for urgent, advanced, large-impact industrial technologies. Field: Mining and Manufacturing	• Industry-University-Government Laboratory Cooperation • Selection of the projects reflects the views of the Large-Scale Project Development Advisory Committee. Experts provide input into each project through the Research and Development Liaison Conference
		Basic Technologies for Future Industries (1981, MITI)	To target basic technologies that will be important to next generation industries in 10 years; diffuse the results widely. Very broad in scope. 4 Fields: New Materials, Biotechnology, New Function Devices, Superconductivity.	• Industry-University-Government Laboratory Cooperation • Pursuit of several R&D approaches at the same time (parallel development). • The 10-year overall plan is divided into 3 stages, with goals established and evaluated at each stage.
		Exploratory Research of Advanced Technologies (ERATO) (1981, Science and Technology Agency, Japan Research and Development Corporation)	To uncover the basic characteristics of life and matter; to bridge the gap between science and technology; pursue basic research of high potential and high creativity.	• Project guidance is left to the discretion of a project leader. • Researchers are recruited from industry, universities, government, and overseas. Emphasis is on the individual • In each project, there are 3-4 research groups, with 5 researchers in each group • Each project is scheduled for 5 years, with an average, funding of 2 billion yen annual

TABLE 2.2. (Contd)

Support	Principal Promoter	Cooperative R&D System[(a)]	Purpose	Comments
100%	Government	International Frontier Research System (1986, RIKEN)	Basic, frontier research to uncover new knowledge that will contribute to technological innovation in the 21st centry. Fields: Homeostasis, frontier materials, thought processes	• Foreigners also invited as research leaders • Researchers are recruited from industry, universities, government, and overseas. Emphasis is on the individual • 3 research fields and 10 teams (6 members per team) • 1 research term is 5 years. Total of 3 terms, or 15 years.
Maximum 70% - Investment	Private Sector	Key Technology Center (1985, MITI and Ministry of Posts and Telecommunications)	To develop technologies for mining, manufacturing, telecommunications, broadcasting (including cable transmission), and related technologies for the use of radiowaves.	Key Technology System - Investment in R&D Companies • An investment system to supply capital to the private sector for experimental research in basic technologies by the private sector. Two or more companies invest in a R&D company to conduct cooperative base technology research, or in practical demonstrations Maximum center investment - 70% Maximum investment period - 7 years (10 years in special cases)
		Special Life Sciences Industry and Technology Promotion System (1986, Ministry of Agriculture, Forestry and Fisheries)	To develop technologies to enhance the maintenance of living functions or to reveal the mechanisms of living functions for future industries. Agriculture, forestry and fisheries, food, tobacco, etc.	
		Medical Welfare Technologies (1987, MHW)	To increase the safety, quality, and effectiveness of pharmaceutical products; improve and protect the health of the citizenry	• The life sciences system and the medical technologies system are largely the same.

TABLE 2.2. (Contd)

Support	Principal Promoter	Cooperative R&D System[a]	Purpose	Comments
Tax and Equipment Concessions	Private Sector	Engineering Research Associations (1961, MITI, MAFF, and MOT)	Mining and manufacturing	• Non-profit organizations for the overall benefit of the association members. Not a capitalized entity • Distribution of surplus funds is prohibited • The principal users of research results are association members

(a) Information in parentheses indicates the sponsoring agency and year that sponsorship began.

2.2 INTERSECTORAL PARTICIPATION AND SECTORAL DIVERSITY

One of the principal advantages of the collective R&D associations is that they provide firms from several industries the opportunity to participate in and take advantage of a new field. The firms can improve their integration with other firms or can expand into new business and technology areas.

Recent analysis by Shirai and Kodama (1989) has revealed that such a mixing of industrial sectors has been a prevalent feature of the collective R&D associations and of the groups formed in the KTC and ERATO. Table 2.3 summarizes the number of research groups formed under each program as of the spring of 1989. The table shows the average number of firms participating in each of the groupings and the types of participants. Listed companies refers to firms listed on the public stock exchange; these tend to be somewhat larger firms. The unlisted firms are smaller or medium-sized firms that do not sell their stock through the Tokyo market. Foundations, university, and foreign firm participation is also summarized.

The table shows that among the larger firms or listed companies, the average number of industrial sectors represented is 3.1 to 3.8 in most programs, except the Next Generation Program, which has an average of 5.3 sectors represented. This broader representation in the Next Generation Program might be expected because the research projects address a generic technology base rather than the more specific technology areas of earlier ERAs and Large-Scale National Project System.

Table 2.3 also shows that the Next Generation Program has the smallest representation among the unlisted (medium and small) firms: 0.7 versus 1.9 for the Large-Scale National Projects and 3.7 for the ERAs. The reason for this is not clear but may be related to the desire to have firms of similar strength that can participate as equals in a technology base research activity. Although contributors to more prototype-targeted ERAs may allow small firms to contribute some skills and large firms to contribute others, the more horizontal and generic nature of the Next Generation Program may make technologically equal partners a more important criteria for participation.

TABLE 2.3. Participation in Collective R&D Associations (Shirai and Kodama 1989)

	No. of Projects	Avg. No. Firms per Project	Listed Companies			Others				
			No.	Avg. No. Sectors	Firms per Sector	No.	Unlisted Firms	Foundations	Universities	Foreign Firms
Engineering Research Associations	94	13.7	9.5	3.4	2.8	4.2	3.7	0.5	--	--
Large-Scale National Projects	16	14.1	11.0	3.8	2.9	3.1	1.9	1.2	--	--
Next Generation Program	3	13.7	13.0	5.3	2.4	0.7	0.7	--	--	--
Key Technology Center	35	11.1	8.5	3.1	2.7	2.6	2.5	0.1	--	--
Exploratory Research for Advanced Technologies	15	13.2	6.1	3.4	1.8	7.1	2.1	0.3	2.9	1.8

The ERATO programs have noticeably the highest average participation of small and medium firms, 7.1. As mentioned earlier, this program emphasizes the individual rather than the organization, making participation more open to individuals with various affiliations.

Participation by firms from various industrial sectors in the ERAs (MITI), the ERATO Program, and the KTC Program is summarized in Tables 2.4, 2.5, and 2.6. The tables show that for all three programs, the largest participation was by firms in the electronics sector, reflecting the health and priority of this area. Chemistry is a consistent second and iron and steel third, reflecting activity in the materials sciences and development of new materials (Shirai and Kodama 1989).

TABLE 2.4. Engineering Research Associations (MITI)--Firm and Project Participation by Industry (Shirai and Kodama 1989)

Industry Category	of Participating Firms			Project Participation			Avg. No. Firms
	Rank	No.	%[(a)]	Rank	No.	%[(b)]	
Mining, fisheries, forestry	--	8	0.9	--	5	5.3	1.6
Construction	--	20	2.2	--	10	10.6	2.0
Food	5	70	7.9	--	12	12.8	5.8
Textiles	9	38	4.3	--	12	12.8	3.2
Paper and pulp	--	15	1.7	--	2	2.1	7.5
Chemistry	2	107	12.1	3	31	33.0	3.5
Pharmaceuticals and chemicals	--	21	2.4	8	15	16.0	1.4
Oil and rubber	--	18	2.0	--	7	7.4	2.6
Glass and cement	10	29	3.3	7	17	18.1	1.7
Iron and steel	3	84	9.5	3	31	33.0	2.7
Non-ferrous metals	7	58	6.5	6	25	26.6	2.3
Machinery	6	69	7.8	2	34	36.2	2.0
Electronics	1	173	19.5	1	46	48.9	3.8
Shipbuilding	4	78	8.8	3	31	33.0	2.5
Autos and transportation	--	23	2.6	8	15	16.0	1.5
Precision machinery and manufacturing	--	24	2.7	--	10	10.6	2.4
Trading, finance, transport	--	8	0.9	--	4	4.2	2.0
Utilities (gas, electric, etc.)	8	44	4.9	10	13	13.8	3.4
Listed companies	--	887	100.0	--	320	340.4	2.8
Others							
Unlisted companies		353					
Foundations		45					
Total		1,285					

(a) Percent of total number of projects.
(b) Percent of total number of participants.

TABLE 2.5. Exploratory Research for Advanced Technologies--Firm and Project Participation by Industry (Shirai and Kodama 1989)

Industry Category	Participating Firms Rank	Participating Firms No.	Participating Firms %/[a]	Project Participation Rank	Project Participation No.	Project Participation %/[b]	Avg. No. Firms
Mining, Fisheries, Forestry	--	0	--	--	--	--	--
Construction	--	1	1.1	--	1	6.7	1.0
Food	5	6	6.6	7	2	13.3	3.0
Textiles	7	3	3.3	6	3	20.0	1.0
Paper and pulp	--	1	1.1	--	1	6.7	1.0
Chemistry	1	24	26.4	2	9	60.0	2.7
Pharmaceuticals and chemicals	3	12	13.1	3	7	46.7	1.7
Oil and rubber	--	0	--	--	--	--	--
Glass and cement	8	2	2.2	7	2	13.3	1.0
Iron and steel	8	2	2.2	7	2	13.3	1.0
Non-ferrous metals	6	5	5.5	5	4	26.7	1.3
Machinery	8	2	2.2	7	2	13.3	1.0
Electronics	1	24	26.4	1	11	73.3	2.2
Shipbuilding	--	1	1.1	--	1	6.7	1.0
Autos and transportation	--	0	--	--	--	--	--
Precision machinery and manufacturing	4	8	8.8	4	6	40.0	1.3
Trading, finance, transport	--	0	--	--	--	--	--
Utilities (gas, electric, etc.)	--	0	--	--	--	--	--
Listed companies	--	91	100.0	--	51	340.0	1.8
Others							
Unlisted companies		32					
Foundations		5					
Universities		43					
Foreign Orgs.		27					
Total		198					

(a) Percent of total number of projects.
(b) Percent of total number of participants.

TABLE 2.6. Key Technology Center--Firm and Project Participation by Industry (Shirai and Kodama 1989)

Industry Category	Participating Firms Rank	Participating Firms No.	Participating Firms %[(a)]	Project Participation Rank	Project Participation No.	Project Participation %[(b)]	Avg. No. Firms
Mining, fisheries, forestry	--	0	--	--	--	--	--
Construction	--	2	0.7	--	1	2.9	2.0
Food	--	5	1.7	--	4	11.4	1.3
Textiles	--	7	2.4	8	5	14.3	1.4
Paper and pulp	--	0	--	--	--	--	--
Chemistry	6	13	4.4	5	7	20.0	1.9
Pharmaceuticals and chemicals	--	1	0.3	--	1	2.9	1.0
Oil and rubber	--	4	1.3	--	3	8.6	--
Glass and cement	--	7	2.4	8	5	14.3	--
Iron and steel	2	38	12.9	4	8	22.8	--
Non-ferrous metals	3	26	8.8	2	13	37.1	--
Machinery	7	10	3.4	8	5	14.3	--
Electronics	1	116	39.3	1	26	74.3	4.5
Shipbuilding	10	9	3.0	6	6	17.1	1.5
Autos and transportation	5	17	5.8	--	4	--	4.3
Precision machinery and manufacturing	7	10	3.4	6	6	17.1	1.7
Trading, finance, transport	7	10	3.4	8	5	14.3	2.0
Utilities (gas, electric, etc.)	4	20	6.8	3	10	28.6	2.0
Listed companies	--	295	100.0	--	109	311.4	2.7
Others							
Unlisted companies		89					
Foundations		3					
Total		387					

(a) Percent of total number of projects.
(b) Percent of total number of participants.

3.0 MINISTRY OF INTERNATIONAL TRADE AND INDUSTRY

As described in Chapter 2.0, MITI has been the principal supporter of multiparticipant R&D programs since its inception. In this chapter, MITI's management and organization are described in more detail. In Section 3.1, MITI's commonly used forms of coopertive R&D arrangements are discussed and compared with the DOE's. Section 3.2 describes MITI's three forms of management of large cooperative R&D projects. Section 3.3 discusses MITI's typical R&D program funding. In Section 3.4, the two largest projects in MITI's Next Generation Program are described: the Fine Ceramics R&D Project and the Advanced Composite Materials Project. Finally in Section 3.5, Management of the patents developed under the programs is reviewed.

3.1 ORGANIZING GROUPS FOR COMPETITION

The MITI uses various arrangements to direct companies to engage in R&D, and most of these are different from the techniques used by DOE. DOE's primary technique, direct contract research with individual companies to perform individual R&D tasks, is not common in MITI programs. For example, direct contract research is virtually absent in the technical R&D supported by MITI in ceramics. Two commonly used forms of cooperative R&D arrangements used by MITI are the multiparticipant group R&D arrangements, which are largely funded by the government, and multiparticipant joint R&D arrangements, where costs are shared between government and industry.

Japan's reasons for preferring group R&D to contract R&D with individual companies appear to relate to the commercial intentions of the research programs and MITI's desire to avoid the appearance of favoring a particular company and thereby providing an unfair, excludable advantage to one firm. This practice of ensuring that more than one firm receives the benefit of government policies dates back to the Meiji Restoration of the late 1800s as Japan began to catch up with the more industrialized countries of the West. Initially, the Japanese government was the major investor in many of the nation's larger industries, such as mining, railroad, shipping, and steel. In the late nineteenth century and early twentieth century, the government sold many of its enterprises to private firms, and usually selected more than one company in an industry to ensure competition.

The Japanese R&D environment is thus unlike DOE or other "mission-oriented" agencies, which focus more on good technical progress to address noncommercial national needs. Instead of promoting research _for_ commercial exploitation, the major R&D funders in the U.S. government often support research to address the negative consequences of commercial exploitation. Some of the consequences are discussed further below.

Group R&D offers the advantage of providing an incentive for pursuing activities that are more generically valuable to general industry, and less likely to be taken over by specific firms. Perhaps the most important feature of group R&D, as illustrated by project examples used in Section 3.4, is the role of competition versus cooperation.

Competition becomes important in two ways in group R&D. First, during the project, a firm's performance is evaluated against every other firm, and funding may shift to the more successful firms. Poor performers are, however, almost never asked to leave the project prematurely. In the worst cases, lateral shifts are made, and new companies are brought in. Second, competition in the marketplace as new techniques are developed is more significant than competition during the R&D projects. By including a mix of competitive firms in technology development, MITI better ensures that one firm does not gain monopoly rent from the activity, which is indicative of its traditional approach in industrial development. Some degree of competition is thus designed to best use new knowledge and skills. This is not to imply that the technologies developed quickly diffuse to other firms via an "open" market. Rather, Japan's approach seems to more closely reflect a Schumpeterian notion[a] that oligopolies can strengthen innovation because of the market rewards from limited participation and the presence of other firms against which performance must be measured. "Competitive cartels" for nurturing new technologies seem to be the appropriate model. The overall approach used by MITI reflects an underlying philosophy that technology

(a) Credited to Joseph Schumpeter (1883-1950), Czechosolvakian-born American economist.

development or research alone is not sufficient. The work must be carefully planned and promoted toward its end-use.

Selection of participants for the group R&D therefore becomes important. The criteria used in Japan to select firms to participate in cooperative R&D are significantly different from the typical emphasis of sponsors of U.S. contract research. A Japanese firm's commercial potential (its perceived ability to effectively use the research) is a priority in the participant selection process. The relevant technical capability of the candidate firm is also important, but less so than its commercial strength. In the United States, the priorities typically are reversed, with a company's technical capability receiving the priority and the commercial capability given less weight. The Japanese do not assume that successful commercialization follows successful technical development, and selection of participants is considered the key in making that bridge.

3.2 ORGANIZATION OF COLLECTIVE R&D ASSOCIATIONS

Under the category of large cooperative R&D projects, MITI uses three forms of management, all of which remove MITI from day-to-day operations of the projects. The three forms can be classified according to their managing organization: 1) research association, 2) research foundation, and 3) public corporation.

The research association and research foundation are referred to as Engineering Research Associations (ERAs). An ERA is often formed to manage industrial participation in a collective R&D project. For example, the Fine Ceramics Research Association (also called the Engineering Research Association for Fine Ceramics) manages the companies participating in this project. The general manager is always a retired bureaucrat from MITI, with the senior management positions allocated to the larger firms and other staff positions rotated among the participating companies.

The research association, the first form of management, is funded by a national project, or funding is split with the government. When the national project terminates, the research association also is likely to terminate unless it receives new government funding or the firms continue to support the association for coordinative or information-gathering reasons. If funding is split with the government, however, the research association most likely will merge with or transform into a more general industrial association.

In the case of more explicitly cost-shared projects, a group of companies will gather and define an R&D program and will then share the cost with MITI. The terms vary with the projects, but a common division is a 50-50 split in financing, with the MITI share often given in the form of a conditional loan. That is, if the project leads to commercially successful activity, all or part of the loan from MITI is to be repaid according to generous repayment schedules. In practice, few of these loans are paid back to the government.

The research foundation, the second form of management, is very similar to the research association in its relation and contribution to the national R&D project, but its origin and future are different. The general manager is a retired MITI bureaucrat, and the staff positions are rotated among the companies. However, in addition to government funding, the companies participating in the national project will invest in a continuing fund for the foundation. This arrangement allows the foundation staff to conduct or support supplementary activities, such as establishing a database for software development, in addition to the national project. For example, the Research Institute for Metals and Composites, which manages the Advanced Composite Materials Project and the Metal Alloy Project, devotes approximately 95% of its activities to the national project and about 5% to other projects. The most important difference between research associations and research foundations is that rather than disband when the national project terminates, the research foundation continues as an entity. The research foundation can support further R&D, although likely at a smaller scale, and can provide a vehicle for cost-shared R&D with the government.

The third form of management under the category of national cooperative R&D is the public corporation. The Sunshine and Moonlight Programs, both managed by NEDO, a public corporation, were established to provide greater attention to day-to-day management than MITI could provide. The NEDO is staffed in approximate equal proportions by personnel from MITI who are on 1- to 2-year rotations, by personnel from private companies who are also on rotations, and by its own fulltime staff. All the direct expenses are again paid for by MITI. This organization differs from the research association and research foundation because it includes several national projects and continues with new projects initiated by the government after the old projects end.

3.3 R&D PROGRAM FUNDING

The importance of private companies' financial contributions to government-promoted R&D is often debated in Japan. Some assert that the key to success for Japanese projects has been the substantial cost-sharing by participating industries. Others, including those in the Japanese government, note that large projects are designed with 100% government financing.

Although a precise financial accounting for the projects reviewed here was not available, most participating industries appear to make a significant commitment, even on projects supposedly funded entirely by the government. One major reason for the various perceptions stems from differences in the accounting systems used in the United States and Japan.

Since World War II, U.S. government R&D contracts to the private sector typically have been written to include allowances for the overhead costs of supporting the R&D: nonsalary benefits, administration, facilities, etc. By constrast, contracts issued by MITI, most notably those used in multiparticipant projects, do not provide a general overhead fund. For example, the typical arrangement in MITI's Basic Technologies for Future Industries Program provides for payment of the direct costs of the researchers' salaries only, and the participating companies are left to cover the remaining supporting costs. Equipment and facilities are paid for by the program, but it is not clear to what degree the facilities costs of the participating companies are fully reimbursed. Some participants indicate that the companies should also bear a share of these plant costs.

Without a more precise accounting, it is difficult to provide a figure for the split in cost-sharing between the government and participating companies. If personnel costs alone are considered, the companies seem to have more than a trivial cost. Assuming that the actual overhead cost is approximately twice that of direct salaries and that personnel costs accounted for half of the project's expenses, then companies invest equally with the government. If facilities are subsidized by private industry, then their share would become greater than one-half. Therefore, it is not unreasonable to estimate that the public and private groups share costs 50-50.

In addition, funding for the national laboratories generally goes to experiments, facilities, and equipment costs, with salaries of researchers paid for by the laboratory's separate personnel budget. Although funds that go to labs tend to be a small portion of the overall budget, these funds can nonetheless be significantly leveraged.

Again, it should be emphasized that a variety of financial aid systems are used; therefore, it is important not to expect that Japanese government-promoted R&D programs reflect a uniform policy.

3.4 BASIC TECHNOLOGIES FOR FUTURE INDUSTRIES (NEXT GENERATION PROGRAM)

The two projects selected for review are the two largest in MITI's Next Generation Program and represent the two forms of private sector management: research associations and research foundations. The first project described is the Fine Ceramics R&D Project, followed by the Advanced Composite Materials Project.

3.4.1 The Fine Ceramics R&D Project

Initiated in 1981 as one of the first projects in MITI's Basic Technologies for Future Industries Program, the Fine Ceramics R&D Project is the largest project under way. In FY 1988, funding for this project was 1.099 billion yen (about $8.79 million), which is almost twice the amount allocated to the next largest project, the Advanced Composite Materials Project.

In the area of fine ceramics R&D, the Fine Ceramics R&D Project is by far the largest project supported by MITI, accounting for 80% to 90% of the total budget. Table 3.1 lists MITI's fine ceramic-related activity,

TABLE 3.1. Summary of Advanced Ceramic R&D Projects Supported by MITI[a] (Fine Ceramics Office 1987 and 1988)

Project	Million Dollars		
	1986	1987	1988
Consumer Goods Industries Bureau	10.0	0.92	0.30
1. Survey of Trends in Fine Ceramics Industry	0.020	0.020	--
2. Administration of Problem Discussions	0.020	0.20	0.30
3. Surveys			
- Surveys for each ceramic material	0.020	0.020	--
- Surveys for international cooperation	0.040	0.040	--
Other Bureaus			
1. Survey of Standardization	0.92	10.8	0.18
- Survey of electrical power devices	--	--	(0.36)
2. Basic Technologies for Future Industries	6.48	8.02	8.79
- Fine ceramics	--	--	(8.49)
- Superconductive materials and devices	--	--	(8.79)
3. Advanced Material Processing and - Machining	(0.13)[b]	(7.32)	--
4. Moonlight Project			
- Ceramic gas turbine	--	--	3.08
- Superconductor power application	--	--	(13.2)
- Fuel cell power generation	--	(27.1)	(28.4)
5. Government and Private Joint Research	(1.51)	(2.08)	(2.14)
- Super plastic ceramics	0.19	undetermined	--
- High-function medical materials	0.27	undetermined	--
6. Electrically Conductive Inorganic Comp.	0.54	1.40	1.96
7. Advanced Nuclear Equipment	0.15	undetermined	--
8. Oil Production Technology under High Temperature and Corrosive Environments	(3.68)	(4.40)	(4.84)
9. Database and Information Service	(0.44)	undetermined	--
	0.11	--	--

(a) Funds are converted to dollars at an exchange rate of 125 yen/dollar.
(b) Parentheses () indicate overall project funds, of which a portion is directed toward ceramics.

including surveys. The "Government and Private Joint Research" entry in the table shows that less than 5% of MITI's funding is invested in formal cost-shared joint ventures.

Fine ceramics, in contrast with traditional ceramics, are ceramic materials with a very finely controlled material composition. The precise control allows exploitation of useful electrical, magnetic, thermal, and other physical characteristics. Since the late 1960s, fine ceramics have been increasingly used in the electronics field, and the worldwide market for electronic ceramics is in excess of several billion dollars per year.

The emphasis of MITI's Fine Ceramics R&D Project is not, however, in the electrical and magnetic areas in which the private sector is already very active. The MITI project addresses structural ceramics that could be used in high-temperature corrosive environments, such as in a gas turbine or an automotive engine. The Fine Ceramics R&D Project is typical of MITI projects: it does not address areas in which the private sector is already strong or in which national technologies are at the leading edge internationally. Instead, MITI targets an area of high commercial potential in which industry is still trying to develop an internationally competitive position, a policy that is consistent with the philosophy of "leveling up" a technology area.

The overall project plan for the Fine Ceramics R&D Project is divided into three phases (Figure 3.1). [Detailed technical information on the project is shown in Tables A.3 through A.6 in Appendix A.] The primary emphasis of the first phase (FY 1981 to 1983) focuses on developing powder-synthesizing techniques to obtain uniform materials and on forming and sintering techniques to mold very small test pieces. Because these techniques were carried out at the same time, their relationship could not be investigated in this first phase. Investigating this sequence was started in the project's second phase.

In the second phase (FY 1984 to 1987), the relationship between powder composition and characteristics to forming, sintering, and machining was explored. In addition, the size of the test pieces was scaled up several hundred times to approach more commercially relevant dimensions. Finally, in the third and final phase (FY 1988 to 1992), the results from the earlier

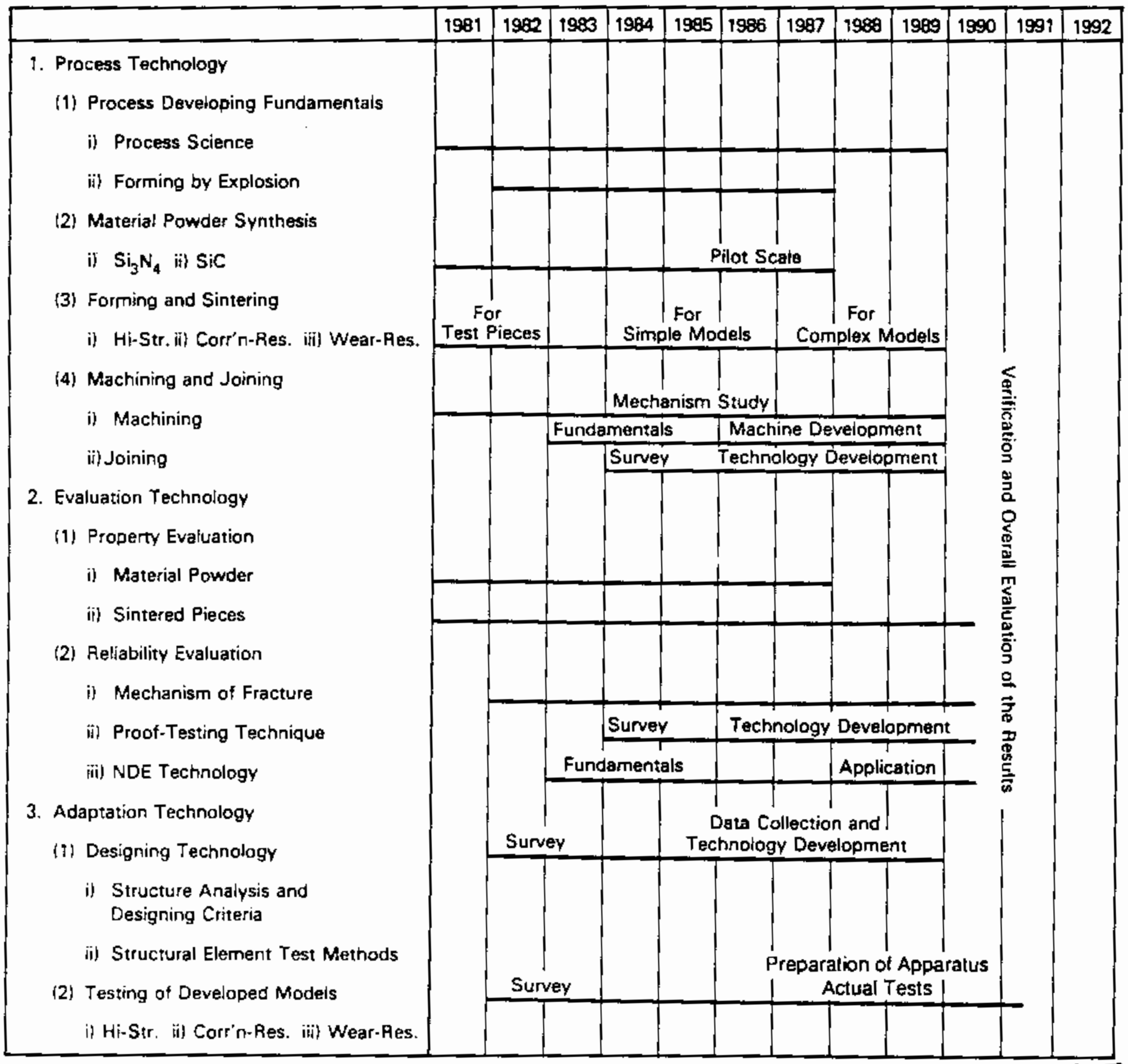


FIGURE 3.1. Overall Schedule for the Fine Ceramics R&D Program (Nagahiro 1986)

experiments will be integrated and test pieces will be scaled up even further to sizes appropriate for a ceramic gas turbine. The project was originally scheduled to terminate in FY 1990, but re-evaluation of the time needed for full-scale materials testing led MITI to justify extending project.

In addition to the phases described above, one other characteristic of the project plan is the large number of elements or "line items." These elements reflect a substantial division of tasks in which each participant is primarily responsible for one task. Although the participating entities share some materials, much R&D is conducted independently. This characteristic is elaborated on in the next subsection.

Project Organization and Execution

Consistent with the pattern of traditional large-scale MITI R&D programs, the Fine Ceramics R&D Project involves well-established companies, several national laboratories, the government, and an advisory council. The first two participants are responsible for carrying out the R&D and the latter two for managing and directing the R&D. A rough division of tasks between the companies and the national laboratories is shown in Table 3.2. As the table shows, the research in the national laboratories focuses on methods for evaluating materials and the production processes; the companies focus on the actual processing, reliability testing, and applications.

As expected, the key research organizations are from industry. Companies participating in the project are among the most technically capable and commercially powerful in the structural ceramics industry. In addition, these companies were undoubtedly included for their interest in applying the ceramics research findings to their own technology. The industry participants are as follows:

- Asahi Glass Co., Ltd.
- Ishikawajima-Hirima Heavy Industries Co., Ltd.
- Inoue JAPAX Research, Inc.
- Kyocera Corporation
- Kurosaki Refractories Co., Ltd.
- Kobe Steel, Ltd.
- Shinagawa Refractories Col, Ltd.
- Showa Denko K. K.
- Sumitomo Electric Industries, Ltd.
- Denki Kagaku Kogyo K. K.

TABLE 3.2. Division of R&D Between the Companies and National Laboratories (Japan External Trade Organization 1987)

National Laboratories

1. Studies on high-temperature fracture mechanism

2. Technology for production process
   1) Evaluation of process technology
      a) Design of microstructure
      b) Explosion forming/sintering technology
   2) Machining technology

3. Evaluation technology
   1) Starting powder
   2) Sintered body
      a) Strength, corrosion resistance
      b) Corrosion resistance against high-temperature gases
      c) Wear resistance

The Engineering Research Association for High-Performance Ceramics

1. Research into conceptual design of ceramics

2. Process technology
   1) Material powder synthesis
   2) Forming and sintering
      a) High-strength materials
      b) High corrosion-resistant materials
      c) High wear-resistant materials
      d) High toughness materials

3. Machining and joining
      a) Machining
      b) Joining
      c) Surface technology

4. Reliability evaluation
   1) Proof test
   2) Nondestructive test

5. Application technologies
   1) Designing technology
      a) Design standard
      b) Structure analysis and designing criteria
   2) Model evaluation
      a) High-strength model
      b) High corrosion-resistant model
      c) High wear-resistant model

- Toshiba Corporation
- Toyota Motor Co.
- Toyota Machine Works, Ltd.
- NGK Insulators, Ltd.
- NGK Spark Plug Co., Ltd.

As mentioned earlier, each company has its own principal task. These organizations have a somewhat more parallel arrangement than does the Advanced Composite Materials Project. The reasons seem to be related to the technology and the stage at which the companies have a competitive interest.

Most companies are very interested in processing the powders and then forming and synthesizing them because the companies that best master these skills have the competitive advantage in the marketplace. Thus, companies included as participants because of their capabilities in materials production and companies strong in applications want to become stronger in that area of technology. The result is competition, rather than a cooperative effort among the companies, and this directed approach to individual company goals prevents the companies from achieving mutual goals.

3.4.2 Advanced Composite Materials

The Advanced Composite Materials Project is one of two projects managed by the Research and Development Institute of Metals and Composites for Future Industries, which was established in 1981 through the impetus of MITI. The three general activities of the institute are 1) R&D, 2) investigation and survey, and 3) information dissemination. The principal role of the institute was to assist in managing two projects within the Basic Technologies for Future Industries Program: the Advanced Composite Materials Project and the Advanced Alloys with Controlled Crystalline Structures Project. Managing the 12 private-sector organizations involved in the two MITI projects consumes about 90% of the institute's funding.

The Institute is a research foundation and therefore will continue to operate after the current MITI projects are completed because of industry support. A list of the current supporters is shown below:

- Ishikawajima-Harima Heavy Industries, Ltd.
- Isolite-Babcock Refractory Co., Ltd.
- Kawasaki Heavy Industries, Ltd.
- Kawasaki Steel Cor.
- Kobe Steel, Ltd.
- Nippon Steel Cor.
- Shin Meiwa Industry Co., Ltd.
- Sumitomo Metal Industries, Ltd.
- Sumitomo Electric Industries, Ltd.
- Daido Steel Co., Ltd.
- Dainippon Ink & Chemicals, Inc.
- Teijin, Ltd.
- Tao Nenryo Kogyo K. K.
- Toshiba Machine Co., Ltd.
- Toray Industries, Inc.
- Toyota Motor Cor.
- Nisshin Steel Co., Ltd.
- Nippon Carbon Co., Ltd.
- Nippon Kokan K. K.
- Japan Aircraft Mfg. Co., Ltd.
- Nippon Petrochemicals Co., Ltd.
- Hitachi, Ltd.
- Hitachi Metals, Ltd.
- Fugi Heavy Industries, Ltd.
- Mitsui Petrochemical Industries, Ltd.
- Mitsui Engineering & Shipbuilding Co., Ltd.
- Mitsubishi Chemical Industries, Ltd.
- Mitsubishi Metal Cor.
- Mitsubishi Heavy Industries, Ltd.
- Mitsubishi Electric Cor.
- Mitsubishi Rayon Co., Ltd.
- The Yokohama Rubber Co., Ltd.

The purpose of the Advanced Composite Materials Project, as stated in an excerpt from the institute's project outline, is as follows:

> . . . is to develop not only high performance composite materials, but technologies on how to design, form, fabricate and assure qualities of various structures consisting of such materials, assuming precursory fields of application as aircraft, spacecraft and automotive industry.

This project was designed to run for 8 years, from FY 1981 to FY 1988. In FY 1986 and 1987, $4.7 and $4.2 million, respectively, was spent, as shown in the budget history in Table 3.3. The funding is distributed among the national laboratory and private-sector participants shown in Table 3.4. The table shows that the private firms can be broadly divided into two categories: 1) materials developers and 2) fabricators. The fabricators

TABLE 3.3. Funding of the Advanced Composite Materials Project (FY 1981 - 1988) (Research and Development Institute of Metals and Composites for Future Industries 1989)

	Fiscal Year							
	1981	1982	1983	1984	1985	1986	1987	1988
Million yen	197	417	504	514	526	705	633	548
Million dollars	0.90	1.81	2.10	2.14	2.29	4.70	4.22	4.38
Exchange rate	220	230	240	240	230	150	150	125

TABLE 3.4. Participants in the Advanced Composite Materials Project (Research and Development Institute of Metals and Composites for Future Industries 1989)

National Laboratories

- Industrial Products Research Institute
- Mechanical Engineering Laboratory
- Research Institute for Polymer and Textiles
- Government Industrial Research Institute, Osaka

Private Sector - Materials Developers

- Toray (fiber & polymer)
- Teijin (polymer)
- Mitsubishi Chemicals, Ltd. (polymer)
- Nippon Carbon (fiber)
- Kobe Steel Ltd. (metals)

Private Sector - Fabricators

- Ishikawajima-Harima Industries [turbine engine, space (rocket)]
- Kawasaki Heavy Industries [aircraft, space (satellite)]
- Fuji Heavy Industries (aircraft, automobiles)
- Mitsubishi Heavy Industries [aircraft, space (rocket)]
- Toyota Motors (automobile)
- Mitsubishi Electric [space (satellite)]
- Toshiba Machine (fabrication machines)

represent the high-priority areas of application that were identified in the institute's statement of purpose: aircraft, spacecraft, and automobiles.

Although project expenses in FY 1986 and FY 1987 were not significant, they do not fully reflect the expenses of the national laboratories during those years. As discussed earlier, national laboratories receive funds only for facilities and equipment expenses. The researchers' salaries are provided through a laboratory's normal operating budget. Also, as noted earlier, the government only pays for the direct salary of the private-sector researcher, not for company benefits and other overhead charges that are typically attached to R&D contracts.

Project History

Although the Advanced Composite Materials Project officially began in October 1981, the project was first discussed in the spring of 1978. The Aircraft and Weapons section of MITI then held discussions with its technical committee and the Society of Japanese Aerospace Companies (SJAC). As a result of these discussions, a forum on advanced composite materials for aerospace was created.

In 1979, proposals were sought by MITI's Agency of Industrial Science Technology (AIST) for candidate projects that might be included in the Basic Technologies for Future Industries Program. By the spring of 1980, seven proposals were received from seven MITI divisions in the composite materials area. For example, the Japan Carbon Forum submitted a proposal through the Ceramic and Construction Materials Division, and the Japan Society for Industrial Machinery submitted a proposal through the Industrial Machinery Division. Rather than choose one proposal, AIST formed an ad hoc committee to mediate and choose several proposals. The committee was chaired by the current Director of the Advanced Composite Materials Project, Mr. Miroda, who was then with Fuji Heavy Industries. The AIST wanted a project that would address potential applications in a variety of fields, including aircraft, space, energy, and automobiles.

By March 1981, a tentative program plan was developed by the ad hoc committee. The MITI then called for a meeting of seven relevant engineering societies to announce an informal call for proposals. Between March and

October, MITI, its laboratory staff, and advisory committees evaluated the various proposals and the compatibility of the companies with the overall plan. The composite program was evaluated in the Machinery and Information Industries Bureau.

In October 1981, an official call for participation was announced, but by then, all the participants had been selected. The national laboratories conducted some surveys and developed software for the first few months, and R&D formally began in April 1982.

Project Operation

Project research focuses on developing two types of composite materials, fiber-reinforced plastics and fiber-reinforced metals. (See Table A.6 in Appendix A for a summary of the project's technical goals and achievements.) Both projects are further divided into a materials development task and a forming and fabrication technologies task. Figure 3.2 shows the overall project schedule. Qualitatively, the goal is to develop the state of technology materials equivalent to those of the United States.

Another component of the project is directed at design and quality evaluation technologies. The elements, taken from the outline of the institute's projects, are described in Table 3.5.

The goals for this project were established by a steering committee created in AIST. The committee is chaired by the preeminent composite researcher in Japan, Professor Tsuyushi Hayashi. Professor Hayashi also chairs the evaluation committee, which coordinates evaluation of the research. At the end of each of the three stages, a formal evaluation of progress is conducted. At the end of Stage 1, the companies largely supply test data. At the end of Stage 2, the materials are tested in the national laboratories. The polymer matrix compounds were tested at the Industrial Products Research Institute with environmental effects evaluated by the Research Institute for Polymers and Textiles. The metal matrix material was tested at the Mechanical Engineering Laboratory. A similar arrangement was used for the final testing at the end of Stage 3.

Study Theme	'81	'82	'83	'84	'85	'86	'87	'88
1. Resin Group Composite Materials								
A. Development of Advanced Fiber-Reinforced Plastic Materials	Materials Development ('81–'83)			Increasing the Effectiveness of the Materials ('84–'88)				
	Improving the Compatibility Between the Fibers and the Mother Materials							
B. Development of Molding Techniques	Development of Primary Processing Methods ('81–'83)			Advanced Molding and Processing Methods ('84–'88)				
C. Development of Measurement Techniques	Quality Evaluation Techniques, Measurement Techniques							
2. Metal Group Composite Materials								
A. Development of Advanced Fiber-Reinforced Metal Materials	Development of Intermediate Materials ('81–'82)		Improving the Compatibility Between Fibers and Mother Materials ('83–'86)				High-Level Intermediate Materials ('87–'88)	
B. Development of Molding Techniques	Development of Primary Processing and Molding Techniques -Press, Roll, Ejection, Powder, Melting ('81–'82)		Advanced Molding Methods and Processing Methods ('83–'86)				High-Effictiveness Processing Methods ('87–'88)	
C. Development of Measurement Techniques	Development of Optimal Measurement Techniques							
3. Quality Evaluation, Measurement Techniques	Quality Evaluation Techniques, Measurement Techniques							

FIGURE 3.2. Advanced Composite Materials Project Schedule (obtained in project interview)

TABLE 3.5. Summary of the Research Areas of the Advanced Composite Materials Project[a]

FIBER-REINFORCED PLASTICS

Development of High-Performance Materials

The current research program is concentrated on developing temperature resistive matrix resins, such as high-performance epoxy, easily formable polyimide, or other resins suitable to graphite-fiber reinforcement, including improvement of impregnation and curing processes.

Development of Forming and Fabrication Technologies

Aiming at the evolution in productivity and reliability of advanced composite structures, the research program emphasizes the need to develop adequate co-curing techniques for aircraft integrated laminate structures, a low-pressure rapid curing technique for automotive panels, and a continuous forming technique of thin-wall, long columns for spacecraft use. The program covers the application of new technologies such as high-energy trimming, automatic layup and non-autoclave fabrication.

FIBER-REINFORCED METALS

Development of High-Performance Materials

The main scheme of the program is to develop preformed wires, consisting of multifilament yarn of graphite or polymer-based silicon-carbide and infiltrated aluminum matrix, which might be easily formed into a composite sheet as if it is a deposited mono filament.

Investigation and improvement of the interfacial structures are emphasized in this program with the support of university researchers.

Development of Forming and Fabrication Technologies

Using both polymer-based multifilament yarn and deposited mono filament as reinforcement, such basic forming and fabrication technologies as hot-press, roll-forming, HIP (hot isostatic press), liquid metal infiltration and extrusion will be conducted in this program.

Investigation and improvement of the interfacial structures are also being undertaken by researchers of national research laboratories.

DESIGN AND QUALITY EVALUATION TECHNOLOGIES

Development of Design Technologies

University and civilian researchers are conducting research to find the best method to convert the inherent directional characteristics of fibers into composite structures. Also, to give guidance for material or process researchers and analytical and experimental investigation of composite structures, including development of an optimum construction program.

Development of Quality Evaluation Technologies

To characterize and assure the quality of composite materials developed by the project, a systematic research program covering both government and civil laboratories has been established.

In the present phase, the institute shares investigation of a) the effect of space environments on fiber-reinforced plastics and b) process control technologies, emphasizing development of the electrical-curing-process control technology.

(a) Information in this table was obtained in an interview with the Research and Development Institute of Metals and Composites for Future Industries.

A pattern common to MITI programs can be noted in this evaluation system: using national laboratories as a neutral vehicle to evaluate benchmarks and help direct desired technical changes. The laboratories' unbiased evaluations also promote clear communication among participating firms by confirming their technical status. In addition to formal reviews, the various working groups meet quarterly, and all supervisors convene for a general program review twice a year.

Project Coordination

The Advanced Composite Materials Project provides a good example of an organizational strategy that reflects a serial scheme. Each organization fulfills a role as a distinct component in the scheme, with the desired flow of material and coordination of competitive interests designed as part of the plan. A summary of materials processed by participants is presented in Table 3.6, and a schematic of the organizational linkages in the Polyimide Matrix Composite Element of the Advanced Composite Materials Project is shown in Table 3.7.

The material manufacturers each focus on a particular aspect of materials development. In the case of the Polyimide Matrix Composite Project, Toray Industries, Inc., is principally responsible for research of the composite terminals. Teijin, Ltd. is responsible for the oligomer, and MCI for the main chain. The companies share basic information, and then each develops a resin that is prepregnated in a machine purchased from the United States.

Each material manufacturer then works with a different fabricator to apply the material to different end-uses. Toray works with MHI and IHI, MCI works with KHI, and Teijin works with FHI. The testing and evaluation are conducted by the Industrial Products Research Institute. According to the director of the program, Mr. Minoda, the plan has been largely carried out without major problems. He noted, however, that it took time for participants to develop the trust and relationships needed for effective communication.

TABLE 3.6. Material Types Processed by the Participating Organizations (Minoda 1989)

Agency of Industrial Science and Technology, MITI

Program Evaluation Committee — Program Steering Committee

Mechanical Engineering Laboratory	P	M	Q
National Chemical Laboratory for Industry	P		Q
Government Industrial Research Institute, Osaka	P	M	Q
Research Institute for Polymers and Textiles	P		Q
Industrial Products Research Institute	P	M	Q
National Research Institute for Metals, STA		M	

University of Tokyo, Fac. of Eng.		M	Q
*Kanazawa Institute of Technology			Q
University of Osaka Prefecture, Coll. of Eng.			Q

R&D Institute of Metals & Composites for Future Industries

Toray Industries, Inc.	P	M	
TEIJIN Ltd.	P		
Mitsubishi Kasei Corp.	P		
Nippon Carbon Co., Ltd.		M	
Ishikawajima-Harima Heavy Industries Co., Ltd.	P	M	Q
Kawasaki Heavy Industries, Ltd.	P	M	Q
Fuji Heavy Industries, Ltd.	P	M	Q
Mitsubishi Heavy Industries, Ltd.	P	M	Q
*Toshiba Machine Co., Ltd.	P		
Mitsubishi Electric Corp.	P	M	Q
*TOYOTA Motor Corp.	P		
Kobe Steel Ltd.		M	

P = Polymer Matrix Composites.
M = Metal Matrix Composites.
Q = Quality Evaluation and Design Technology
* = Sub-schemes already finished.

TABLE 3.7. Organizational Linkages Between Materials Suppliers and Systems Developers

Systems Developers / Material Suppliers	Jet Engine IHI	Aerospace KHI	Aerospace FHI	Aerospace MHI	Space MELCO	Auto Toyota	Machine Toshiba Machine[b]	Pre-Preg[a] Toray
Toray P/M	P M	M	P M	P M	M	Fiber	P	P/P
Teijin P			0					P/P
Mitsubishi Chemical P		0						P/P
Japan Carbon M	0	0	0	0	0			
Kobe Steel M		0						
Japan Ink Chemistry P						0		

(a) Auto lay-up machine.
(b) Pre-pregnated.
(c) Key: 0 = Main partner; P = Polymide; M = Metal matrix; P/P = Pre-preg.

Project Termination

The first interviews were conducted 1-1/2 years before the project ended, and some companies are already preparing for commercialization. NCK began constructing a pilot plant for producing the 500-filament nicalon/aluminum developed through the program. Toray is also moving its high-temperature resins on for private development. The development of the graphite/aluminum wire and polyimide is still somewhat uncertain, however.

3.5 JAPAN INDUSTRIAL TECHNOLOGY ASSOCIATION

The Japan Industrial Technology Association (JITA) is a wholly public, nonprofit organization, which was established in 1969 to assist with the administration of patents and "know-how" developed through R&D supported by

AIST. The JITA manages both the patents developed by MITI's national laboratories and those resulting from contracts. In addition, JITA licenses software developed on government research funds. All patents that have been developed in large-scale R&D programs are owned by MITI and licensed by JITA. Table 3.8 summarizes the number of patent applications submitted in 1985 and in 1988 by the national laboratories and through the national R&D programs. Approximately 60% of the patent applications were submitted by the national laboratories; and of the patents resulting from commissioned R&D, 49% were developed in the Basic Technologies for Future Industries Program and 37% in the Large-Scale National Project System.

JITA's policy is to offer the licenses openly to domestic and international applicants. It will grant both exclusive and nonexclusive licenses with 90% of the royalties returned to AIST and 10% retained as a handling fee. Table 3.9 summarizes the number of patents held domestically and internationally, and the total number of patents licensed, and cumulative revenues as of March 31, 1986. Domestically held patents appear to outnumber international patents by about 10 to 1, and of the 14,873 patents held, only 644

TABLE 3.8. AIST Patent Applications to the Japanese Patent Office, 1985 and 1988 (data obtained from JITA)

Classification of Technology	Number of Applications	
	1985	1988
Basic R&D and special R&D in AIST's national laboratories and institutes	857	372
Commissioned R&D		
Basic technologies for future industries	270	169
Large-scale industrial technologies	201	294
New energy technologies	8	0
Energy conservation technologies	3	0
Medical welfare equipment technology development	66	98
Total	1,405	933

TABLE 3.9. AIST-Owned Patents and Their Licensing as of March 31, 1986 (data obtained from JITA)

	Domestic	Foreign	Licensed Patents	Revenue from Licensed Patents
National Laboratory	8,461	1,153	644[a]	$2.1 Million (310 million yen)
Commissioned R&D	4,994	265		
Total	13,455	1,418		

(a) Out of 14,873.

or about 4% were licensed, with royalties totaling 310 million yen ($2.1 million). Table 3.10 more specifically breaks down the sources of the licensed patents in 1985 and 1988.

In recent years, there has been concern that 100% ownership of the patents by the government discourages private companies from submitting patents. As a result, in 1986, a system was introduced that allows companies

TABLE 3.10. Sources of Licensed Patents in JITA (data obtained from JITA)

Licensing Agreements in Japan	1985	1988
Licensing agreements based on AIST laboratories' R&D	55	26
Licensing agreements based on contract research (commissioned R&D of AIST and private business)	11	8
Patents used	128	55
Patents and know-how used	85	89
Licensing Agreements in Foreign Countries	1985	1988
Licensing agreements based on AIST laboratories' R&D	4	1
Licensing agreements based on contract research (commissioned R&D of AIST and private business)	0	0
Patents used	10	1
Patents and know-how used	0	0

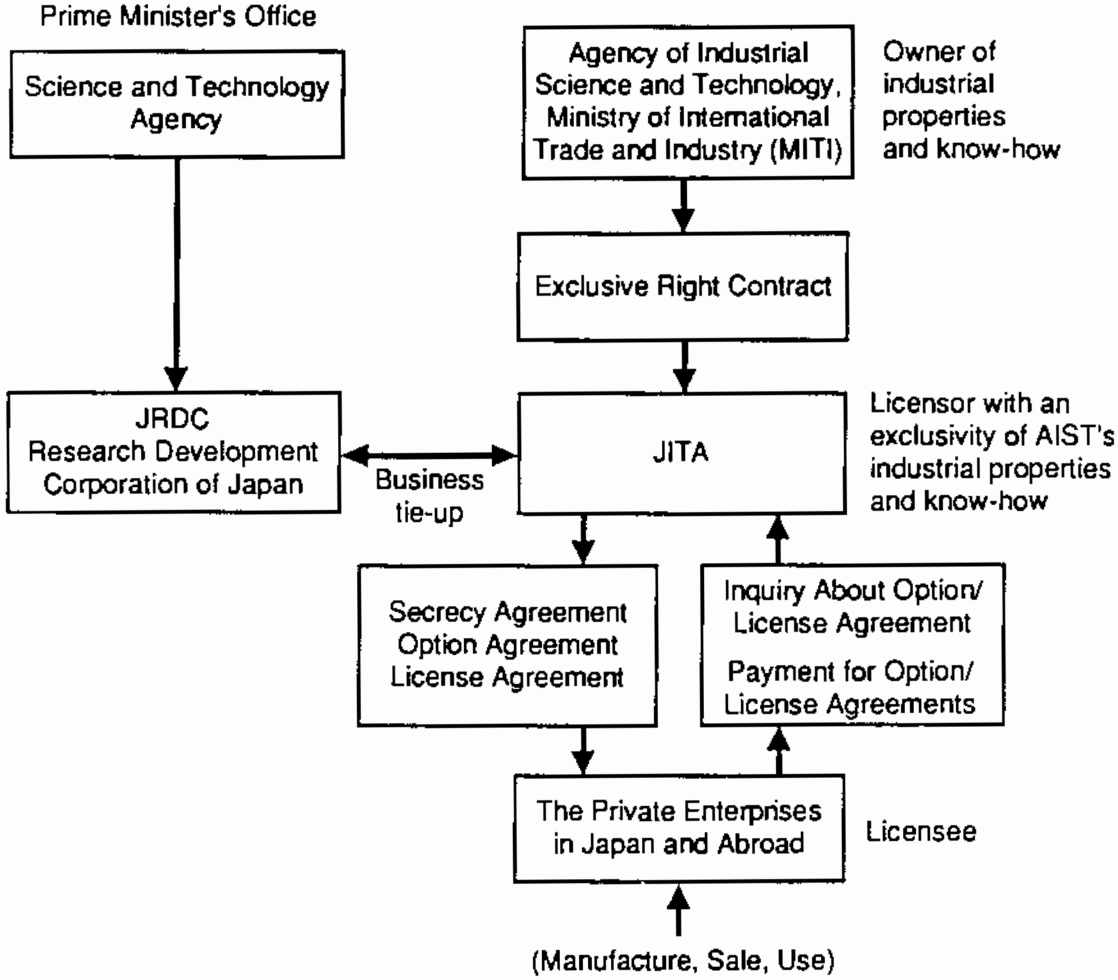
to hold 50% of the right to contract a license, effectively an exclusive right-to-use clause. This right would be sold to the company for some nominal fee that would be negotiated. To date, however, no companies have used this system. When asked why not, the representative interviewed at JITA noted that the companies feel that they gain their advantage in the know-how and that holding patents are considered a lesser priority. This view may be the result of two factors: 1) in the group organization of R&D, the results are supposed to be discussed and shared, making it difficult for the companies to withhold information from each other; and 2) the patent approval process in Japan takes 5 to 10 years. The system is still new, so more time is required to see if companies find a way to make use of it. This option may be exercised more regularly as the MITI projects turn toward truly frontier developments instead of simply "catch up" work. According to the JITA representative, the trend will be increasingly toward shared patents.

A patent question has arisen regarding whether a patent is really the extension of R&D that has been conducted in the private laboratories, or whether it is a result of the government-funded program. MITI addresses this problem by conducting a review of the state of relevant R&D in the private laboratories before the government-funded program commences. When disputes arise, both MITI and JITA representatives have said that the review document is referred to and that the issues are "resolved through negotiation."

One other aspect of the JITA program that is important to its operation is the process of encouraging the transfer of patents to the private sector. One program is designed to encourage patent transfer from the national laboratories to the private sector and a second is designed to transfer patents that require the disclosure of proprietary information. In the first case, JITA acts as an intermediary for the transfer by arranging for the national laboratory to give instruction on effectively using the patent. In addition, JITA occasionally arranges for joint research between the national laboratory and the company to allow for the patent's needed further development into a commercially useful technology.

The second program involves encouraging technology transfer through an options and licensing agreement. In the first stage, a company desiring to license a patent that requires the disclosure of additional proprietary information agrees to an option agreement. The company pays some nominal price and has access to the information for up to 6 months but is obligated to keep the information secret by signing a secrecy agreement. If the company then wants to continue using the patent, it can enter into a license with JITA. The license usually requires some initial royalty payment and quarterly running payments over 10 years.

Information about the patents that come available is published monthly in Japanese in the JITA Nyusu. A cumulative summary of selected patents is also available in National Technologies Held by MITI. To assist in promoting patents overseas, JITA has contracted with the Mitsui Trading Company. JITA's mirror organization, the Research and Development Corporation of Japan (JRDC) of the Science and Technology Agency, has a similar contract with the other large trading house, the Mitsubishi Trading Company. A chart showing the various linkages of JITA to AIST and the patent licensors is presented in Figure 3.3.



Industrial properties/patents and know-how of AIST can be licensed to both domestic and foreign companies on certain conditions that

1) A license fee is paid
2) The licensee is capable of using the patents in the technological and financial aspects
3) The license is non-exclusive

FIGURE 3.3. Flow of Technology Transfer Between JITA and Related Organizations (obtained in interview with JITA)

4.0 EXPLORATORY RESEARCH FOR ADVANCED TECHNOLOGY

This chapter describes in more detail the Exploratory Research for Advanced Technology (ERATO) Program. Section 4.1 describes the organization and management of the program. Section 4.2 describes four ERATO projects.

4.1 ERATO ORGANIZATION AND MANAGEMENT

In the following subsections, ERATO's funding, organization process for generating ideas, staff recruitment, project participation and motivation, patent ownership, and project termination are described.

4.1.1 Funding for the ERATO Program

Funding for the ERATO Program comes almost entirely through the Service and Technology Agency (STA) of the Japanese government. Each project is funded for 5 years, at an average annual funding of 300 to 400 million yen ($2 to $2.7 million). Table 4.1 lists the projects, their duration, and their project directors. Each project is divided into four subprojects or five subthemes that are located in different laboratories. Because ERATO funds projects only for a short duration, all the laboratory facilities are rented, rather than purchased or constructed. ERATO purchases only experimental equipment needed for the research.

4.1.2 Organization of the ERATO Program

Responsibility for administering and managing the ERATO Program resides in the ERATO program office within Research and Development Corporation of Japan (JRDC). The JRDC was established in 1961 to encourage the transfer of university and national laboratory research to the private sector. Consequently, JRDC has a well-developed program for tracing, identifying, and promoting public patents.

The organizational structure is further decentralized within ERATO. Each project selected for support is a separate activity, and each project director has the effective power over organizing and operating each project. The project director then divides the research into several subthemes, and

TABLE 4.1. Summary of ERATO Projects (Japan Research and Development Corporation 1989)

Project	Director	Duration
Amorphous & Intercalation Compounds	Masumoto	81-86
Perfect Crystal	Nishizawa	81-86
Fine Polymer	Ogata	81-86
Fine Particle	Hayashi	81-86
Bioholonics	Mizuno	82-87
Bioinformation Transfer	Hayaishi	83-88
Superbugs	Horikoshi	84-89
Solid Surface	Kuroda	85-90
Nano-Mechanism	Yoshida	85-90
Molecular Dynamic Assembly	Hotani	86-91
Quantum Magneto Flux Logic	Goto	86-91
Biophoton	Inaba	86-91
Morpho Genes	Furusawa	87-92
Molecular Architecture	Kunitake	87-92
Terahertz	Nishizawa	87-92
Quantum Wave	Sakaki	88-93
Microphoto Conversion	Masuhara	88-93
Plant Ecochemicals	Mizutani	88-93
Electron Wavefront	Tonomura	89-94
Atomcraft	Aono	89-94
Genosphere	Ikeda	89-94

each subtheme is located in a separate laboratory with an assigned group leader. This overall structure is shown in Figure 4.1.

According to Mr. Genya Chiba, ERATO's director of research administration, the project director is the key to the success of an ERATO project. The project director is authorized to design the technical subthemes and has complete authority (at least nominally) over who is recruited into his project. The most important characteristics of a project director appear to be seniority, creativity, and the ability to inspire young researchers. The project director needs to be senior and well recognized because in Japan

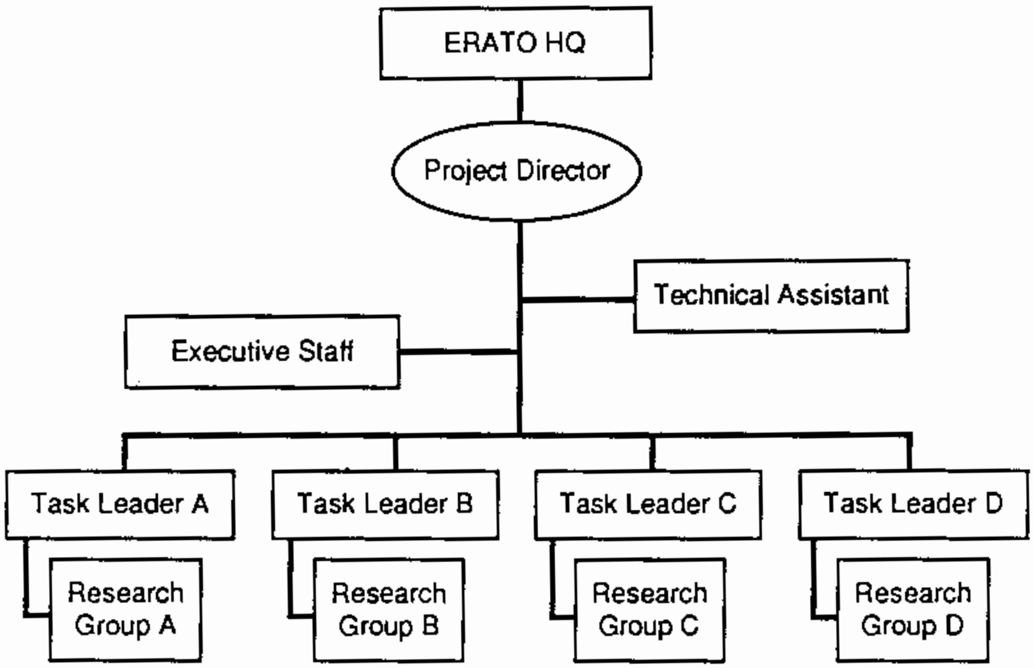


FIGURE 4.1. Organizational Structure of an ERATO Project (obtained in ERATO interview)

respect is based largely on seniority. Therefore, to gain enthusiasm in the general industrial and academic community, having a senior person at the head of a project is important. Recognition of the prominent position of these leaders also seems to be important in gaining funding for research projects from the Ministry of Finance. Creativity is an important characteristic because the areas selected for support are often a multidisciplinary mix of fields in fundamental science. Therefore, a director's creativity is seen as essential for successful synergism among the subthemes. The ability to inspire young researchers is an important characteristic because an authoritarian style would be counterproductive.

The program designers have attempted to allow individual creativity to be expressed while taking advantage of the possible synergies that might result from assembling researchers to press forward the frontiers of science. Although the MITI and Key Technology Center programs both try to develop a cohesive organizational culture and a common sense of organizational mission, the ERATO Program strives for the opposite. Thus, when viewed in terms of some of the traditional aspects of a tightly knit organization, ERATO is seen to possess the opposite features: the organization is decentralized in authority and geography and minimizes features that might contribute to developing a group consciousness.

The project director has the authority for making research decisions. Further, according to the formal policy, individual researchers are encouraged to be more free spirited, with the course of their work negotiated directly with the project director. Other conforming routines are also absent. For example, reporting schedules and forms are determined by each project or individual, and there are no uniform dress requirements.

The ERATO laboratories have also been intentionally dispersed geographically to prevent the formation of large group cultures, as will be discussed in Section 4.2.

4.1.3 Generating Ideas for ERATO Projects

The ideas for ERATO projects are proposed by candidate project directors and developed by ERATO staff and its advisory committee. Although the two paths are difficult to differentiate, they seem to have at least two differences. Early in the ERATO Program, ERATO staff developed most research ideas, which were in areas well recognized for their promise, such as amorphous alloys, fine polymers, or large crystals. As the program became more widely known, more ideas were proposed from the outside, many of which were highly interdisciplinary and innovative. If ERATO originated the idea, the project director had less control over the structure. The ERATO staff had more influence in the subthemes, and the project directors seemed to allow relatively more independence among researchers because they were not as tied to some template of a master plan as were those who conceived the project.

4.1.4 Recruiting Staff for ERATO Projects

Generally, project directors recruit the researchers by conducting several general information and recruiting symposia to explain the general research plan to all interested organizations. Individuals and companies submit proposals describing their desire and qualifications to participate. The project director then, at least according to the plan, is allowed to select the most qualified candidates, with the single stipulation that the researchers must be less than 35 years old.

In practice, this plan was achieved with varying success. All the project directors who were interviewed emphasized the importance of getting good people, but it was noted that this was often not a variable under their control. For example, because all facilities are rented spaces in existing laboratories, often the group leader will be hired from that hosting laboratory to make the interface between ERATO and its host operate more smoothly. If the host laboratory recommends a person to act as the group leader, it is very difficult for ERATO to refuse. Further, when companies with sophisticated researchers express an interest in having one of their staff participate, it is again difficult to reject that person. Because ERATO has been a relatively new program with a very different philosophy from the traditional Japanese approach to research, the private sector has been wary. The best researchers in companies are usually kept in house to work on issues closer to the market concerns of the individual companies. The result has been that the skill level of the ERATO researcher has been somewhat average, which is a handicap for conducting research at the frontiers of science.

Each project director is allowed to select 15 to 20 researchers who will at any one time be funded by ERATO, not by their affiliated organization. The intent of this scheme is to <u>insulate</u> the researchers from external pressures that might put constraints on their research. Each researcher is required to stay in the program for at least 2 years. In past programs, some have stayed for the entire 5-year duration. Table 4.2 summarizes the number of researchers who had participated in ERATO projects as of May 1987. As the table shows, the largest percentage (59%) of researchers have come from companies. The next largest percentage (26%) were researchers listed as unaffiliated. Of the unaffiliated, a little less than 50% were from overseas. ERATO likes to emphasize that researchers from overseas are welcome to apply and will be judged equally with domestic researchers. Of the 22 researchers who have come from overseas, the largest group (9) has been from the United States. There also have been 2 West German, 2 English, and 2 Taiwanese participants, and one each from Canada, Italy, Sweden, Hungary, India, China, and South Korea (<u>Purometeusu</u> 1987).

TABLE 4.2. ERATO Participants and Their Organizational Affiliation (Purometeusu 1987)

Type of Organization	Number of Participants	Number of Organizations
Companies	144	83
Universities	5	4
National Laboratories	4	2
Others	4	2
Individuals (unaffiliated)	63	--
International Participants	26	16
Total	246	107

In addition to the researchers funded by ERATO, during a project often another two to five researchers will participate in the project at the expense of the affiliated company. According to the project directors interviewed, these researchers are treated equally with the others.

4.1.5 Participation and Motivation

Although many project directors are university professors, their participation in ERATO projects has disadvantages. For example, most receive little compensation from the ERATO Program.

The problems university professors face in participating in the ERATO Program are a sign of well-known bureaucratic rivalries that permeate the Japanese government. In this instance, the opposing forces are the Ministry of Education, which oversees the universities, and the STA. According to the formal rules of the Ministry of Education, a national university professor must work 44 hours a week at the university, for the university. When professors succeed in obtaining an ERATO project, the Ministry of Education has been largely unsympathetic and inflexible. There is an apparent concern that the Ministry will lose control over its professors if it allows them to enjoy the use of advanced research facilities, which the Ministry cannot provide.

Formally, the Ministry of Education has conceded to allow its professors to work on the ERATO project, but only on Saturday afternoons and Sundays; and the professors are not allowed to receive any compensation from ERATO because the Ministry of Education is paying their full salary. Consequently, each professor must negotiate with the Ministry for minor concessions that would allow for a more practical arrangement. It appears that each professor works out an individual arrangement. For example, some professors are allowed to exchange 1 day of work and salary for ERATO with 1 day of work and salary for the Ministry. Other professors are allowed to accept a small salary from ERATO for a Saturday afternoon's worth of work with an implicit, not explicit, understanding that the professor will be mixing hours during the week, but that all commitments for the Ministry will still be fulfilled. If these professors were not among the most well known in the country, which they are, their ability to extract concessions from the Ministry of Education would be far reduced. Whatever the details of the agreement, it is fairly clear that national university professors may be engaged in tough bureaucratic tussles to gain approval to work on research projects which will return little in the way of direct financial reward.

For many professors, the main appeal to being involved in an ERATO project seems to be the opportunity to conduct innovative, state-of-the-art research with a relatively young staff and an annual budget of $2 to $2.7 million. This attraction to work with new equipment and a research staff of 15 to 20 is particularly attractive considering the day-to-day reality of minimal funding from the Ministry of Education and aging university facilities.

Most visitors to laboratories in Japanese universities, even major Japanese national universities, will comment on the meager facilities with which the professors work. In some departments, some professors use laboratories comparable to those seen in U.S. universities, but these are still more the exception than the norm.

Compounding the problem of facilities is the cap on new hiring because of overall government fiscal austerity and regulations on employing assistants. Because of continuing restraints on the growth of the government budget, hiring new faculty has been very difficult. Many universities must wait for a professor to retire or to move out to industry (which is rare) before a new member may be brought on. The average age of the faculty has consequently been increasing. An additional problem has been the restriction on hiring support staff. Each professor is allowed to hire one assistant: either a technician or a secretary. Furthermore, if a secretary is hired, this secretary cannot stay for more than 1 year before another secretary must be rotated in. This regulation apparently has its roots in labor union unrest that occurred about a decade ago. As the secretary becomes more and more knowledgeable in one position, the professor increasingly relies on her. This provides the secretary with some amount of power, which was apparently leveraged well during the union strikes. To prevent this from occurring again, the Ministry of Education devised the current system of frequent rotations. As one professor noted, before a secretary can work "too well," she is transferred out.

Therefore, because of the bleak outlook for conducting advanced research in the university setting, national university professors seem to find the opportunity to experiment with new ideas compelling enough to endure the bureaucratic travail.

4.1.6 Patent Ownership

Half of the right to a patent is given to the discovering researcher and half is held by the JRDC. Researchers have the option to transfer their rights of patent to their affiliated companies only after the project has terminated. Since 1961, the JRDC has handled the patents for STA national laboratories and for national and private universities. The JRDC's functions are similar in this way to those of the JITA, which handles patents for MITI-sponsored R&D.

JRDC has three principal methods of encouraging the transfer of techniques represented by the patents: 1) screening all the patent applications for the most promising candidates, 2) acting as an intermediary to facilitate transfer, and 3) providing conditional loans to further develop a patent. To screen the many patent applications it receives, JRDC employs both its own staff and advisory groups. The JRDC staff screen applications first, and the advisory group selects the final set. These screened patent applications are then published in Japanese monthly and released to the general public. An English version of the patent applications is also available but is much smaller, containing perhaps one-tenth the number of applications listed in the Japanese publication, and it is published only once a year. The reason given by the JRDC staff for the different levels of advertisement was that foreign companies typically want a patent that is already near the product stage, not one that is only in its infancy of development. Therefore, they screen for the most readily usable patents.

In its role of an intermediary, JRDC acts much like JITA, helping the national laboratories and private firms wishing to use the patents to facilitate any proof-of-concept work that needs to be done. However, JRDC provides the most direct support in providing conditional loans. Through this program, known as their research cooperative program, JRDC provides a conditional loan of up to 80% of the cost of the further cooperative development of a patent between the inventor and the potential user. The loan is repaid if the patent contributes to a successful commercial venture.

4.1.7 Termination of ERATO Projects--The High Technology Consortia

Although ERATO research projects address fundamental areas, many of the techniques may still have some commercial relevance. To encourage the use of the techniques and results developed in each project, JRDC formed a High Technology Consortium Program in 1986. The purpose of the High Technology Consortium Program is to encourage the formation of groups, or consortia, of companies interested in further developing a particular ERATO research result. Typically, 5 to 10 companies form a consortium, and ERATO will pay for 50% of the costs to effectively train these participants for up to 1 year. ERATO is currently proposing to extend the period of this supplemental development to 3 years.

4.2 ERATO PROJECTS

The following subsections describe visits to four specific ERATO projects: the Perfect Crystal Project, the Amorphous and Intercalated Compounds Project, the Nano-Mechanism Project, and the Solid Surface Project. Included are discussions of the project directors, project details, and other observations. The visits were made in August 1987.

4.2.1 Perfect Crystal Project

In this subsection, the visit with Professor Junichi Nishizawa, project director of ERATO's Perfect Crystal Project, is described.

Project Director

The project director, Professor Junichi Nishizawa, is one of the most highly respected technical figures in Japan today. Although Professor Nishizawa has often found his innovative capabilities stifled by the conservative scientific norms in Japan, and at times his reputation has been higher in the United States than in Japan, he has emerged as the prototype of the path-breaking Japanese scientist, whom the government is hoping the young will emulate. Professor Nishizawa's first significant discovery, made in the early 1950s, was the PIN diode, which has long since become a foundation of semiconductor technology. In 1957, he invented the semiconductor laser. In the early 1980s, Professor Nishizawa was instrumental in developing a high-power thyristor that performed with speed and power capacities that were an order of magnitude greater than state-of-the-art technology in the United States.

An invention that has caused the greatest excitement was Professor Nishizawa's discovery, in the late 1950s, of fiber optics. He was then visited by the research director of Bell Laboratories who had heard about the new development. When the director returned to the United States, he described the new invention to researchers at Corning Glass, the company that holds the first U.S. patents in this technology. Professor Nishizawa does not appear to be upset about the United States usurping his patent because he notes that the recognition he receives in the United States has been influential in enhancing his position in Japan. Japanese organizations, he has noted, have been resistant to his new ideas in the past. In the United States, by contrast, his inventions have met with substantial praise. It was only after this foreign praise that the technical community in Japan openly acknowledged his achievements.

Project Description

The overall purpose of the Perfect Crystal Project was to develop a new type of semiconductor that would combine silicon and gallium arsenide perfect crystal formation technology and static induction control technology. Combining high-speed logic, high-speed switching, optical functions, and crystal photoepitaxy by optical irradiation, static induction thyristors were developed with characteristics such as high operating speeds, low noise, low power consumption, and large power-handling capabilities.

This project was divided into four subthemes: 1) fundamental structures, 2) super high-speed elements, 3) perfect crystal growth, and 4) optical functions. Each of these subtheme projects is described briefly below.

Group 1, the fundamental structure group, was located at the Semiconductor Research Institute in Sendai, toward the northern end of the main island. This laboratory was founded by Professor Nishizawa and is located directly across the street from Tohoku University. The types of research conducted included investigation of the basic performance characteristics of silicon MOS, CMOS, and gallium arsenide (GaAs) static induction thyristors (SITs). Research on GaAs SITs was conducted to explore the possibility of developing insulated-gate SITs by growing superthin perfect crystals on substrates using photoexcited molecular layer epitaxial technology. The eventual goal would be SITs that operate at speeds in the picosecond range.

Professor Nishizawa views this effort as the most successful of the four groups. The growth of epitaxial films for making GaAs semiconductors was achieved through a low-temperature (350°C), high-precision (2.Å5) crystal control technique. In addition, new data were generated on the control and elucidation of the stoichiometric structures of GaAs single crystals.

Group 2, the super high-speed element group, was located at Itami, toward the southern end of the main island. The laboratory space was rented from the Mitsubishi Electric Corporation. The task of this group was to develop a double gate-type SITs that would operate at speeds that were an order of magnitude faster than conventional thyristors and transistors. The basic technique for manufacturing a double-gate SIT was established, with a prototype of a peak voltage of 1 kV, current capacity of 100Å, and a sub-microsecond switching speed. However, further developmental work is still needed and Professor Nishizawa sees this project as only partially successful.

Group 3, the perfect crystal growth group, was located in a laboratory of the Mitsubishi Metal Industry in Saitama Prefecture. This group's task was to develop techniques for growing GaAs single crystals by using the arsenic pressure-controlled Czochralski method. This would allow for the development of ultra high-speed switching elements that are two to three orders faster than ordinary silicon single-crystal elements as well as high-efficiency photoelectric transfer elements. Although progress was made, further research is needed. Professor Nishizawa sees this activity as only partially successful.

Group 4, the optical function element group, was located in the Hamamatsu Photonics Company in Shizuoka Prefecture. Their task was to develop a high-speed, high-sensitivity image sensor in which the optical sensing unit consists of a matrix of SITs. Such a sensor would be capable of discriminating objects in complete darkness. An electrostatic induction thyristor was developed that could detect very weak light, 4×10^{-6} lux-sec. Disturbances caused by lattice vibrations were virtually insignificant. Hamamatsu Photonics, the host laboratory, was enthusiastic enough about part of the development to want to purchase the right to a patent, thereby being the first company to exploit ERATO technology. However, additional work needs to be done, and this research is continuing with private funds at the host laboratory. At the end of the project, Professor Nishizawa judged the task to be only partly successful.

Over the course of the Perfect Crystal Project, 70 patent applications were submitted in Japan, and 20 patent applications were submitted overseas. Ten full papers and several short papers describing original work were published.

Project Termination

After the Perfect Crystal Project was completed, a high technology consortium was formed to continue the research in molecular layer epitaxy.

The work was funded for 6 months, between October 1986 and March 1987, and involved 6 companies. Two of the companies had participated in this ERATO project, and 4 had not.

Professor Nishizawa and his staff asserted that the high technology consortium was not as critical to continued development of the research because the host laboratories were continuing development with their own funds. Mitsubishi Metals was continuing the research on crystal growth. Hamamatsu Photonics was continuing development of the optic sensing unit, and Mitsubishi Electric was continuing work on the double-gate SIT.

Observations

Professor Nishizawa was asked about the policy of emphasizing individual creativity and expression among the young researchers. Although sympathetic with the desire to encourage creativity and expression among young scientists, Professor Nishizawa's primary interest is in pressing forward the state of the technology. He conceived of the research plan for the Perfect Crystal Project and had a well-defined idea of what he would like each researcher to pursue. Where actions of the researchers coincided with his own plan, Professor Nishizawa felt that substantive scientific progress was made. However, the researchers were also aware that, according to ERATO policy, they had the right to influence their own course. So, when researchers strongly insisted on pursuing paths that deviated from Professor Nishizawa's plan, he relented. He asserts in retrospect that when he allowed researchers to pursue paths he advised against, they were invariably wrong. In some ways he sees this as a sign of the generational changes that have occurred in Japan. He adds, "Creative people are often not very cooperative." When queried about whether his attempt to impose a plan doesn't compromise the freedom of the researchers he replied, "Real freedom often has restrictions."

Overall, he gives the project a rating of 50 on a scale of 100. He notes that the biggest problems in a project like this one is to get good organizations to participate and to send good people. Because his ERATO project was one of the first, large companies were hesitant to participate. Further, he notes that most companies will naturally want to keep their best researchers in-house, working on proprietary problems. If the ERATO projects develop a positive record, he feels more companies will want to participate.

In FY 1987, Professor Nishizawa was selected to direct a second ERATO project. The theme of the new project is terahertz. The goal is to improve semiconductor technology by exploiting the properties of waves in the terahertz range, 10^{11} to 10^{13} hertz. Work on molecular layer epitaxy will continue in this project. There is about a 30% overlap in participants with the old project, and Professor Nishizawa noted that he will be striving for greater overall control of the research. Professor Nishizawa said that companies seemed to be a little more interested in this second-generation activity.

4.2.2 Amorphous and Intercalated Compounds Project

In this subsection, the visit with Professor Tsuyoshi Masamoto, director of the Amorphous and Intercalated Compounds Project, is discusssed.

The Director

Professor Tsuyoshi Masamoto is the most highly recognized name in the area of amorphous alloy research in Japan. For example, in 1981 he was the chairman of Japan's first hosting of the triennial International Conference on Rapidly Solidified Materials. Professor Masamoto's father was one of the pioneers in metals research in Japan and was instrumental in developing the reputation of the Tohoku Research Institute for Iron, Steel and Other Metals as the leading materials research facility in Japan.

Project Description

The purpose of research for the Amorphous and Intercalated Compounds Project is to experiment with the structure and composition of new materials with nonequilibrium structures. Solid materials are formed through the rapid quenching of liquids and through the condensation of gaseous atoms and molecules by processes such as chemical vapor deposition (CVD) and physical vapor deposition (PVD). These processes yield amorphous metals, nonequilibrium compounds, intercalation compounds, and ceramics. These new materials are attractive for their unique properties as electronic, optoelectronic, catalytic, and biological materials.

The project was divided into five subtheme groups: 1) basic properties, 2) amorphous compounds, 3) amorphous thin films, 4) special ceramics, and 5) intercalation compounds.

The basic properties group was located at the Research Institute of Electric and Magnetic Alloys in Sendai, which was established and led by Professor Masamoto's father. The primary tasks of this group were to 1) provide structural analysis and evaluation to help support the other four groups, and 2) develop methods for the synthesis of amorphous magnetic thin film and amorphous metallic ultrafine particles.

Amorphous particles, 800 to 1200 Å in diameter, were formed on substrates by sputter-depositing different metals and metal oxides after ionized-argon gas etching of the substrate. In a second area, a transparent, perpendicularly magnetized ferromagnetic thin film was produced by sputtering in the presence of fluorine. A fluorine thin film with nickel and cobalt was also developed and found to have attractive anticorrosion characteristics.

The amorphous compounds group was located at the Otsuka Chemical Company in Tokushima Prefecture on the Shikoku Island. The principal tasks of this group included 1) experimentation of Bi_2O_3, V_2O_5, and TeO_2 matrices as potential optomagnetic and optoelectric materials; 2) research on the synthesis of Fe_2O_3- and Fe_3O_4-based materials for their magnetic and optical properties; and 3) research on the synthesis of amorphous compounds using cluster ion beam vapor deposition.

An amorphous ferromagnetic material with good magneto-optical properties and anticorrosion characteristics was produced through rapid quenching and sputtering after adding oxides to antiferromagnetic $FeBiO_3$. In addition, a new colloidal oxide thin film was produced by rapidly quenching V_2O_5 based on binary amorphous oxides.

The amorphous thin films group was located at Gakushuin University in Tokyo. The tasks of this group were to conduct 1) research of the properties of transition metal-based amorphous thin films, and 2) synthesis and evaluation of different compositions of films and the interdiffusion process in solids. This group was only partially successful in its research.

The special ceramics group was located in the Furukawa Electric Company in Tokyo. The primary tasks of this laboratory were to 1) synthesize and evaluate nitrogen-based and boron-based ceramics by CVD, 2) develop a gas activation process via plasma- or laser-CVD for the synthesis of ceramics, and 3) develop vapor deposition techniques for nonequilibrium phases of ceramics.

At low temperatures CVD successfully synthesized high crystalline rhombohedral BN of hexagonal-based ceramics and of B-N-Ti/B-N-Si-based ceramics. These materials are particularly promising for their electrical and heat resistivity properties. In addition, transparent B-N-Si-based ceramics with 20 to 30 wt% silicon were synthesized by CVD. The addition of silicon was found to improve moisture resistivity.

The intercalation compounds group was based in the Research Institute of Electric and Magnetic Alloys in Sendai. Tasks of this group were to 1) intercalate photoactive chemical species into inorganic compounds, 2) research photochemical energy conversion systems, and 3) research optical memory devices.

A thin film (less than 1 micron) of Tris (1, 10-phenarthoroline) rhodium (III) complex ions was intercalated into the interlayer space of montmorillonite, forming a material capable of optical writing and erasing. In addition, Fe-B-O and Fe-M-O thin films were produced by sputtering. Fe-B-O is a magnetic material with high optical transparency, and Fe-M-O has a perpendicular magnetization. The anticorrosion characteristics are useful for both floppy and hard disks.

During the project, 21 researchers were fully funded by ERATO, and an additional 10 participated as a result of funding by their company. The program has generated about 100 patent submissions domestically and 20 to 25 submissions internationally. About 100 papers have been published describing the research.

Termination of the Project

When the Amorphous and Intercalated Compounds Project was completed, a high technology consortium project was formed to continue the development of amorphous metallic ultra-fine particles for magnetic uses. Five companies joined the consortium. When this consortium was completed in September 1987, a second 1-year consortium was formed to continue the development of thin films for opto-magnetic devices.

Observations

As was the case with Professor Nishizawa, Professor Masumoto explained that his primary motivation was pressing forward the state of the technology. Interestingly, he also gave his program a rating of 50 on a scale of 100. He echoed the problem of getting good companies to participate and convincing them to contribute good people.

The most critical element, however, was the selection of the laboratory sites. Although his laboratories were geographically dispersed, Professor Masumoto did not feel that this was a great problem. The laboratories frequently used the dedicated facsimile ERATO provided, and he noted that the younger researchers looked forward to traveling. The critical features were 1) the quality of the facility, 2) relations with the host laboratory, and 3) capabilities of the group leader, who was always selected by the host laboratory. Professor Masumoto said that he would be much more careful about examining the laboratory options if he were to repeat this experience.

4.2.3 Nano-Mechanism Project

The Nano-Mechanism Project is a relatively new research effort in ERATO, having been initiated in 1985. The principal reasons for visiting this project were to 1) see if significant changes in practice had been implemented after the ERATO Program had several years to "grow up," and 2) observe any differences in motivation or management style that might be apparent when the project director is from the industry rather than academia.

The Director

Mr. Shoichiro Yoshida is the director and general manager of the Industrial Supplies and Equipment Division of Nippon Kogaku, K.K. (Nikon). Nikon manufactures high precision equipment and would benefit directly from any practical advances achieved in the program. One of the company's most famous international products is the Nikon camera.

Project Description

Mr. Iizuka, the project's technical liaison manager, provided a detailed accounting of the process of forming the Nano-Mechanism Project, which is summarized below. The summary is followed by comments on differences in business management style compared with projects run by academics.

In August 1984, ERATO delivered a proposed budget for FY 1985 (began in April 1985) in which the nano-mechanism was vaguely described as a tentative option. Between January and March of 1985, the ERATO staff and technical advisory council developed a project outline, and informal discussions were held with Mr. Yoshida. On May 14, 1985, a formal proposal was made to Mr. Yoshida, but by then, he had already accepted.

Between May and September, Mr. Yoshida was responsible for developing a more detailed plan, and on September 20, the plan was formally approved by the overall ERATO research advisory council. Six days later, on September 26, a press statement describing the project was released, and on October 1, the project formally began. However, the research participants were still in the process of being recruited.

On November 26, 1985, a formal conference was held to describe the technical themes and schemes and to recruit project applicants. About 50 organizations or individuals attended and about half expressed an interest in participating. After further negotiation, 10 to 12 submitted formal requests. (It can probably be assumed that through informal discussions these 10 to 12 were largely confirmed and others excluded before the formal application.) Each candidate had to pass an individual interview with Mr. Yoshida, but it's not clear that any were rejected.

One difference was noted with this project compared with the other three projects reviewed in this study. Because ERATO developed the idea for this project rather than the project director, ERATO had a somewhat larger investment in the concept and the project directors had more flexibility. Unlike the professors interviewed, Mr. Yoshida did not seem as fixed to a detailed structure and notion of the best tasks to pursue. Several researchers came to the project with their own ideas for research, and others reached their decisions through negotiation with Mr. Yoshida. In this project, the flexibility and room for individual initiative seemed to more closely reflect official ERATO policy than other projects. The reasons are unclear, but it may relate, in part, to a relatively lower incentive for Mr. Yoshida to treat the ERATO funds as a precious resource. Also, the Nikon laboratories are certain to be better equipped and less capital constrained than the universities. Whether the performance of the overall system will suffer from this arrangement is something that will be interesting to track.

Research themes for the Nano-Mechanism Project are basic analysis, measurement and control, and processing. The areas of study for each include the following:

Basic Analyses

- analysis of materials (metal, ceramics, etc.) by electron beam and scanning tunneling microscope (STM)
- study of the interaction of x-ray and other material, reflection, and diffraction on the surface
- surface analysis or biological analysis by means of x-ray micro spot made by Fresnel Zone Plate, etc. (scanning type x-ray microscope) or magnified x-ray image (imaging type x-ray microscope).

Measurement and Control

- positioning system with an accuracy of nanometers
- laser measurement methods in units of nanometer, not influenced by air turbulence
- microshape measurement methods based on STM principle (measurement of trench structure, gate width)
- other application technology of STM for industrial use
- micromechanism and microactuator that will be used in micromanipulator.

Processing

- optical multilayer for x-ray reflection by magnetron sputtering and photo chemical vapor deposition
- new principle of high reflecting surface for x-ray without multilayer

- new methods for making an ultrasmooth surface by ion or neutral atom beam.

Observations

The general policies for developing and operating an ERATO project do not seem to have changed compared with the first set of projects. The project director still has substantial autonomy, and the formal emphasis is on the individual researcher. However, ERATO and its advisory committee developed the concept for the Amorphous and Intercalated Compounds Project, and Nippon Kogaku's participation and directorship were solicited. As discussed earlier, this situation has resulted in somewhat increasing the adherence of practice to policy.

4.2.4 Solid Surface Project

The principal purpose of this visit was to see if the organization and management of this relatively recent ERATO project was significantly different from the early ERATO projects. Also, this project was one of the first major attempts at research in a government-promoted project into the area of "materials by design."

Project Director

Professor Kuroda is one of the leading figures in Japan in surface science and the application of high energy techniques to clarify materials structures. He was chairman of the technical committee who designed the photon factory on the 2.5-GeV synchrotron at Tsukuba, and he is currently chairman of a multiagency advisory group who is studying the feasibility of constructing a 6-GeV synchrotron.

Project Description

The project's overall goal is to investigate methods for modifying solid surfaces by chemical, photochemical reactors, or highly controlled physical conditions. Although potential applications include catalysts and sensors, Professor Kuroda emphasized the potential applicability to improving semiconductor performance.

Professor Kuroda currently has 14 scientists conducting research in his program. Eleven scientists are paid by ERATO, and three are paid by their affiliated companies. Of the eleven paid by ERATO, three are foreign scientists: two Americans--one scientist who earned his Ph.D. at the University of California at Berkeley and left a job with Shell Oil to join ERATO--and a second who just completed his post-doctoral work at Northwestern University, and one French scientist.

Observation

This project appeared to have few general differences in recruitment, operation, or management compared with early ERATO projects. When recruiting researchers, particularly domestic researchers, Professor Kuroda described to ERATO the types of expertise he needed, and proposals were then solicited. In this project, each prospective researcher was required to submit a research proposal, undergo an interview, and on acceptance, prepare the actual plans in conference with Professor Kuroda. Because Professor Kuroda's research activities addressed fundamental questions, more individual negotiation with each researcher may have been possible.

5.0 KEY TECHNOLOGY CENTER

As described earlier in Chapter 2.0, during the late 1970s and early 1980s the Japanese government became increasingly concerned about promoting the development of new industries that would be important to Japan's future. In particular was a concern that the strategies that were effective for promoting technological catchup with the western nations were not as appropriate for promoting development in pioneering fields. The goals of the research projects could no longer be clearly defined, and it was becoming more difficult to determine which technologies should be pursued in more detail.

This chapter describes in more detail the Key Technology Center (KTC), which was created to promote research on important future "key" technologies. Section 5.1 discusses the KTC's, organization, and operation. Section 5.2 describes the services that KTC provides. Section 5.3 describes three KTC joint ventures.

5.1 ORGANIZATION AND OPERATION OF THE KEY TECHNOLOGY CENTER

In the following subsections, the KTC's capital investment program and sources of financial support are discussed.

5.1.1 Capital Investment Program

Over the last decade, the Japanese government has slowly spun off some of its profitable public corporations. Two of the more significant have been Nippon Telephone and Telegraph (NTT) and the Japan Tobacco Company. The sale of these organizations has yielded substantial revenue, which the government holds in its supplementary budget accounts (not the general operating budget). This revenue provided the government with a source of funds for ideas.

The sale of NTT, in particular, made a substantial pool of money available. However, NTT was under the jurisdiction of the Ministry of Posts and Telecommunications (MPT), and MPT had very little experience supporting major research projects outside NTT laboratories. In contrast, MITI had extensive experience in administering major R&D projects, but no previous tie to NTT.

As a result of very heated political negotiations, described by Johnson (1989), MPT and MITI agreed to jointly support a separate center for the promotion of research on future technologies, or "key technologies." Consequently, a bill was introduced into the Diet in February 1985 to specifically allow for government investment in private-sector joint R&D ventures. Passed in May 1985, the Law for the Facilitation of Research in Fundamental Technologies led to the formation of the KTC in October 1985.

The KTC's primary operating goal is to encourage a shift of resources in the private sector toward areas that are considered essential for the competitive development of future industries. The principal philosophy behind the KTC is that the private sector is in the best position to identify promising technical challenges and to weigh their commercial potential against research uncertainties. As is illustrated later in this report, the KTC's organization reflects this philosophy.

The KTC will invest 70% of the investment cost of all the research projects for periods from 5 to 10 years. The telecommunications demonstration projects are funded at 50% of the investment cost, with funding periods being somewhat shorter, 3 to 5 years. However, the remainder of this discussion focuses on joint research ventures, not telecommunications demonstrations. The KTC projects supported in FY 1985-1988 are listed in Appendix B, Tables B.1 through B.4.

Virtually all proposals for joint research ventures are generated in the private sector by the proposing companies. In this way, the KTC Program allows the companies to decide which technologies would serve their greatest mutual benefit, which participants would present the best synergism of interests, and what form of research management and organization would most effectively enhance cooperation and minimize conflict. During the KTC's proposal review process, these elements may be changed, but the important difference between these projects and the transitional MITI programs is the initiation and planning that is given to the private sector through KTC.

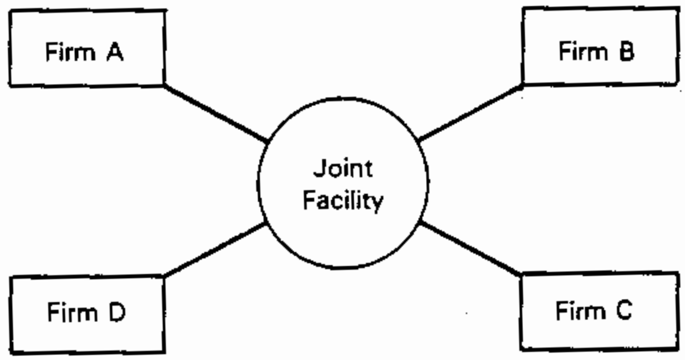
To evaluate projects, the KTC has subcontracted with many university professors who serve as anonymous judges. The KTC staff emphasize the evaluators' anonymity because they feel this is critical to prevent undesired lobbying by the proposing companies. Mr. Masashi Ogawa, the Director of Research Evaluation, commented that the principal criteria for evaluation were 1) the technical competence and promise of the proposal, and 2) the "financial stability of the applicant." A detailed evaluation of the commercial promise is not conducted but is left more to the proposing firms. Mr. Ogawa noted that developing a systematic, detailed method of project evaluation was a difficult and continuing challenge. He was quite interested in learning from the techniques used by the DOE and other research supporting agencies in the United States and Europe.

Joint research rather than direct contract research is supported for several political and technical reasons. Because research is supported for its eventual commercial relevance, the KTC does not want to appear to favor individual companies. By forcing several firms to agree on research, the KTC is trying to better ensure that no one firm creates a monopoly from the research and that the work is beneficial to more than one firm, and preferably to the industry in general. Furthermore, the inclusion of several firms is hoped to better ensure continued development of the research when KTC project is completed and the companies vie for the most useful application in the market.

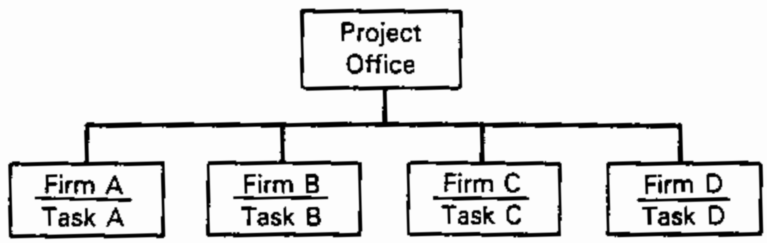
The joint research ventures are only required to include a minimum of 2 companies but most include groups of 8 to 14. The largest participation is about 20 companies.

The companies are allowed to select the form of cooperative research to match their mutual interest. At one end of the spectrum is the single facility, which serves as the center for the joint research. At the other end is the divided program, in which research is divided into tasks that are each conducted in the laboratories of the participating organization. In between these two forms are various intermediate arrangements such as the rental, rather than the investment, of a common facility and use of separate facilities, but with spaces dedicated to the project through which participants from other companies can freely pass. Figure 5.1 shows these arrangements.

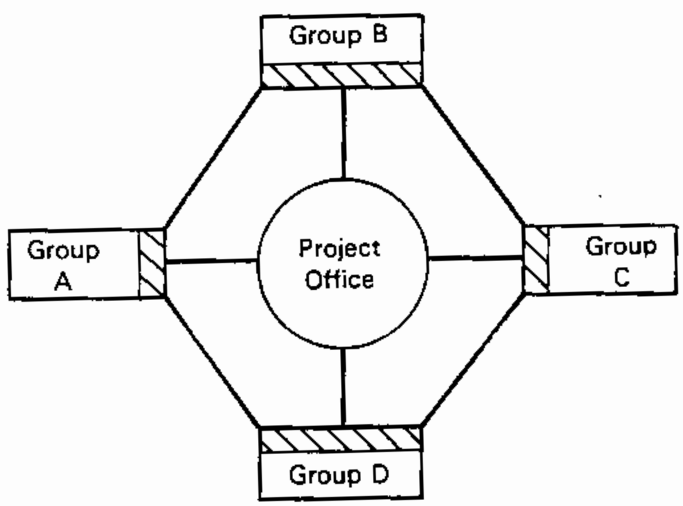
The investment in common laboratory space is an indication that the companies see substantial promise for research that is collectively



Joint Research Facility
- Investment or Rental



Divided Labs, Divided Tasks



Group Facilities, Divided Tasks

FIGURE 5.1. Three Possible Laboratory Arrangements in a Joint Research Venture

beneficial. These facilities are also the most likely to continue to operate beyond the term of the formal KTC program, indicating the greatest long-term commitment of the different companies. The Protein Research Institute, a collaboration of 14 companies, is an example of this arrangement.

When companies are more hesitant about committing to a long-term joint facility but see other benefits of collaboration at a single site, one option used is the rental of space at one facility, with the research conducted jointly. Beyond the technical advantages of this formal joint arrangement are additional political influences. For example, the KTC or MITI might desire broader participation by firms as a precondition to approval. However, these firms may be less committed to the research, willing perhaps to add their names and some nominal funding but not wanting to commit staff or significant resources. The rental of a joint facility thus provides for leveraging of group size and accommodation of varying interests.

A third arrangement, mentioned above, involves dividing tasks among laboratories, which will then dedicate sections of the laboratories to the KTC project. The 17 companies participating in the Research Institute for Metal Surface of High Performance have such an arrangement. When the skills and tasks are relatively discrete but the mixing of researchers and communication is needed for effective development, this arrangement may be preferred. For example, this arrangement would allow companies to take advantage of existing research equipment that otherwise might be quite expensive.

Another option is largely divided tasks at divided facilities, which would allow companies to contribute discrete results that would be shared and would reduce anxiety about the disclosure of their proprietary skills and capabilities. From the KTC's viewpoint, however, this arrangement involves the least communication and the greatest potential for conflict when determining patent rights.

5.1.2 <u>Source of Financial Support</u>

The KTC draws its financial support from several sources, principally dividends from government-owned shares in Nippon Telephone and Telegraph and in the Japan Tobacco Company. These sources are combined with contributions from government financial institutions to form the special account for industrial investment in the KTC. In FY 1985, these sources provided 10 billion yen to the KTC and increased to 20.5 billion yen in FY 1986. Other funding sources include the Japan Development Bank (JDB), which contributed 3 billion yen in FY 1985 and 1.2 billion yen in FY 1986; and contributions from the private sector, which totaled 5 billion yen in FY 1985 (Key Technology Center 1987). Figure 5.2 shows the flow of these sources.

The total commitment in 1985 was 20 billion yen for 25 projects. In 1986, an additional 25 billion yen was allocated to start 22 new projects. However, the first year of projects is typically an organizing year. Because no major plant or land investments are made in this program, the expenses tend to increase as the projects get under way. Thus, for example, the 20 projects initiated in 1985 had their total allocations increased from 2.0 billion yen to 10.0 billion yen in the second year of operation. The acceleration in the projects' costs therefore limit the addition of new projects over time. In 1987, 15 projects were initiated, and in 1988, only 8 projects were initiated. Because the total budget was expected to increase only 5% from 1988 to 1989, not many new projects were expected to be announced in 1989. Table 5.1 summarizes the number of applications for investment projects each year, the number selected, and the funds allocated to new and ongoing projects (Key Tech News 1989).

Table 5.1 also summarizes activity under the loan program. As will be described below, the conditions for qualifying for these funds are not as strict as they are under the investment program. In the first year of the program, 60 projects were approved out of 95 applications, totaling a commitment of 2.0 billion yen. In subsequent years, the number of applications and acceptances has been fairly steady, ranging from 50 to 60 applications and 30 selections annually (Key Tech News 1989).

As part of a political compromise, the de facto split is close to 50/50 between telecommunications projects and other research projects that more traditionally have fallen within MITI's domain. Many of the telecommunications projects are not R&D activities, but technology demonstrations. These "teletopia" projects and new media projects, which are demonstrations of

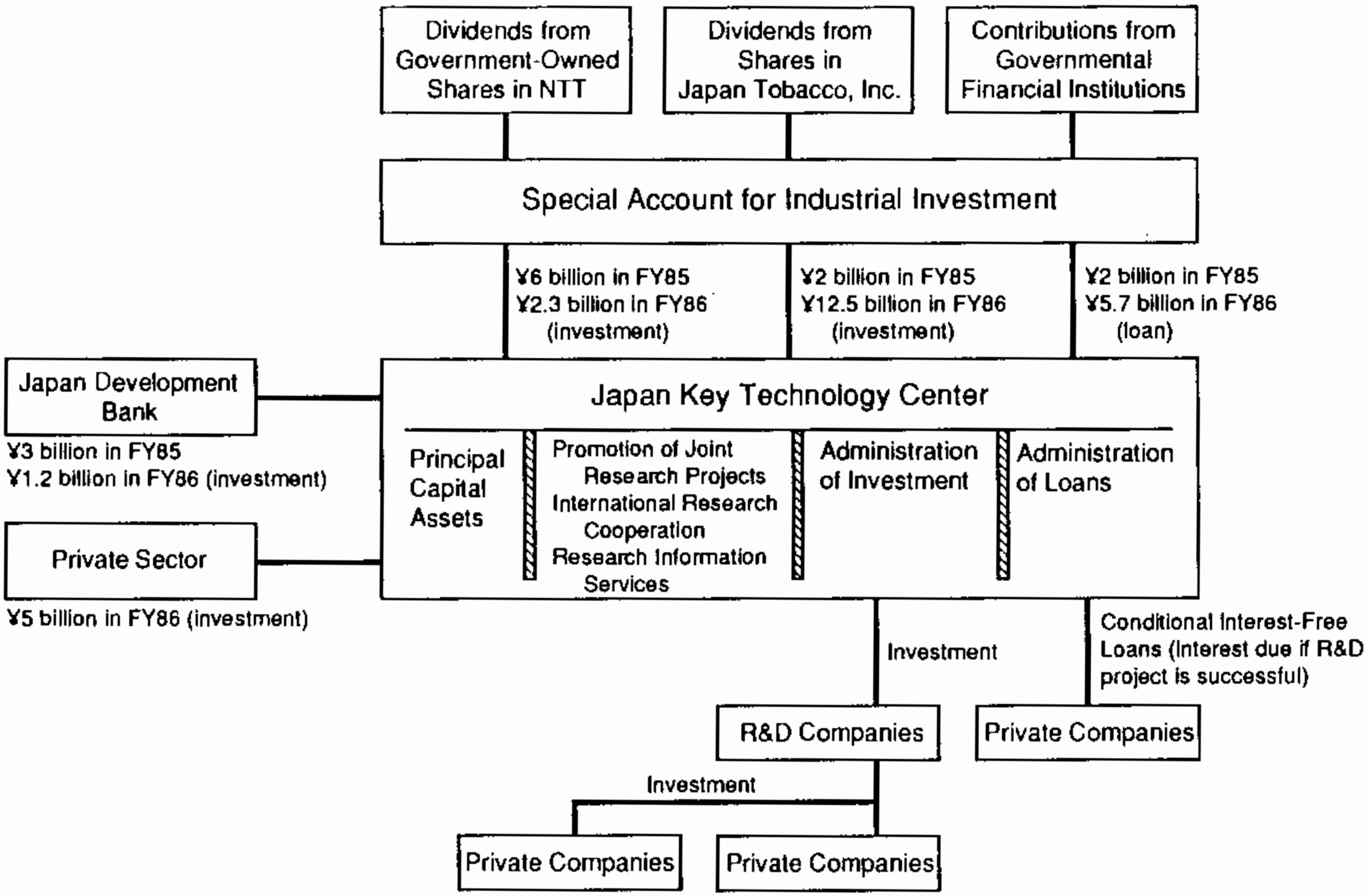


FIGURE 5.2. Flow of Funds to and from the Japan Key Technology Center

TABLE 5.1. Summary of Investment and Loan Program Activities (FY) (Key Tech News 1989)

	1985	1986	1987	1988	1989
Investment Programs					
Applications (no. of projects)	36	36	28	18	--
Acceptances (no. of projects)	25	22	15	8	--
New projects (billion yen)	2.0	2.5	1.04	0.7	--
Total investment	2.0	12.5	17.3	19.2	20.2
Loan Programs					
Applications (no. projects)	95	60	53	5B	--
Acceptances (no. projects)	60	30	29	29	--
New Projects (billion yen)	2.0	1.25	0.75	0.5	--
Total Investment (billion yen)	2.0	5.7	7.7	7.0	6.4

community networked systems, represented 7 of the first 15 telecommunications-related projects initiated in FY 1985 and 11 of the next 15 started in FY 1986. Funding tends to be rather modest, with the KTC contribution amounting to only 5% of the amount invested by the KTC in FY 1986.

5.2 SERVICES PROVIDED BY THE KEY TECHNOLOGY CENTER

In the following subsections, several services currently being provided or planned by the KTC are briefly described: loan services, mediation in arranging joint research, execution of consigned research, the Japan Trust International Research Cooperative Service, the research information service, and a survey service.

5.2.1 Loan Services

A conditional interest-free loan program was created in the KTC to assist companies in reducing the risks and capital burden of R&D and to ease the financial burden (interest payments) for unsuccessful R&D projects. These loans are made available to "research projects pertaining to key basic technologies" and can be granted to individual companies as well as consortia. Any company, including those with foreign affiliations, are eligible for this service. The loans will cover up to 70% of the cost of a research project (which is specified in advance) with repayment schedules stretched out up to 10 years. The maximum length of an R&D project is 5 years.

The titles of the KTC R&D projects that received loans in FY 1985, 1986, 1987, and 1988 are listed in Appendix B, Tables B.5 through B.8. General areas within which projects are supported include new materials, biochemistry, advanced manufacturing, electronics, radio and satellite communications, transmission, image communication, and networking.

In interviews at ERATO, it was noted that the decrease in the number of new loans issued in 1986 was not a conscious decision, but the result of a decreased number of applications. In February 1987, the interest rate of repayment for a commercially successful project was set at 6.05%. This is set to be equal to the interest received on the Special Account for Industrial Investment Fund. However, this interest rate was about 1% greater than the prevailing commercial interest rate, making the KTC loan unattractive.

The loans are still not entirely unattractive, however, because there is a sliding scale of interest schedules that vary with the degree of success of the R&D. For R&D projects that are judged "completely successful," the full interest rate is used. If the R&D is judged a complete failure, repayment is only required on the principal, with no interest compounded. Partially success projects have three intermediate levels of partial interest repayment, 0.75%, 0.5%, and 0.25%. Therefore, for risky R&D projects, the possibility of zero interest repayment may be attractive.

It was unclear how the measure of "degree of success" was determined. The commercial effects of the R&D may not be fully known for many years after the project is completed. In addition, it would seem as though the organizations conducting the research would have an incentive to present a bleaker picture of progress than may actually be the case in an attempt to obtain a lower interest schedule. It does not appear that the KTC staff have yet resolved these uncertainties to their satisfaction. They have shown a strong interest in studying the R&D project evaluation methods of agencies in other countries, including the DOE, and this project appears to be a principal cause of that interest.

5.2.2 Mediation in Arranging Joint Research

A mediation service is offered by KTC to private companies wishing to engage in joint research in national laboratories. The mediation offered is intended to include identifying the needs of the private companies, transferring research information between companies and national laboratories, negotiating the agreement, and providing procedural assistance to ease bureaucrat formalities associated with such an agreement. The application fee for this service is 10,000 yen (about $70). The service is restricted to laboratories in Japan.

At the time of the interviews, the KTC had undertaken three projects. Although the center was not explicit in defining a national laboratory, it most likely refers to the MITI laboratories because the STA already has a similar service in the JRDC.

5.2.3 Execution of Consigned Research

The eventual goal of this service is to provide the opportunity for private companies to engage in contract research with KTC laboratory facilities or national laboratories. This would be a significant change in the practices of the national laboratories because they have been prevented from engaging in direct research for individual firms until now. However, the KTC does not currently have any laboratory facilities. The laboratories are still in the planning stages, and the plans are not public. Beyond the eventual KTC labs, it is not at all clear that there will be much impact on the 16 MITI laboratories because each would probably resist interference from the KTC. For the near future, this is likely to be a low-level activity.

5.2.4 Japan Trust International Research Cooperative Service

Through this service, the KTC is planning to offer research grants that would allow foreign researchers the opportunity to engage in research in the laboratories of private firms in Japan. The fund would include separate memorial trusts registered in the name of individuals and corporations.

KTC intends this trust to function somewhat similarly to a post-doctoral research program; and as such, they emphasized that they were only interested in high-quality researchers (presumably experts in areas where Japanese firms are weak). In general, companies that wish to invite the researchers will initiate the project.

To date, only two researchers have been invited through this program. One American, Nancy Tyson, was invited by the Fine Ceramics Center and a Swede, Matt Nielson, was invited by the Dempa System Kaihatsu Center. Both stayed for 6 months.

5.2.5 Research Information Service

The goal of this service is to gather and make available technical reports and technical data developed by the national laboratories. For example, one of the earliest sets of data made available was a chemical spectral database compiled by the MITI laboratories.

In addition to the technical data, a series of video tapes is being made to describe the research results made available at the laboratories and to introduce new techniques and technologies. More than 100 such videos already are available, and they can be rented for 1 day for prices ranging from $45 to $90 depending on the length of the tape. The average length of a tape is 20 minutes.

5.2.6 Survey Service

The KTC is planning to offer a survey service to industries and other organizations. The KTC plans to provide newsletters, reports, and surveys conducted as ongoing activities and at the request of outside organizations.

5.3 JOINT RESEARCH VENTURES WITHIN THE KEY TECHNOLOGY CENTER

In the following sections, three KTC joint research ventures are briefly described. Because the program is rather new, no venture has yet to established much of an operating record. However, the interviews at sample locations allow some opportunity to view the extent to which policy is reflected in operation. The primary questions asked were: 1) How were the ventures motivated? 2) What is the mutual self-interest? For example, do the companies represent some vertical alignment of interests? 3) Are the companies a mixture of large and small? 4) Does the research appear to be designed for some collective benefit, or are the tasks and results discrete and particular to each participant?

5.3.1 Research Institute for Metal Surface of High Performance

The purpose of this joint research venture at the Research Institute for Metal Surface of High Performance (RIMES) is to develop techniques for treating existing metal material surfaces to improve corrosion resistance, weather resistance, heat resistance, wear resistance, and the surface's electrical and magnetic properties. Such improvements are anticipated by the joint venture to have wide ranging applications in industries such as aerospace, chemicals, marine structures, and automobiles.

To press forward these advances in surface treatment and surface science, 18 companies joined to form RIMES:

Investors

- Materials Manufacturers
- New Japan Iron Works
- Japan Steel Tubing
- Kawasaki Iron Works
- Sumitomo Metals
- Kobe Steel
- New Japan Steel
- Ohji Specialty Steels
- Japan Steel
- Japan Metallurgy
- Kanto Specialty Steel
- Japan Mining
- Mitsubishi Metals
- Sumitomo Metals and Mining

Materials Users

- Yoshikawa Electric
- Fujikura Electric Wire
- Hitachi Electric Wire
- Ishikawajima-Harima Heavy Industries

The list shows participation by many major firms, including Ishikawajima-Harima, a major aerospace manufacturer, Kawasaki Iron Works, Sumitomo Metals, and Mitsubishi Metals. The joint-research venture was planned for a 6-year period (1986 to 1991) with a total budget of 4.0 billion yen ($26.7 million). The KTC pays for 70% of this cost, and the joint venture managers estimate that half of the budget goes to equipment, 25% to staff, and 25% to other expenses. Table 5.2 shows an annual breakdown of the budget.

Research Plan and Organization

The overall technical goal of RIMES is to develop technologies that will allow high-performance films at high speeds to be formed into large complicated metal shapes. Processes to be used and further developed include PVD (vacuum evaporation, sputtering, and ion plating); thermal CVD; plasma-assisted CVD; MOCVD; and ion implantation.

The project is roughly divided into three phases. In the initial phase, experiments are conducted with the various processes to refine the techniques used and explore various combinations. These experiments will be conducted on test pieces of simple shapes, and the characteristics explored will include improved adhesion of the film to substrates, density and uniformity of film, and high-deposition rate. In the second stage, the techniques will be applied to increasingly complicated shapes using the concurrent

TABLE 5.2. RIMES Budget (obtained in interview with RIMES)

Year	Million Yen	Million Dollars[(a)]
1986	622	4.15
1987	929	6.19
1988	957	6.38
1989	729	4.86
1990	435	2.90
1991	328	2.19
TOTAL	4000	26.67

(a) At 150 yen/dollar.

experimentation with multiple evaporation sources, larger plasma sources, substrate temperature control methods, pretreatment of the substrate surface, and atmospheric control.

In the third stage, various surface treatment techniques will be combined in search of combinations that will yield the advantages of several techniques at once for the surface characteristics mentioned earlier. However, each process has different optimum conditions. Thus, the variety of variables will be altered to achieve optimal sets of conditions. These variables include the temperature of the substrates, cleaning of the substrate surface, positional control, pressure of the process (or the system), ratio of ionization of vapor, plasma generation reaction, gas distribution, reaction of the interface (between film and substrate), deposition rate, and prevention of the contamination of the surface film. The flow of contributions of these processes to improved metal surface performance is shown in Figure 5.3.

In summary, the expected results of the research are as follows:

- technology to form a uniform, defect-free, and highly adhesive surface film over large-size, large-area, and complicated shapes of metal substrates
- film technologies, such as deposition technology, to form highly adhesive films over the metal surface at high speed and low temperature deposition technology, and low residual-stress deposition technology
- high-grade deposition technology (composite deposition, multilayer coating) and efficiency improvement through combinations of various process technologies and continuous deposition technologies.

As mentioned earlier, these technologies are expected widely applied. Brochures in Japan illustrate the potential impact of these generic capabilities by drawing a tree, the roots, and trunk, which represent the base technologies and the branches, which represent the applications. Figure 5.4 shows this diagram. As the figure shows, major applications include heat resistance, wear resistance, corrosion resistance, fatigue resistance, and improved electrical and magnetic properties.

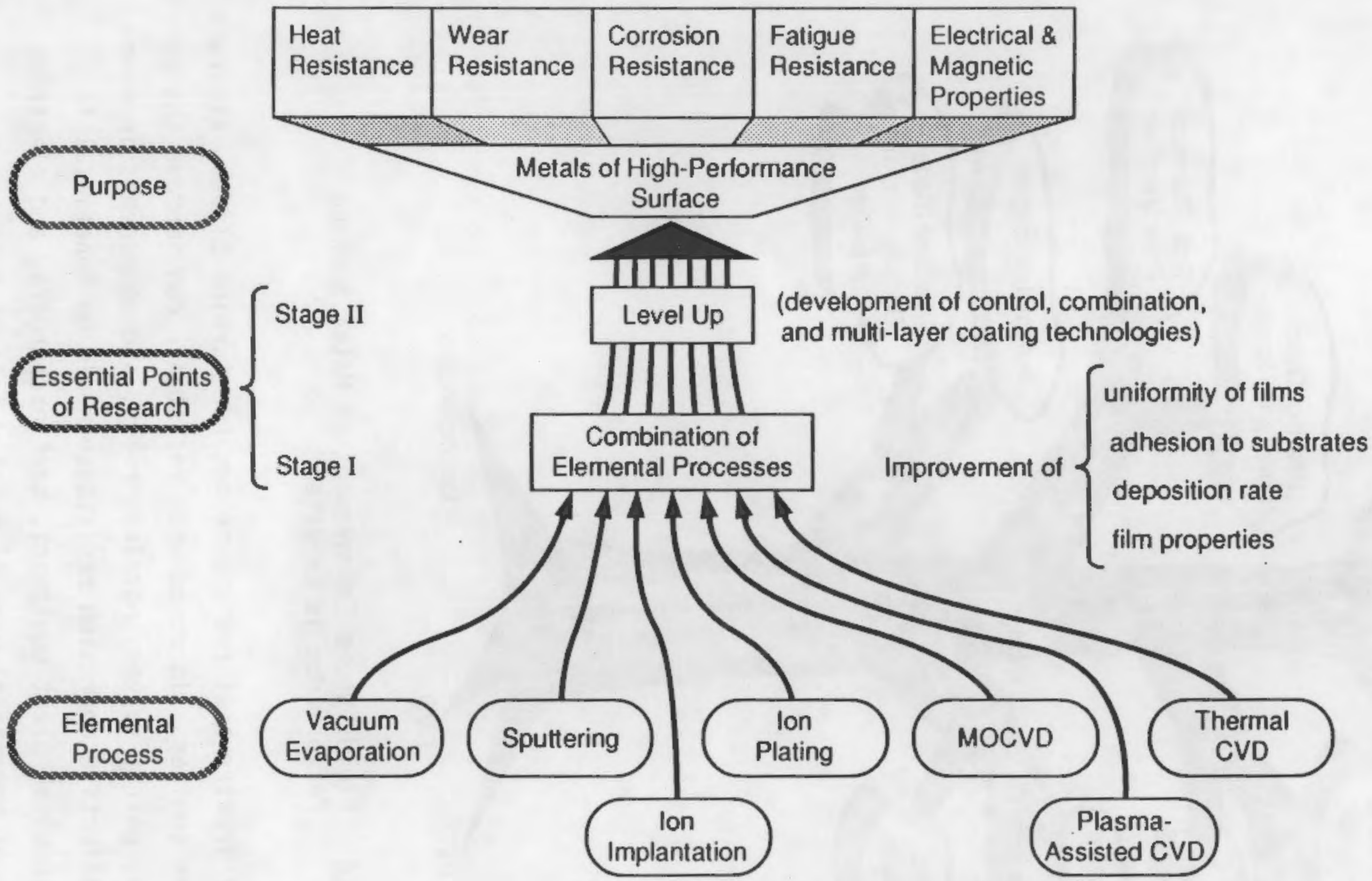


FIGURE 5.3. Research Flow Chart

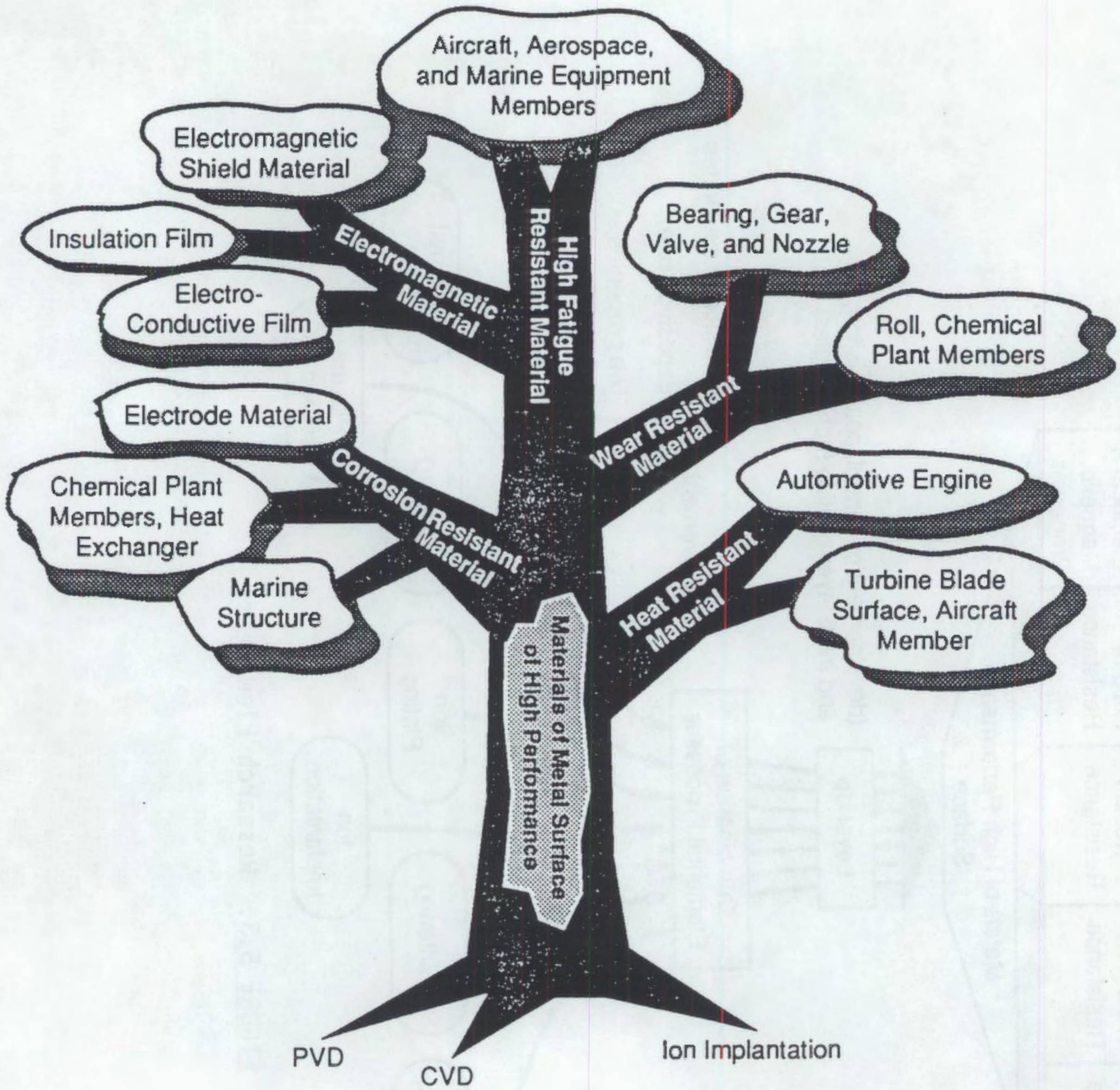


FIGURE 5.4. Fields Where Improvement of Metal Surface Performance is Expected

Applications of greater heat resistance include turbine blades, aircraft parts, and automotive engines. Improved wear resistance can improve the performance of bearings, gears, valves, nozzles, rolls, and components in chemical plants. More effective corrosion resistance would be beneficial to marine structures, chemical plant equipment, heat exchangers, and electrode materials. Examples of beneficial uses of greater fatigue resistance include aircraft parts, aerospace equipment, and marine equipment. Finally, potential benefits could be derived from improved electrical and magnetic properties such as electromagnetic shield materials, electroconductive film, and insulation film.

Staffing

Currently, the joint research venture employs 20 people, 16 of whom are researchers. In practice, the KTC pays only 80% of the researcher's salary. The remaining 20% is made up by the affiliated company. This appears to be considered in the overall balance of 70% KTC funding and 30% company funding, so the overall balance is not affected. However, it should again be noted that the manpower compensation is direct salary without other benefits and overheads. In addition to the fulltime staff, the joint venture employs special researchers and consultants for the short term. Visits by these researchers occur for about 1 week per month; about 20 such visits had occurred by the summer of 1987.

The purpose of these visits appears to be training for transfer back to the companies. However, this points to a dilemma for the KTC because the joint venture is supposed to function as a separately incorporated company, with the benefits of the research returned first to the joint venture. For example, any work leading to patents is supposed to be the proprietary property of the joint venture, with the royalties returned to its investors, including 70% back to the KTC. However, with visiting researchers traveling through frequently, and with the tenure of a full-time researcher being only 1 to 2 years, the technology transfer is difficult to stop. The official position of the joint venture is that patentable developments must not be released early. In reality, however, it is likely that there is a significant amount of transfer through "know how," with some sort of gentleman's agreement regarding the patents.

Task Organization

The research is divided into 4 research groups, each located at one of the participants' laboratories. Group 1 is located at a laboratory of Ishikawajima-Harima Heavy Industries, a major aircraft and aerospace manufacturer. The principal research activities include ion-plating of large-scale complicated parts. Group 2 is located at a laboratory of Kawasaki Iron Works in Chiba Prefecture; its principal task is to evaluate various composite and multilayer coatings for improved performance characteristics. Group 3 is located in the central research laboratory of Sumitomo Metals. The principal task of this group is to combine techniques such as high temperature, plasma, and MOCVD and apply them to large and complex shapes. Group 4 is located in the Chiba laboratory of Mitsubishi Metals. The principal task of this group is to refine techniques of ion implantation.

General Observations

The project's overall management and organization appear to be consistent with the KTC's goals. Surface modification techniques have widespread generic applications and are likely to be influential in a range of uses.

Motivation seems to have legitimately occurred in the private sector. As Table 5.2 showed, most companies are involved in metals manufacturing, and few of the companies appear to be major users. Among the user firms are moderate-sized electrical materials suppliers, and only one is involved in heavy machinery, turbines, aircraft, and aerospace. Thus, vertical integration of interests does not appear to be a major element, possibly because 1) the type of surface experiments is so complex that only companies with advanced capabilities can contribute, or 2) transferring these skills to end-users would increase conflicts because the competitive advantage in the application of these techniques overlaps.

5.3.2 Non-Oxide Glass

The non-oxide glass joint research venture is one of the smallest of the KTC investment projects. The Non-Oxide Glass R&D Company was established in April 1986 by Nippon Sheet Glass and the HOYA Corporation, with financial assistance from the KTC.

The overall technical objective of this effort is to develop chalcogenide glasses that can be used for mid-infrared transmission fibers or for enabling disc memory media. (Chalcogenide refers to the elements S, Se, and Te, which join with various other elements to form various nonoxide glasses such as As-S, As-Se, Ge-Se and Ge-Se-Te.)

Nippon Sheet Glass and the HOYA Corporation are major manufacturers of traditional glass products. HOYA is the larger of the two firms and has been particularly strong in manufacturing products such as crystal and eye glasses. Nippon Sheet Glass has its traditional strength in manufacturing sheet glass. Although its strengths are somewhat different, the two companies' markets overlap. Also, future markets that are targeted through the KTC program, optical disc memory and transmission fibers, are the same.

One participant in this program noted that, in concept, a more mutually beneficial division of tasks would occur if the interests of each firm followed one another rather than overlapped (that is, a vertical matching of interests in the technology development). The potential for dispute and unproductive competition is somewhat offset by the historical relationship between these two companies and by a division of tasks in the organization. HOYA has always been much larger than Nippon Sheet Glass and has had a quasi-subcontractor relationship with the company. In the past, HOYA has trained Nippon Sheet Glass in certain techniques and has purchased products from Nippon Sheet Glass. The previous relationships have allowed for the development of trust, which mitigates the concern that one party will cheat the other. The organizational division is described further below.

Over the 5-year period of the project, 720 million yen ($4.8 million) will be expended. The KTC will pay 70% of this amount, and each company will contribute 15%. In the first year of the project, 200 million yen ($1.33 million) was spent.

Research Plan and Organization

This joint research venture will focus on two types of technology: mid-infrared (MIR) fiber and disk memory media. MIR fibers that operate in the IR region up to 15 μm wavelength can be used to transmit the beam for a CO_2 laser (10.6 μm wavelength) or to transmit IR emitted from heated bodies. Potential uses include medical equipment, laser processing, and remote sensing.

Because of its transparency in the IR region, chalcogenide glass is one promising candidate for use in MIR fibers. The technical target of this research is to obtain low loss (0.1 dB/M at 10.6 μm) glass fibers that can be applied in industry.

Erasable optical memory media is a second area of potentially significant application for chalcogenide glass. Certain chalcogenide glasses exhibit the property of reversible light-induced crystallization. Accompanying this phase change from the amorphous to crystalline states, there is a substantial change in reflectivity, which is the characteristic desired for this function. The focus will be on glasses that have a stable amorphous state and a high crystallization rate.

MIR Fibers

Specific areas of research planned for this study include the following.

MIR fibers

- glass compositions - longer IR cut-off wavelength, curability, and thermal stability
- purification of raw materials - oxide impurities
- glass melting - without further contamination
- fiber drawing - core-clad structure
- related technologies - anti reflection coating and cable structure.

Disk memory media

- glass compositions - stable amorphous state and rapid crystallization
- preparation of this film on substrates.

The research is conducted at a single facility rented for this joint research venture. The space is located in the Japan Perunokusu Technical Research Laboratory in Kanaguwa Prefecture, with the administrative office located in the center of Tokyo.

Management and research are divided between the two companies. The current president of the joint research venture is from Japan Sheet Glass, the vice president from HDYA, and the two directors are from the two companies.

To conduct the research, each company assigns two researchers to the laboratory for 1- to 2-year rotations.

The manager-to-worker ratio is high, and therefore the managers are only engaged part time on the project. The most active managers, the two directors, spend about half of their time overseeing this joint venture and the other half working at their affiliated companies. Each researcher is said to have a discrete task, making cooperation unnecessary for achieving the project goals. However, in papers describing research results, all researchers are listed as joint authors, so it is difficult to know how discrete the tasks are.

According to the formal rules, the participants in the joint venture are not supposed to reveal the conduct of their work to their affiliated companies, but it was admitted that this is very difficult to control. It was noted that there is a "gentleman's" agreement to avoid potential patent disputes.

5.3.3 Advanced Combustion Engineering Institute

The Advanced Combustion Engineering (ACE) Institute was formed at the end of FY 1986 by 12 companies to carry out advanced combustion research. Most of the companies are from the automobile industry:

- Isuzu Motors
- Nissan Diesel
- Hino Motors
- Mitsubishi Motors
- Toyota Motors
- Nissan Motors
- Mazda
- Daihatsu Industries
- Diesel Equipment
- Japan Denso
- Japan Catalysis and Chemicals
- Tokyo Equipment.

More specifically, the principal concern of the institute is to investigate ways of reducing diesel engine emissions so that medium- to large-sized truck engines will be able to meet stringent emission standards that are anticipated to be implemented in the United States by the middle of the 1990s. Thus, the motivating concern seems to be future tighter emissions standards in their major export market.

Although 12 companies are nominally involved, 4 companies have been the principal planners and bear 80% of the private sector investment in this project. These four firms, Isuzu, Nissan Diesel, Hino Motors, and Mitsubishi Motors, are particularly interested in improving emission control for their medium- to large-sized diesel engines. Smaller vehicles can more readily switch back to gasoline if the diesel emissions standards prove too stiff.

These four firms contribute about 360 million yen ($2.4 million) of the 450 million yen ($3 million) private sector investment in this project. The total budget over the 6-year life of the project is 1.5 billion yen ($10 million.)

Research Plan and Organization

The basic research plan for this project is divided into six activities:

- ultrahigh-pressure fuel and atomization technology - to develop a 3,000 kg/cm^3 high-pressure fuel jet and a highly combustible, atomized spray
- high-pressure fuel supply control technology - to precisely control the supply of fuel to the engine whether needed in an instant or continuously
- optimal air supply control technology - to match the supply of combustion air with the timing of combustion
- emission control technology - to control the harmful effluents in exhaust emissions through technologies such as catalysts
- sensor technology - to quickly and precisely identify inputs (e.g., fuel or air) needed for control of the engine
- high-strength ignition technology - to control combustion and the positive combustion of various fuel-air mixtures.

Figure 5.5 shows how these areas feed into the overall research plan. Although a wide range of applications is possible, the focus of this work is diesel exhaust emissions.

To conduct the research, the ACE is renting laboratory space on the site of the Japan Automobile Research Laboratory in Tsukuba. As of summer 1987, they were still in the process of constructing a building that would house

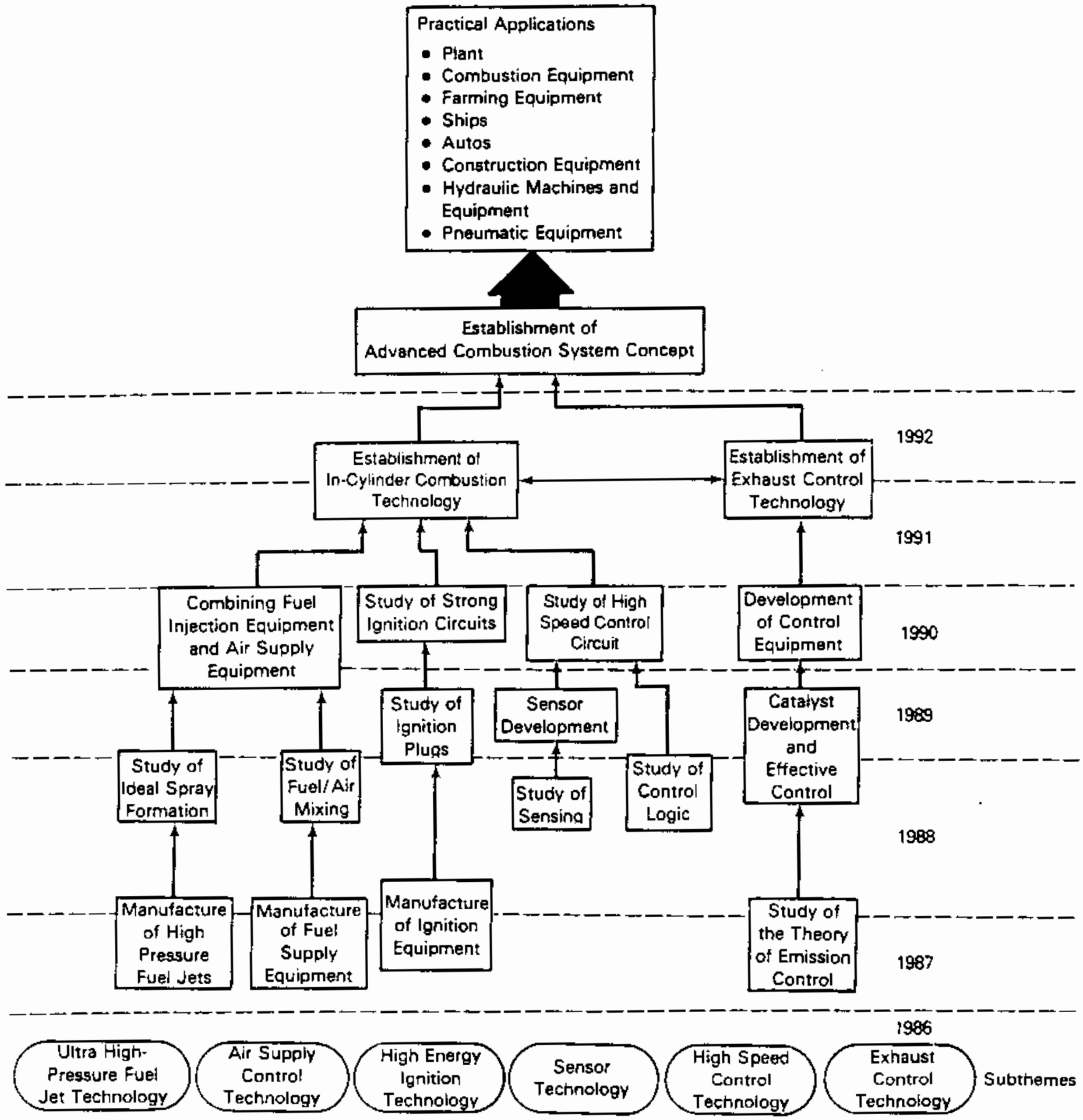


FIGURE 5.5. Advanced Combustion Engineering Research

most of the ACE equipment. However, they had conducted some preliminary experiments with laser holography and short pulsed techniques to examine diesel exhaust from a direct injector. The main facilities were expected to be ready by mid-1988.

The president of the ACE is selected in consultation among the four primary firms. The president in 1987, Suzuki, was from Hino Motors. Beneath the president are four directors, one representing each of the principal firms. Three of the directors and the president spend only part of their time on the ACE project. Most of their time is spent with the affiliated companies. Only one director, Mr. Tsujimura from Mitsubishi Motors, is assigned to ACE fulltime.

Currently conducting the research are four researchers, one from each principal company. Each researcher is selected by the affiliate company, and each is expected to be at the ACE for 2 to 3 years. The division of research tasks was not clear, partly because research is just beginning. However, there do not seem to be major barriers to cooperation, and the staff indicated that collaboration was expected.

Observations

From viewing the organization and operation of ACE, an immediate question is to why 12 companies participate but only 4 are involved in the bulk of the work. The staff insists that the reason for this is MITI's influence. Unlike typical KTC projects, the ACE was an idea that was initially motivated by the Transportation Division of MITI. MITI generally wants to encourage advanced collaborative research among the manufacturers. However, the manufacturers were apparently less enthusiastic about the idea. MITI was thus apparently instrumental in gaining the acquiescence of all 12 firms. After some discussion about common needs, the four firms that are currently the principal participants proposed diesel engine exhaust emissions as the primary research activity, and MITI agreed. As a result, these firms fund 80% or the private sector contribution and currently provide all the staff. The other 8 firms are much less involved. Thus, MITI acted as the primarily initiator of the general concept, and a small group of private firms then negotiated and defined a project of common interest.

APPENDIX A

MINISTRY OF INTERNATIONAL TRADE AND INDUSTRY PROGRAM - PROJECT INFORMATION

APPENDIX A

MINISTRY OF INTERNATIONAL TRADE AND INDUSTRY PROGRAM - PROJECT INFORMATION

In this appendix, any detailed project information obtained during the study on the Ministry of International Trade and Industry (MITI) Program is presented.

Table A.1 lists the 107 Engineering Research Associations (ERAs) formed as a result of the Mining and Manufacturing Industries Technological Cooperatives Law, which in 1961 authorized MITI to organize cooperative research programs. Table A.2 lists completed projects under the Large-Scale National Project System, which was MITI's first largely government-promoted R&D program.

Tables A.3 through A.6 present technical information on the Fine Ceramics R&D Project in MITI's Basic Technologies for Future Industries Program. Table A.3 provides a sampling of the properties and possible areas of application of the range of thermal and mechanical fine ceramics. The details of the project's technical goals are summarized in Table A.4. The goals are divided into three components that emphasize material characteristics: strength, corrosion resistance, and wear resistance. The temperature goals may be viewed as modest, although they are considered to be state of the art. The project managers noted that their target for the Weibull modulus (a measure of reliability) of 20 to 22 is well above that of 6 to 10 for conventional ceramics and 15 for the advanced gas turbine in the United States.

The project plan for the Fine Ceramics R&D Project is divided into three phases. The primary emphasis of the first phase (FY 1981 to 1983) focuses on developing powder-synthesizing techniques to obtain uniform materials and on forming and sintering techniques to mold very small test pieces. Characteristics of the powders synthesized and their performance properties are shown in Tables A.5 and A.6. The project managers pointed out that materials with Weibull moduli that exceed 30 have been produced. Because the powder synthesis technique and the forming and sintering technique were carried out at the same time, the relationship between the two processes could not be investigated in this first phase. Investigation of this sequence was initiated in the project's second phase.

In the second phase (FY 1984 to 1987), the relation between powder composition and characteristics to forming, sintering, and machining was explored. In addition, the size of the test pieces was scaled up several hundred times to approach more commercially relevant dimensions.

Finally, in the third and final phase (FY 1988 to 1992), the results from the earlier experiments will be integrated, and test pieces will be scaled up even further to sizes appropriate for a ceramic gas turbine. The project was originally scheduled to terminate in FY 1990, but re-evaluation of the time needed for full-scale materials testing led MITI to justify extending the project.

Table A.7 summarizes the technical goals and achievements of the Advanced Composite Materials Project. Project research focuses on developing two types of composite materials: fiber-reinforced plastics and fiber-reinforced metals.

TABLE A.1. Engineering Research Associations (Shirai and Kodama 1989)

Research Association of Macromolecular Materials

Research Association for Industrialization of High-Grade Alcohol

Research Association - Tenchi Institute

Research Association of Creep Experiments

Research Association of Optical Industry

Research Association of Preferential Refining

Research Association of Electronic Computers

Research Association of Solvent Dyeing of Wood Products

Research Association - Naniwa Foundry

Research Association of Buffer Materials

Research Association for Selective Use of Light in Agriculture

Research Association for Sintering Lime with Heavy Oil

Research Association Surface Processing of Aluminum

Technology Research Association of Automobile Appliances

Automotive Safety and Anti-Pollution Technology Research

Research Association of Complex Materials of Light Metals

Research Association for Development of Super-Performance Computers

Research Association of New Computer Series

Research Association of Super-Performance Electronic Computers

Research Association for Safety of Medical Equipment

Research Association of Nuclear Iron Manufacturing

Research Association for NO_x Prevention in the Iron and Steel Industry

Research Association of Software Modules in Design Calculation

Research Association of Software Modules in Administration

Research Association of Operations Research Calculation

TABLE A.1. (contd)

Research Association of Software Modules in Management

Research Association of Software Modules in Automation

Research Association of Automatic Measuring Technology

Research Association for Construction Safety Under High Temperatures

Research Association for General Control of Motor Traffic

Research Association of Polyvinyl Chloride and the Environment

Research Association for Obtaining Chemical Materials from Heavy Oils

Engineering Research Association for Aero-Jet Engines

VLSI Technology Research Association

Technology Research Association of Medical Apparatus and Welfare

Research Association of New Housing Supply System

Research Association of Pattern Information Processing System

Electric Vehicle Engineering Research Association

Research Association Association of Seabed Production System

Research Association of Flexible Manufacturing System Complex Provided with Laser Engineering

Engineering Research Association for Advanced Gas Turbines

Research Association for Residual Oil Processing

Computer Basic Technology Research Association

Research Association for Selective Packaging of Vegetables and Fruits

Research Association for Petroleum Development Alternatives

Research Association for Macromolecules Applications

Research Association of Waste-Water Treatment Machine System for Permanent Residences

Research Association for Ci Chemistry

Research Association of Light Application Systems

TABLE A.1. (contd)

Research Association for Gas Engine Heat Pump System

Research Association of Synthetic Dyes

Engineering Research Association for High Performance Ceramics

Research Association Association for Biotechnology

Research Association for Basic Polymer Technology

Scientific Computer Research Association

Technology Research Association of Manganese Nodules Mining System

The Research Association of Industrial Furnace Manufacturing Technology

Research Association for New Smelting Technologies

Research Association of the Membrane of Enriching Oxygen and Combustion

Research Association of Pulp and Paper Technology

Research Association for Membrane Use in the Food Industry

Enhanced Oil Recovery Research Association

Technical Association of Surfactants for Energy Use

Technology Research Association of Automated Sewing System

Surface Mining Equipment for Coal Technology Research Association

Research Association of Aluminum New Refining Technology

Research Association for Utilization of Light Oil

Research Association for Synthetic Fiber Technology

Research Association for New Chemicals Production by Utilizing Biological Functions

Research Association of Electric Conductive Inorganic Compounds

Research Association for New Technology Development of High Performance Polymer

Research Association of Aluminum Powder Metallurgy

Engineering Research Association of Shape Memory Alloy

TABLE A.1. (contd)

Technological Research Association of Highly Reliable Marine Propulsion Plant

Fuel Alcohol Research Association

Advanced Robot Technology Research Association

Research Association of Extrusion Technology in the Food Industry

Research Association for Biotechnology of Agricultural Chemicals

The Japanese Research and Development Association for Bioreactor System in Food Industry

Research Association of Alkali Dry Cells

Technology Research Association of Resources Remote Sensing System

Technology Research Association of Super Heat Pump Energy Assumulation System

Research Association of Advanced Housing Technology

Advanced Nuclear Equipment Research Institute

Research Association for Regional System Development in Toyama Prefecture

Aqua Renaissance Research Association

Research Association for Hydrogen from Coal Process Development

Engineering Research Association for Integrated Coal Gasification Combined Cycle Power Systems

The Group of Research Association for Wood Substances

Research Association for Multi-Use of Wood Carbon Content

Research Association for Practical Performance Improvement of Gas Turbines

Research and Development Association for Sensing Systems in Food Industry

Research Association for Sophisticated Use of Hokkaido Wood

Agrobiological Gene Analysis Research Association

Research Association for Use of Biological Activity of Organic Manure

Research Association for Transplant of Livestock's Impregnated Eggs

Research Association for Production System of Textile Products

TABLE A.1. (contd)

Advanced Material - Processing and Machining Technological Research Association

Laser Atomis Separation Engineering Research Association of Japan

Advanced Cogeneration Technology Research Association

Engineering Research Association for Superconductive Generating Equipment and Materials

The Japanese Research and Development Association for Improvement of Enzyme Function in Food Industry

Research Association for Development of Complex Material Products

Technology Research Association for Molten Carbonate Fuel Cell, Power Generation System

Research Association for Artificial Clay Synthesis

The Japanese Research and Development Association for High Separation System in Food Industry

Technology Research Association of Techno-Superline

TABLE A.2. Completed National Research and Development Projects (Large-Scale Projects) (Agency of Industrial Science and Technology 1989)

Project Name	Period (FY)	Total Expenditure	Outline of Project
Super-high performance electronic computer	1966 - 1971	10,100	Large scale computer system with super-high performance.
Desulfurixation process	1966 - 1971	2,700	(1) Efficient removal of the SO_2 contained in the gases exhausted from power or other. (2) Direct removal of sulfur from heavy oil.
New method of producing olefin	1967 - 1972	1,200	Economic production of olefins by direct cracking of crude oil instead of using naphtha.
Remotely controlled undersea oil drilling ring	1970 - 1975	4,500	Remote-control oil drilling rigs for undersea use.
Sea water desalination and by-product recovery	1969 - 1977	7,000	Economical large-scale production of fresh water and economical by-product recovery technology.
Electric car	1971 - 1977	5,700	Various types of electric car to replace ordinary vehicles in urban areas.
Comprehensive automobile control technology	1971 - 1979	7,400	Integrated control technology with a view to relieving traffic congestion, reducing automobile pollution and traffic accidents, etc.
Pattern information processing system	1971 - 1980	22,100	Computer technology for the recognition and processing of pattern information such as characters, pictures, objects and speech.
Direct steelmaking process using high temperature reducing gas	1973 - 1980	14,000	Direct steelmaking technology aims at a closed system which uses the heat energy from a multi-purposes high temperature gas-cooled reactor in the steelmaking process.
Olefin production from heavy oil as raw material	1975 - 1981	14,200	Technology for manufacturing high-value-added olefin (commonly known as ethylene, propylene, etc.) using a high sulphur-content heavy oil fraction (so-called asphalt), which is difficult to desulphurize, as the raw material.
Jet engines for aircraft	1971 - 1975 (1st phase)	6,900	Research and development of large scale turbofan engine designed for the use in commercial transports in the 1980s.
	1976 - 1981 (2nd phase)	12,900	
Resource recovery technology	1973 - 1975 (1st phase)	1,300	R&D on technical systems for the disposal of solid urban waste, centered on resource recycling with a view to promoting the efficient utilization of resources and facilitating the smooth application of solid urban waste treatment.
	1976 - 1982 (2nd phase)	11,400	

TABLE A.2. (contd)

Project Name	Period (FY)	Total Expenditure	Outline of Project
Flexible manufacturing system complex provided with laser	1977 - 1984	13,500	R&D on new, automatic, integrated, production systems that are flexible and provide quick through-put in the manufacture of small batches of machine components.
Subseas oil production system	1978 - 1984	17,200	R&D on an efficient system for subsea oil production which would be applicable to the continental shelf and slope surrounding Japan and to deep sea oil field.
Optical measurement and control system	1979 - 1985	15,700	R&D on an optical measurement and control system permitting massive volume of data, including picture images, to be measured and controlled in adverse environments.
C_1 chemical technology	1980 - 1986	10,500	R&D on a technology for the economic production of basic chemicals from C_1 compounds like carbon monoxide from alternative carbon sources such as coal, natural gas, and tar sand.
Observation system for earth resources satellite-1	1984 - 1988	10,900	R&D on an observation system for earth resources satellite-1 (ERS-1) which is expected to realize effective and economical acquisition of data on the world's natural resources such as oil and other resources from space.

TABLE A.3. Potential Applications for Structural Ceramics [Japan Export Trade Organization (JETRO) 1983]

Fields of Application	Parts	Demands and Characteristics
Gas Turbine Engine	Blade	Oxidation resistivity, thermal shock resistivity, high-temperature strength
	Rotors	Strength, creep rupture resistivity
	Stators, shroudings, combustion cylinders	Oxidation resistivity, high-temperature strength, thermal shock resistivity
	Bearings	Wear resistivity, tenacity
Diesel Engine	Pistons	Oxidation resistivity, high strength, low thermal conductivity, thermal shock resistivity
	Cylinders	Wear resistivity, strength, low heat conductivity
	Preheating chambers, nozzles	Thermal shock resistivity, oxidation resistivity, corrosion resistivity
	Valves	Strength, mechanical shock resistivity, corrosion resistivity, wear resistivity
	Tappets, cams	Wear resistivity
	Turbochargers, rotors	High-temperature strength, thermal shock resistivity, oxidation resistivity
	Bearings	Wear resistivity
Molten Metal Structural Members		
Aluminum Diecasts, Iron Diecasts	Pistons, cylinders, etc., diecast pump parts	High-temperature strength, molten state corrosion, wear resistivity
Molten Metal Claddings	Guide rollers, dies	Molten state corrosion and wear resistivity
Papermaking Machine	Suction boxes, wet box covers, felt boxes	Wear resistivity
Tools	Cutting tips, rock drills, etc.	High strength, tenacity, wear resistivity
Chemical Equipment	Pump parts, valve balls, etc.	Corrosion resistivity, wear resistivity
Heat Resistant Jigs	High-temperature testing jigs, heat treatment holding fixtures, etc.	High-temperature strength, oxidation resistivity, thermal shock resistivity

TABLE A.4. Technical Goals of the Fine Ceramics R&D Project (JETRO 1987)

Classification	Condition	Objective	Values
High-Strength Materials	After 1000 h holding at 1200°C in air	Average tensile strength at 1200°C	$\bar{\sigma} \geq 30$ Kg/mm^2
		Reliability (Weibull modulus)	$m \geq 20$
		Creep rupture strength after 1000 h continuous loading at 1200°C in air	$\bar{\sigma} \geq 10$ dg/mm^2
High Corrosion-Resistant Materials	After 1000 h holding at 1300°C in air	Average tensile strength at 1300°C	$\bar{\sigma} \geq 20$ kg/mm^2
		Corrosion resistance (weight gain)	$\Delta W \leq 1$ mg/cm^2
		Reliability (Weibull modulus)	$m \geq 20$
High Wear-Resistant Materials	After 1000 h holding at 800°C in air	Average tensile strength at 800°C	$\bar{\sigma} \geq 50$ kg/mm^2
		Reliability (Weibull modulus)	$m \geq 22$
	As prepared	Wear resistance at R.T.	$\Delta W \leq 10^{-8}$ mm^3/kg·mm
		Surface flatness	$R_{max} \leq 2$ µm

TABLE A.5. Representative Characteristics of Powders Developed (Nagahiro 1986)

	True Density (g/cm^3)	Specific Surface Area (m^2/g)	Mean Particle Diameter (µm)	α-Phase Content (in Si_3N_4) (%)	Purity (%)	Metallic Impurities (ppm) Total	Fe	Ca	Al	Total Oxygen Content (%)
Si_3N_4 Reduction of Silica	3.13_6	6.85	1.07	97.8	98.47	123	54	3	15	0.82
Si_3N_4 Silicon Nitridation	3.12	20.7	0.50	93.1	98.3	283	31	14	144	1.20
Si_3N_4 Gaseous Reaction	3.19	7.0	0.65	95.4	99.3	34	4	<1	5	0.42
SIC(β) Silicon Carburization	3.18_9	14.9	0.71	--	98.72	236	48	2	17	0.59

TABLE A.6. Representative Properties of Sintered Specimens (Nagahiro 1986)[a]

Category	High Strength		High Corrosion Resistance		High Wear Resistance	
Circumvent temperature (°C)	1200		1300		800	
Material	Si_3N_4	SiC	Si_3N_4	SiC	Si_3N_4	Sic
Reliability (Weibull modulus)	32.9 (>20)	20.3 (>20)	23.0 (>20)	18.6 (>20)	17.4 (>22)	19.4 (>22)
Mean tensile strength (converted from bending strength)	55.0 (>30)	39.5 (>30)	48.4 (>20)	32.6 (>20)	67.0 (>50)	59.1 (>50)
	Creep Rupture (after 1000 hr kgf/mm^2)		Oxidation Weight Gain (after 1000 hr mg/cm^2)		Specific Wear Amount (mm^3/kgf mm)	
Specific properties	No rupture (>10)	No rupture (>10)	0.32 (<1)	1.0 + -0.1 (<1)	7.5×10^{-9} (10^{-8})	6.0×10^{-9} (10^{-8})
					Surface Flatness (Rmax. µm)	
					0.8 (<2)	0.51 (<2)

(a) Figure in parens () are the target values.

TABLE A.7. Composite Project Goals in 1987 and Achievements in 1989 (Research and Development Institute of Metals and Composites for Future Industries 1989)

1987 Goals	Tensile Strength at Room Temperature (kgf/mm^2)	90% Tensile Strength at Elevated Temperature (kgf/mm^2)	Reliability
Polymer Matrix Composite (PMC)	250	21 Reliability	
Polymer Matrix Composite (PMC)	250	210 (250°C)	90%
Epoxy	264	246 (200°C)	--
Polymide	250	245 (250°C)	--
Polyphenylquinoxaline	253	227 (250°C)	--
Metal Matrix Composite (MMC)	150	135 (450°C)	90%
PMC	--	240 (250°C)	--
MMC	--	150 (450°C)	--
Aluminum-carbon wire	155	147 (450°C)	--
Aluminum-carbide wire	170	170 (450°C)	--
Aluminum-carbide-Ti-4V	172	172 (450°C)	--

APPENDIX B

KEY TECHNOLOGY CENTER - PROJECT INFORMATION

APPENDIX B

KEY TECHNOLOGY CENTER - PROJECT INFORMATION

In this appendix and detailed project information obtained during the study on the Key Technology Center (KTC) Program is presented.

The KTC projects supported in FY 1985 to 1988 are listed in Tables B.1 through B.4, respectively. Tables B.5 through B.8 list the KTC R&D projects that received loans in FY 1985, 1986, 1987, and 1988, respectively. General areas within which projects are supported include new materials, biochemistry, advanced manufacturing, electronics, radio and satellite communications, transmission, image communication, and networking.

TABLE B.1. Investment Projects Started in FY 1985 (data obtained in interview with KTC)

	Amount of Investment (million yen) FY 1985	FY 1986
New Material		
• Research and development of nonoxide glasses	35	105
• Development of high performance surface materials	35	400
Biochemistry		
• Research related to establishing production method of active peptide through gene manipulation and chemical synthesis and development of active screening method	30	200
• Protein engineering	200	800
Electronics		
• Research and development of the second-generation optoelectronic integrated circuit	100	635
• Research of basic instrumentation technology for coherent light communication	90	370
• Research of advanced information processing-type image information system	80	520
• Research and development of technology to use synchrotron-radiated light	150	750
• Electronic dictionary for natural language processing	200	600
New Media Community		
• Development of wholesale residential community information system (Takasaki City)	5	145
Other		
• Overall research of space environment use	75	475
Man-machine Interface		
• Basic research of automatic translation telephone	210	1,270
• Basic research of intellectual communication system	110	1,110
• Basic research of associative stored information communication system that uses personal computer to enable vocal input/output	20	31

TABLE B.1. (contd)

	Amount of Investment (million yen)	
	FY 1985	FY 1986
FY1986Basic Information Communication		
• Human scientific research of audio visual mechanism	130	1,230
Switching Network		
• Development of intrabuilding integrated information communication system	64	135
• Research and development of basic technologies to establish common backup communication network	105	210
Radio and Satellite Communications		
• Basic research of photoelectric wave communication	105	865
Teletopia		
• Test and research related to Kumamoto information guide system (Kumamoto and other cities)	10	--
• Test and research related to area information system that stimulates hometown (Matsue City)	70	50
• Test and research related to integrated information system in Suwa wide-area teletopia (Suwa and other cities)	70	30
• Test and research related to Yamaguchi triangle teletopia area information communication system (Yamaguchi and other cities)	40	5
• Test and research related to INF-integrated information system (Fukushima City)	20	10
• Test and research related to technologies to Kureme teletopia area information communication system (Kurume City)	30	37
• Test and research related to Kagoshima videotex system (Kagoshima City)	16	17
TOTAL	2,000	10,000

TABLE B.2. Investment Projects Started in FY 1986 (data obtained in interview with KTC)

	Amount of Investment (million yen)
New Material	
• Research and development of production technology of high-performance ceramics with controlled colloidal solution used as a precursor	140
• Research and development related to bioactive material	110
Biochemistry	
• Research and development of useful substance production technology by engineering use of plant cells	270
Machine	
• Research and development of advanced combustion engineering	123
• Research and development of ATP propulsion system	450
• Research and development of intellectualized food processing technology	112
Communication process	
• Research and development of telematique library system	340
• Research and development of conditional access technology	120
Radio and Satellite Communication	
• Research and development of static platform communication and broadcasting satellite technologies	350
Transmission	
• Research and development of high-speed processing architecture for digital moving image communication system	155
New Media Community	
• Research and development of city health and medical information system	45

TABLE B.2. (contd)

	Amount of Investment (million yen)
Teletopia	
• Research and development of Fukuoka center city community formation system	58
• Research and development of refreshing Kitakyushu district life information communication system	24
• Research and development of new Imari area information system	20
• Research and development of Hachioji area information system for creating heart-warming city life	30
• Research and development of SSN base city traffic system adaptation system (Niigata)	18
• Research and development of Gobo and Tanabe wide area teletopia area information communication system	10
• Research and development of integrated information system in the wide area of Yonezawa City	32
• Research and development of Ueda area business information system	15
• Research and development of Hida Takayama tourism and business promotion system	30
• Research and development of Oita City and Beppu City teletopia area information communication system	9
• Research and development of Okayama local information offering system	39
TOTAL	2,500

TABLE B.3. Investment Projects Started in FY 1987 (data obtained in interview with KTC)

	Investment (million yen)
New Materials	
• Partially solidified manufacturing process	105
New Materials/New Devices	
• Solid fabric composite materials	49
Electronics	
• Improving the level of AI system languages	95
• Amorphous magnetic materials and electronic devices	77
New Media Community	
• Information system for the promotion of small and medium enterprises (Hiroshima City)	55
• Information system to promote regional industry (Nishiwaki City)	90
• Distribution for a wide area network (Kumamoto City)	49
Communication Management	
• Basic studies of low power high speed communication	45
Network	
• Digital signal connection technology for a CATV network	160
• Development of a new language for communication between computers in an office system	135
Telecommunication	
• Remote inspection control system using millimeter waves	120
Teletopia	
• Tottori regional activity information system	7
• Sedai community information system	20
• Yokohama image information system	20
• Sapporo "snowtopia"	13
TOTAL	1,040

TABLE B.4. Investment Projects Started in FY 1988 (data obtained in interview with KTC)

	1988 Investment (million yen)
New Materials	
• High strength alloy (Al-Li alloy) R&D	90
Electronics	
• Fundamental research of large-surface area circuit elements	200
Telecommunications	
• Experimental research of technology for high power satellite telecommunications	77
Image Processing	
• Experimental research of a high quality high vision image display system	258
New Media Communities	
• Research and development of an advanced information system for the fashion industry (Gifu City)	19
• Promotion of the research and development of a systems industry information system (Okayama City)	16
• Research and development of an overall information system to promote small- and medium-sized industries (Tokushima City)	25
• Research and development of an information system to promote regional trade (Himeji City)	15
TOTAL	700

TABLE B.5. KTC Loan Projects Started in FY 1985 (data obtained in interview with KTC)

	Amount of Loan (million yen) FY 1985	FY 1986
New Material		
• Research of functional super fines of high-melting point metal	15	53
• Research of high-strength mullite engineering ceramics	55	106
• Research of application of fine ceramics to biotechnologies	6	100
• Research of catalytic system to convert heavy oil into light oil	34	99
• Research of composite materials of tough aluminum alloy using viscous casting method	67	47
• Research of application of new materials to automobile tires	28	20
• Research of technologies to separate and use coal tar ingredients	31	140
• Research of refining niobium and producing niobium ingot	15	73
• Research of new IPN composite materials	12	80
• Research of technologies to produce high-performance pitch carbon fiber	80	103
Biochemistry		
• Research of basic technologies to produce and use oils and fats, including gamma linoleic acid	83	179
• Research of effective use of chitin as a new material for bioindustry	14	40
• Research of mass cultivation method of anaerobic bacteria, especially butyric acid bacteria	28	28
• Research of bioprocess related to manufacturing method of high-function chemical products	37	46
• Research of technologies to extract and use protein A	15	18

TABLE B.5. (contd)

	Amount of Loan (million yen)	
	FY 1985	FY 1986
• Research of composition of chitin and collagen	10	10
Machine		
• Research of triaxial accelerometer	2	8
• Research of super-cleanliness air cleaning system	19	15
• Research of automated assembly of aircraft frame using robots	2	7
• Research of technologies to configure super-precision work space	11	70
• Research of shape of variable geometry amphibian aircraft	3	14
Electronics		
• Research of sensor for machine tools and robots	48	--
• Research of three-dimensional visual system, including functions applicable to automatic selection and assembly	21	21
• Research of special-purpose computer for logic simulation use	3	107
• Research of measurement method of gear tooth surface and free curved shape	39	129
• Research of high-performance environmental instrumentation sensor	14	62
• Research of high-quality III-V thin film using metal organic chemical vapor deposition (MOCVD) method	43	80
• Research of superheat-resisting temperature sensing fiber	3	41
• Research of super high-precision distance measuring system	100	46
• Research of technologies to create new thin film using plasma	13	90

TABLE B.5. (contd)

	Amount of Loan (million yen)	
	FY 1985	FY 1986
• Research of active optical fiber	14	215
• Research of digital map display	16	37
• Research of high-precision superconducting magnet	57	62
• Research of substrates for microwave IC requiring less power consumption and packaging method of circuits	62	79
Radio and Satellite Communication		
• Research of radio wave absorbers to handle disagreeable visibility	40	67
• Research of high-performance and high-frequency filter	14	90
• Research of antenna multiplexor technologies	2	13
• Research of small-sized and high-performance Ku-Band transmission and reception system	12	27
• Research of high-performance microwave oscillator	28	55
• Research of integrated mobile radio communication technologies	32	31
• Research of plane antenna for direction finding	10	15
• Research of technologies of simple earth station for satellite communication, automatic tracking of satellites, and means of communication, automatic tracking of satellites, and means of communication secrecy	11	50
• Research of data broadcasting system	3	30
• Research of mobile antenna system for satellite communication	16	56
Transmission		
• Research of digital optical space transmission system	22	32

TABLE B.5. (contd)

	Amount of Loan (million yen)	
	FY 1985	FY 1986
• Research of composite-type optical CATV transmission system	5	45
• Research of optical fiber for coherent communication	106	66
• Research of automatic communication cable expansion system	1	9
• Research of inter-terminal communication system via CATY	30	71
• Research of next-generation submarine cable communication system	2	244
• Research of higher-performance and lower-cost multicomponent fibers	39	85
Image Communication		
• Research of high-definition television-related technologies	15	83
• Research of technologies to improve telecasting picture quality	109	266
• Research of next-generation moving image-bandwidth compression system	26	204
Network and Other		
• Research of digital distribution system for moving image signal using optical fiber	50	270
• Research of small and high-performance hydrogen maser	7	30
• Research of technologies to use map database transmit graphic data	200	200
• Research of total communication network system for a ship	1	6
• Research of communication support system	200	168
• Research of integrated network control system	19	12
TOTAL	2,000	4,450

TABLE B.6. KTC Loan Projects Started in FY 1986 (data obtained in interview with KTC)

	Amount of loan (million yen)
New Material	
• Research of ceramics welding technology using electric discharge welding method	114
• Research of new method to produce aramid fiber materials	48
• Research of high-performance FRP pipe using filament winding method	129
• Research of electrolytic production of special metal foil	28
Biochemistry	
• Research of enzymatic synthesis of fluoroamino acid	57
Machine	
• Research of small-sized and high-performance gas turbine	34
• Research lubricating mechanism and technology under high surface pressure (for machines installed beneath the sea that do not destroy the biological environment)	32
Electronics	
• Research of high-speed processing system of multichannel and weakest signal	40
• Research of magneto-optics element materials	14
• Research of expert system for analogue circuit design	12
• Research of high-performance thermoelectric module	36
• Research of application technology of 0.2 μm electronic device	81
Communication Processing	
• Research of high-precision distance measuring system using satellite	30
• Research of architecture of distributed proc-cessor supporting communication protocol	8

TABLE B.6. (contd)

	Amount of loan (million yen)
• Research of communication control technology for VAN using independent stored information method	32
Network	
• Research of high-security network configuration technology	9
• Research of superhigh-speed multiple line switching network communication processing system	119
• Research of CATV network system using satellite	58
Radio Communication	
• Research of larger-capacity MCA system	47
• Research of portable data terminal transmission system	25
• Research of high-efficiency terminal-type wideband radio system using scan beam antenna	6
• Research of small-capacity data distribution and collection satellite communication technology	70
• Research of high-speed and high-sensitivity electromagnetic wave sensing system	11
• Research of dielectric waveguide application technology	13
• Research of new satellite communication system via all solid-state small earth stations	72
• Research of quantitative measurement of noise jamming radio wave	42
• Research of earth station technology for mobile radio communication using satellite	13
• Research of high-performance satellite transmission and reception system technology using Gregorian antenna	50
• Research of high-speed radio polling system for identifying of personnel	4

TABLE B.6. (contd)

	Amount of loan (million yen)
Picture and Transmission	
• Research of high-speed digital transmission and storage system of high-definition and variable-density still picture	16
TOTAL	1,250

TABLE B.7. KTC Loan Projects Started in FY 1987 (data obtained in interview with KTC)

	1987 Investment (million yen)
New Materials	
• Multicrystalline diamond manufacturing technique	21
• Magnetic manufacturing process using ultrafast cooling,	59
Biotechnology	
• Metallic enzymes for recombinant DNA technology	75
Machinery	
• Hydrodynamic analysis system for increasing the performance of machinery designs and engineering plant designs	10
• High-efficiency power and speed transformation machinery	50
Electronics	
• High accuracy light sensing device using super-conductivity	21
• Low current-driven EL display	57
• High heat transfer metallized aluminum	31
• Infrared image fiber sensor	24
• Color filter for clear liquid large-scale flat displays	27
Communication Management	
• High reliability technologies for an open network system	11
• Dispersed file communication system in a multimedia operation environment	20
Network	
• High-speed composite exchange system for a distributed work station	20
• Network management support integration technology	23

TABLE B.7. (contd)

	1987 Investment (million yen)
• International data storage management system using packet exchange	8
Telecommunications	
• Microwave communication control slot array antenna system	47
• Ka-band high-reliability, high-efficiency satellite communication	62
• Completely automatic measurement of barriers to unused radiowaves on the open side	15
• SHF EHF-band telecommunication conversion technology	30
• Small-scale telecommunication system using long wavelengths	35
• A system to measure radiowave interference for a quiet electric environment	16
• Basic technology for a satellite communication phased array system	11
• A millimeter wave radar system for automobiles using high-speed expressways	15
• Mobile land automatic satellite broadcast reception system	6
• High-altitude satellite communication and measurement composite terminals	3
Display and Transmission	
• Increasing the Efficiency of optional character information coding and transmission technology	12
• Next-generation display communication terminals	26
• A method for multiple lightwave communication	12
• Ultra-flexible direct display communication system	3
TOTAL	750

TABLE B.8. KTC Loan Projects Started in FY 1988 (data obtained in interview with KTC)

	1987 Investment (million yen)
New Materials	
• Diamond grindstone and metal for high hardness ceramics	5
• High performance structural materials for the space environment	7
• Ultra-high temperature, high-efficiency injection molding technology	18
• Ultra-heat-resistant composite ceramics for use in extreme environments	4
Biotechnology	
• Basic technologies for the use of macrophage clotting factor (MCF)	42
Machinery	
• High-performance, non-circular processing technology	79
• High-efficiency, high-precision, conversion management technology for blending special printing characteristics in high-density regions	6
• Technologies exploiting centrifugal force for measuring and analyzing deep earth	10
Electronics	
• Large-screen projection system using a high-precision active matrix LCD	15
• High-function "human office desk" combining "human interface technology"	40
• Large-area glass board employing hetro-epitaxy	11
• Variable-level even controls for an interconnected composite construction board	13
Communication Management	
• Development of an ultra-high-speed communication analogue-digital control system	42

TABLE B.8. (contd)

	1987 Investment (million yen)
Network	
• Mutual conversion directory for a numbered network system	41
• Distribution management technology for a general systems network electronic mail system	28
• ultra-wide region multiple-level vertically connected network for CATV	6
• Technology to prevent barriers from forming at the beginning and end of the network	12
Telecommunications	
• Ultra-small microwave directional antenna for a portable receiver	25
• Radar system for inspecting the soil	16
• Radio wave interference protection for a multiple-purpose shield antenna	9
Display and Transmission	
• Digital storage and transmission technology for a large-screen display for broadcasting	56
• Basic technology for extra-long wavelength long-distance light transmission	15
TOTAL	500

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