International Technology Research Institute
World Technology (WTEC) Division

WTEC Panel Report on

Japan's Key Technology Center Program

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WTEC Panel on Japan's Key Technology Center Program

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WTEC at Loyola College (previously known as the Japanese Technology Evaluation Center, JTEC) provides assessments of foreign research and development in selected technologies under a cooperative agreement with the National Science Foundation (NSF). Loyola's International Technology Research Institute (ITRI), R.D. Shelton, Director, is the umbrella organization for WTEC. Elbert Marsh, Deputy Assistant Director for Engineering at NSF's Engineering Directorate, is NSF Program Director for WTEC. Several other U.S. government agencies provide support for the program through NSF.

WTEC's mission is to inform U.S. scientists, engineers, and policymakers of global trends in science and technology in a manner that is timely, credible, relevant, efficient, and useful. WTEC's role is central to the government's effort to measure its performance in science and technology. Panels of typically six technical experts conduct WTEC assessments. Panelists are leading authorities in their field, technically active, and knowledgeable about U.S. and foreign research programs. As part of the assessment process, panels visit and carry out extensive discussions with foreign scientists and engineers in their labs.

The ITRI staff at Loyola College helps select topics, recruits expert panelists, arranges study visits to foreign laboratories, organizes workshop presentations, and finally, edits and disseminates the final reports.

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FINAL REPORT

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ABSTRACT

This report reviews Japan's Key Technology Center Program (JKTC) with the objectives of comparing JKTC to U.S. programs, assessing the potential for initiating similar programs in the United States, and identifying opportunities for enhanced collaboration between the United States and Japan. The panel found that differences in U.S. and Japanese economic and technological development policies would prevent a practical implementation of the JKTC model in the United States. However, selected aspects of the JKTC model hold potential for the design of U.S. technology development programs. A notable feature of the JKTC model is the latitude allowed firms in the choice of research trajectories and project management activities once they have received a JKTC award. Another appealing feature of the JKTC program is that all researchers work under one management chain and get paid from the new company. This links the staff members together, making it easier for them to form teams and work together.

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Sincerely,

Geoffrey M. Holdridge
WTEC Division Director and ITRI Series Editor

The ISBN number for this report is 1-883712-54-8. This report is distributed by the National Technical Information Service (NTIS) of the U.S. Department of Commerce as NTIS report PB99-142424. A list of available JTEC/WTEC reports and information on ordering them from NTIS is included on the inside back cover of this report.

FOREWORD

Timely information on scientific and engineering developments occurring in laboratories around the world provides a critical input to maintaining the economic and technological strength of the United States. Moreover, sharing this information quickly with other countries can greatly enhance the productivity of scientists and engineers. These are some of the reasons why the National Science Foundation (NSF) has been involved in funding science and technology assessments comparing the United States and foreign countries since the early 1980s. A substantial number of these studies have been conducted by the World Technology Evaluation Center (WTEC), managed by Loyola College through a cooperative agreement with NSF.

The purpose of the WTEC activity is to assess research and development efforts in other countries in specific areas of technology, to compare these efforts and their results to U.S. research in the same areas, and to identify opportunities for international collaboration in precompetitive research.

Many U.S. organizations support substantial data gathering and analysis efforts focusing on nations such as Japan. But often the results of these studies are not widely available. At the same time, government and privately sponsored studies that are in the public domain tend to be “input” studies. They enumerate inputs to the research and development process, such as monetary expenditures, personnel data, and facilities, but do not provide an assessment of the quality or quantity of the outputs obtained. Studies of the outputs of the research and development process are more difficult to perform because they require a subjective analysis performed by individuals who are experts in the relevant scientific and technical fields. The NSF staff includes professionals with expertise in a wide range of disciplines. These individuals provide the expertise needed to assemble panels of experts who can perform competent, unbiased reviews of research and development activities. Specific technologies such as telecommunications, biotechnology, and nanotechnology are selected for study by government agencies that have an interest in obtaining the results of an assessment and are able to contribute to its funding. A typical WTEC assessment is sponsored by several agencies.

In the first few years of this activity, most of the studies focused on Japan, reflecting interest in that nation’s growing economic prowess. Then, the program was called JTEC (Japanese Technology Evaluation Center). Beginning in 1990, we began to broaden the geographic focus of the studies. As interest in the European Community (now the European Union) grew, we added Europe as an area of study. With the breakup of the former Soviet Union, we began organizing visits to previously restricted research sites opening up there. Most recently, studies have begun to focus also on emerging science and technology capabilities in Asian countries such as the People’s Republic of China.

In the past several years, we also have begun to substantially expand our efforts to disseminate information. Attendance at WTEC workshops (in which panels present preliminary findings) has increased, especially industry participation. Representatives of U.S. industry now routinely number 50% or more of the total attendance, with a broad cross-section of government and academic representatives making up the remainder. Publications by WTEC panel members based on our studies have increased, as have the number of presentations by panelists at professional society meetings.

The WTEC program will continue to evolve in response to changing conditions. New global information networks and electronic information management systems provide opportunities to improve both the content and timeliness of WTEC reports. We are now disseminating the results of WTEC studies via the Internet. Twenty-seven of the most recent WTEC final reports are now available on the World Wide Web (http://itri.loyola.edu) or via anonymous FTP (ftp.wtec.loyola.edu/pub/). Viewgraphs from several recent workshops are also on the Web server.

As we seek to refine the WTEC activity, improving the methodology and enhancing the impact, program organizers and participants will continue to operate from the same basic premise that has been behind the program from its inception, i.e., improved awareness of international developments can significantly enhance the scope and effectiveness of international collaboration and thus benefit the United States and all its international partners in collaborative research and development efforts.

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EXECUTIVE SUMMARY

INTRODUCTION

The Japan Key Technology Center (JKTC) was established in 1985 by the Japanese government to promote research and development (R&D) in key technology areas in cooperation with the private sector. It is funded by the government's Special Account for Industrial Investment. Funds for JKTC are derived from the Japanese government's equity holdings and annual dividends in the privatized Nippon Telegraph and Telephone Corporation (NTT). The level of government funding for JKTC has been relatively constant since about 1990: no less than about ¥20 billion/year for direct investment and ¥6.0 billion/year for loans; or a total of ¥26.0 billion (approximately $235 million per year).

JKTC's primary role is to help established firms establish new R&D firms that will develop new technologies in the selected areas of materials, information technology, biotechnology, and related physical sciences. JKTC works with private companies: investing in joint ventures with some companies, and providing loans for R&D to other companies. Since its beginning, JKTC has supported over 360 R&D projects through investment and financing. JKTC also arranges joint research with national institutes, invites foreign researchers to work in Japan, and disseminates research data that is related to these key technologies.

In early 1998 the Defense Advanced Research Projects Agency (DARPA), the Department of Commerce (DOC) and the National Science Foundation (NSF) of the United States government asked the World Technology (WTEC) Division of the International Technology Research Institute (ITRI) to evaluate the JKTC program. The objectives of this WTEC panel were to compare JKTC to U.S. programs, assess the potential for initiating similar programs in the United States, and identify opportunities for enhanced collaboration between the United States and Japan. This report documents the findings of the WTEC panel.

FINDINGS AND CONCLUSIONS

This project reviewed Japan's Key Technology Center program from two perspectives:

1. its relevance to U.S. science and technology policy as a model of government–industry partnerships to foster technological innovation
2. the international status of research in information technology, biotechnology, and physical sciences being conducted in JKTC-supported firms

Although forming conclusions on the applicability of the JKTC model to the U.S. setting, the report comments on the strengths and weaknesses of the JKTC model. It is not presented as an evaluation of JKTC in the context of the Japan's science, technology, and economic objectives. Fundamental reconceptualization of roles and relationships between and among the government, industry and universities, and between the national and regional governments, is underway in Japan. This reconceptualization has the potential to considerably change the missions and activities of many Japanese science and technology programs, including those conducted by JKTC.

APPLICABILITY OF JAPAN'S KEY TECHNOLOGY CENTER PROGRAM TO THE UNITED STATES

In an era dominated by global competition in high technology goods and services, widespread beliefs that scientific research can serve as the basis for "industry-creating" technologies and that first-mover advantages enable firms and nations to gain significant technological and economic advantages from being first (or of not falling further behind other leaders), the U.S. and Japan, as well as other industrialized nations, have engaged in systematic, large-scale support of commercially oriented technology. Beyond these generic considerations, the specific design of the JKTC program reflects specific historic events and policy objectives in Japan. Cited frequently by Japanese officials and industrial representatives as factors that influenced the design and operation of the JKTC program were the following:

- The opportunity created by the privatization of Nippon Telegraph and Telephone (NTT) to channel part of the government's revenues into research and development activities. This was a particularly appealing prospect in a period of constrained national budgets.
- Support for continuing level of basic research which might be reduced due to the privatization of NTT. The fear was that a private NTT might reduce the level of research thus hurting Japan's ability to compete effectively in these areas of research.
- Japan's desire to respond to international criticism that it was a "free rider" on investments by the U.S. and European countries in basic research.
- The belief that Japan's venture capital markets were inadequate to support start-up initiatives in research in selected technological areas.

Few of these specific factors hold in the United States. The U.S. national innovation system is significantly different that of Japan in several key respects. Federal funding in the United States of R&D in the key technology areas identified by JKTC (e.g., information technology, molecular and cell biology) has either increased sharply or is proposed to increase sizably in recent years. The U.S. remains the unquestioned leader in basic research in many, albeit not all, scientific areas including those targeted by JKTC. As a matter of long-standing and successful policies, federally funded basic research in the United States is primarily conducted in universities and government laboratories with relatively little channeled through private firms. The U.S. venture capital market is the largest in the world.

Several variants of the JKTC program also exist already in the United States to encourage private sector R&D in selected technologies. These include the Department of Commerce's Advanced Technology Program, NSF's Engineering Research Centers Program, and the Department of Defense's Advanced Research Projects program. SEMATECH is probably the closest U.S. program to JKTC, in that the U.S. government, through the Defense Advanced Research Projects Agency (DARPA), funded a private company with additional funding provided by the private sector. But unlike JKTC projects, SEMATECH was allowed to continue and in fact encouraged to sustain itself after the 5 year funding from DARPA ended. Moreover, several features of the JKTC model are inconsistent with U.S. economic and technology development policies. These include the potential for de facto cartelization of emerging technological areas through control by member firms of key patents and the tacit influence of government agencies on the composition of consortium members.

Selected aspects of the JKTC model would appear, however, to hold potential for the design of U.S. technology development programs. A notable feature of the JKTC model is the latitude allowed firms in the choice of research trajectories and project management activities once they have received a JKTC award. Except for the third year interim review, which, according to statements made to the WTEC panel, appears to have a limited impact on research priorities or activities, firms participating in JKTC are given a degree of latitude that probably extends beyond that found in similar programs in the United States. The impact of this latitude on the level of technological advance obtained for the government's investment in the program, however, is more difficult to determine.

Another appealing feature of the JKTC program is that all researchers work under one management chain and get paid from the new company.[1] This is unique, since in most U.S. programs, industry and academic or laboratory personnel continue to be paid by their own organizations, thus keeping strong loyalty ties to the parent organizations. Linking staff together makes it easier for them to form teams and work together.

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[1] One host commented that personnel transferred from government laboratories get paid direct from the new company; those transferred from private companies may continue to receive salary from their home companies. The new company can then reimburse the home companies on a contractual basis.

The panel finds little novelty in the procedures, criteria, or methodologies used by JKTC to evaluate proposals or to assess the impacts of JKTC-supported firms relative to U.S. program and project evaluation practices. The principal methods used by JKTC are publications, patents, and license and related income accruing to JKTC from these patents. Scientific publications are treated as a measure of the scientific merit of the research being undertaken by JKTC firms; patents are treated as a measure of the commercial potential of technologies developed by JKTC firms; licensing income is treated as the primary and seemingly exclusive measure of the economic impact of the research. (JKTC and MITI officials reported modest levels of license income from patents originating in JKTC-sponsored research. Concern about the level of license income appears to underline comments by some respondents that MITI was placing increased pressure on firms to increase the number of patents they generated.)

JKTC technical review panels are comprised of academic specialists who assist in evaluating proposals from firms for JKTC support. The impact of these panels on the selection of grantees is difficult to isolate. No data were provided to the WTEC panel on the ratio of successful to unsuccessful applications, although it was noted that the credit crunch in Japan has led a larger number of firms to turn to JKTC essentially as a source of low-cost credit. More importantly, ratios of successful to total applications have limited meaning in the larger government–industry context within which JKTC functions. As reported both by government agencies and firms, considerable prior consultation exists between firms seeking to apply to JKTC and MITI bureaus. This consultation includes not only the generic area of technology to be pursued by the new firm, but also in some cases, the composition of firms to be included as applicants. Thus, the likelihood of a fit between the consortium's objectives and JKTC's selection criteria is increased, as is the likelihood that a proposal will be funded.

The WTEC panel received different assessments of the importance of the third year reviews. The reviews were seen by some agency officials as important interim assessments of research activities, leading, as required, to changes in research trajectories and increases or decreases, as recommended, in JKTC funding. Other respondents, including some firms, reported limited impact from these third year reviews, with some suggestions that they were more symbolic than substantive.

A distinguishing feature in the JKTC third year review process is that it is bifurcated into a technical and a business review. Review of the firm's business plan is conducted separately, usually by a third-party "think tank" organization. The panelists did not meet with any reviewers of the business plans and so cannot comment on the procedures or criteria employed in this segment of the review. Responses by some of the JKTC firms indicated that they attached limited weight to this review, considering business plans to be an internal matter.

The emphasis on patents and license income by JKTC and other Japanese ministries as measures of the technological and economic outcomes of JKTC firms is not fully consistent with a building body of scholarly research in the United States and elsewhere that economically valuable knowledge from R&D is bundled and transferred in multiple channels other than patents. Studies, for example, of NSF and DOD cooperative R&D programs point to economic impacts in the form of personnel movements of and nonpatentable insights into new pathways or dead-ends. Indeed, in the panel's review, JKTC's existing criteria of publications and patents likely do not adequately record the benefits Japanese firms receive from the JKTC program. As reported in some site visits to firms, participation in a collaborative joint venture for a period of up to five years increases the knowledge of researchers who staff the JKTC-sponsored R&D firm. These researchers, for the most part, then return to their firms, where they may be conduits for new technologically relevant developments.

CHAPTER 1

INTRODUCTION

SCOPE OF REPORT

Japan's Key Technology Center (JKTC) program was established in 1985 by the Japanese government as a means of stimulating private sector research and development in three broad areas of technology. JKTC is a public policy tool designed to address issues of public support for research and development that are common to most market-oriented economies as well as to address policy issues specific to Japan's political, economic, and budgetary history since the early 1980s.

This report presents findings on the organization, strategies, activities, and impacts of the JKTC program, and its contributions to the standing of Japan's research activities in selected physical sciences, engineering disciplines, and life sciences technologies. Based on these findings, the report assesses the relevance of the JKTC program to policy formation and program management of related civilian technology programs in the United States.

Government support for the development of key technologies is frequent among industrialized nations. This support is typically provided to attain national imperatives—e.g., military technology—and national aspirations—e.g., space exploration. In an era of the increased importance of technological innovation as a source of economic growth, global competition, and shortened product cycles, government R&D funding also is provided to protect or enhance international economic competitiveness. This last objective provides a generic rationale for the support of domestic or civilian technologies, that is, those technologies that are primarily employed in the production of goods and services for civilian consumption, both domestic and foreign.

Sharing essentially similar objectives, nations differ in their innovation systems (Nelson 1993). They differ in the relative roles allotted or taken by the private sector, government, or other sponsors of the research that leads to technological innovation, in the choice of performers of this research (e.g., government research institutes, industrial R&D laboratories, universities), and in the institutional arrangements for transferring research from research performers to producers of goods and services. They differ too in as priority-setting processes and the importance assigned to evaluation. Among these differences, few are as important as the relative role of government as a sponsor of the development of key technologies, and relatedly, given the size of the government role, the mechanisms used by the government to support technological innovation.

JKTC projects represent a mode of funding collaborative research between the Japanese government and the private sector in which the government is an investment partner in creating new companies. This is in contrast to the typical U.S. model for government R&D funding, in which the government is the sponsor of research and development projects with industry providing cost sharing.

This report is based on site visits to JKTC, its parent organizations, the Ministry of International Trade and Industry (MITI), and the Ministry of Post and Telecommunication (MPT), to cognizant Japanese science and technology agencies, and to a cross section of industrial firms formed with JKTC support. It is also based on a review of documents provided by both agencies and firms, as well as a review of the WTEC panel's draft final report by the Japanese site visit hosts. These sources provide the basis for a general assessment of the workings and impacts of the JKTC program.

The assessment, however, refers to but only indirectly touches on cultural factors that pervade the organization and behavior of economic life. As Peter Temin has recently written, "Current Japanese economic culture . . . is the product both of long-standing Japanese ways of acting and thinking and of specific decisions made to solve specific historical problems" (Temin 1997). The relationships affected by these values range from the appropriate bounds of government involvement in developing civilian technologies (as well as the policy mechanisms used to support such development) to the mix of specific R&D allocation mechanisms, such as formula-based and peer-reviewed competitive proposals.

Data on several key variables and impacts that would facilitate comparison between Japanese and American practices either are not collected by JKTC or related agencies or were not accessible to the WTEC site visit team. Strong causal relationships between the terms of enabling legislation, formal, administrative arrangements, and final outcomes are thus difficult to formulate. Moreover, prior analysis of the workings of the Japanese economy, particularly of relationships between government agencies and the private sector, highlight the importance of informal, culturally rooted modes of decision making. Decision making practices are often not transparent and visible to external observers. In this recognition, the panel's views were supported by statements of representatives of Japanese government agencies and firms interviewed during the site visits, which frequently highlighted the importance of informal consultations and understandings.

The members of the WTEC panel recognize the limitations of extrapolating science and technology development policies from one socioeconomic system to another. They also are mindful of recent and pending government proposals to significantly restructure key elements of Japan's national science and innovation system. Both the gestating effects of recent changes, particularly those that have sought to strengthen the research and technology transfer capabilities of Japanese universities, and new proposals advanced since the date of the WTEC site visits may have an effect on the position of JKTC amid other science and technology programs. These developments could not be taken into account in the panel's assessment.

Still, as a long history of fact-finding commissions and reports attest, assessment of practices and experiences of major competitors is a basic feature of benchmarking. Constant scanning of the external environment to determine which approaches, if any, of others may be worthy of emulation or adaptation is a necessary part of remaining competitively vital.

The report is organized as follows: Chapter 1 is an introduction to the report. Chapter 2 describes the history and current organization of the Japan Key Technology Center program. Chapter 3 reviews the contributions of JKTC-funded activities to selected fields of physical sciences, biotechnology, and life sciences. Biographies of study participants are included in appendices A and B. Appendix C contains brief reports on each of the site visits conducted by the WTEC team in Japan. Appendix D is a list of projects supported under JKTC.

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CHAPTER 2

DESCRIPTION OF JAPAN KEY TECHNOLOGY CENTER

OVERVIEW/ORIGINS

The Japan Key Technology Center (*Kiban Gijutsu Kenkyu Sokushin Senta*) was established by the 102nd session of the National Diet on October 1, 1985, under the "Law for the Facilitation of Research on Fundamental Technologies." Its stated goal is to "facilitate experiments and research relating to fundamental technologies which are to be advanced by the private sector, and to devise measures for raising the basic technology level of the private sector with the purpose of maintaining a sound national economic growth and raising the national living standard while, at the same time, contributing to the progress of the world economy" (Law for the Facilitation of Research in Fundamental Technologies). The law further defines by what it means by "fundamental technology":

> The term 'fundamental technology', as used in this law, refers to the technologies relating to the mining industry, manufacturing industry, telecommunications industry, and broadcasting industry (including the cable broadcasting industry) as well as other technologies, which utilize radio waves in connection with electrical telecommunications under the jurisdiction of the Ministry of International Trade and Industry (MITI) and the Ministry of Posts and Telecommunication (MPT), and which are conceived to contribute immensely to consolidating the national economy and the foundation of the national living (Law for the Facilitation of Research in Fundamental Technologies).

The law designated both MPT and MITI as the "competent ministries in charge of JKTC." JKTC came into being with the privatization of Nippon Telegraph and Telephone (NTT) Corporation in April 1985. Though NTT was privatized, the Japanese government retained a share in it, and the dividends from these shares went to fund JKTC. Thus, JKTC was established to ensure that the technologies pursued by NTT were not lost due to NTT's privatization, stemming from a concern that emphasis on profit seeking in the new NTT would lead to a reduction in basic research.[1] The specific choice of the JKTC model as a mechanism for stimulating commercially oriented technological innovation also reflects the belief that venture capital markets were inadequate to support start-up initiatives in research in selected technological areas.[2]

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[1] Interestingly, JKTC came into being about one year after the breakup of the Bell System by the U.S. government. Though there was debate in the United States about the future of Bell Laboratories and its research (viewed by many as the premier U.S. research laboratory), no provision was made to prevent the inevitable decrease of support for research by the new, and much smaller company, AT&T, and its new research arm, AT&T Bell Laboratories.

[2] In discussions with JKTC representatives it was noted that there was little venture capital in Japan for "upstream activities," such as R&D start-ups. Venture capital is, however, said to be available for "downstream" activities to improve manufacturing capacity.

JKTC FINANCIAL RESOURCES

JKTC's annual budget for capital investment and loan services is about ¥28 billion, largely derived from the Japanese government's holdings of shares in NTT.[3] As indicated in Table 2.1, the annual budget for investment and loan services from 1990 through 1997 has stayed fairly constant at about ¥28 billion. Approximately 75% of JKTC's budget is used to support capital investment and 25% for loan services.

Table 2.1
Annual JKTC Budget for Capital Investment and Loan Services
(¥ millions)

Fiscal Year	Capital Investment	Loan Services	Total
FY1985	2,000	2,000	4,000
FY1986	12,500	5,700	18,200
FY1987	17,300	7,700	25,000
FY1988	19,200	7,000	26,200
FY1989	20,200	6,400	26,600
FY1990	21,700	6,300	28,000
FY1991	22,400	6,300	28,000
FY1992	22,000	6,500	28,500
FY1993	21,500	6,500	28,000
FY1994	20,900	7,200	28,100
FY1995	20,600	7,600	28,200
FY1996	20,000	8,500	28,500
FY1997	20,000	8,500	28,500
FY1998	NA	NA	

The dividends provided funding for the first set of four JKTC projects established under the umbrella of the Advanced Telecommunications Research (ATR) Institute situated in Kyoto, Japan. Subsequently, thirteen additional projects also were started up in 1985. In total, seven projects, including four from ATR, were in the area of telecommunications, and the remaining ten, including two in biotechnology, were in mining and industry. For a complete list of projects see Appendix D.

JKTC PROGRAMS

In order to promote R&D by the private sector in key technologies, the JKTC invests in joint R&D companies set up by private concerns and provides loans for R&D to private concerns. JKTC provides up to 70 percent of the needed R&D funds through loans and up to 70 percent through direct investment; the private sector firms provide the balance. From an economic perspective, JKTC support reduces the financial risks that firms face as they pursue technological advances. Since its establishment, JKTC has supported more then 400 investment, loan, and other projects.

JKTC also provides other services, such as coordinating joint research with national research institutes, inviting overseas researchers to Japan, disseminating valuable research data held by government affiliated bodies, and carrying out various surveys related to key technologies.

Firms seek JKTC funding to either help augment their own high risk research, or to pay for work not directly related to their mainstream products or services but of interest to some of their researchers. JKTC projects

[3] To provide a stable funding base for funding JKTC, interest from one-third of the shares held back by the government in the sale of NTT was used. Dividend income from these shares provides JKTC's core annual revenues (of ¥26 billion).

provide the freedom for researchers to pursue either higher academic degrees or unfettered (that is tied to the company's business line) research. Obtaining a PhD has become more fashionable for industrial researchers, and by joining a project, many researchers have this opportunity which they would not have if they stayed with the company. Some companies participate because of the prestige, and in some cases because of active encouragement from the Japanese government.

JKTC also provides an opportunity for corporate researchers to develop a network between companies. Lifetime employment being the norm in Japan, there is little sharing of ideas between companies. While this helps the companies keep "company secrets," it builds walls in Japan in a time when such walls are falling elsewhere due to globalization of industry. Due to this lack of personnel mobility in Japanese industry between companies, little interaction exists between the researchers. JKTC helps them develop relationships that continue beyond the projects. In the United States, this interaction occurs in part as a result of high turnover of personnel between companies.

Direct Investment Program

JKTC provides capital investment for two types of R&D projects, namely (a) fundamental research projects or comprehensive development projects (i.e., from applied research to practical applications) or (b) R&D projects targeted primarily at promoting the so-called "New Media Community" development programs. Typically, two or more companies jointly capitalize and establish a new company in the form of a joint stock limited partnership (*kabushiki-kaisha*) to implement the proposed R&D project.[4] Since its inception, JKTC has funded 109 investment projects. Forty-seven projects have been completed; 82 are ongoing.

The new legal entity created by JKTC and private sector support is a joint stock limited partnership not an "R&D" company. Although as a private firm the company could presumably move into production, JKTC reports no case of this development.[5]

As indicated in Table 2.2 below, JKTC provides up to 50% for capital investment (which takes the form of acquisition of shares in the company) in key technologies. In addition, JKTC provides up to 70% of the capital required for projects aimed at fundamental or comprehensive R&D, particularly for the second type of project targeted at "Teletopia" or "New Media Community" development programs (Table 2.3).

In the case of direct investment, JKTC and the participating companies hold appropriate shares of stock in the new venture company. One of the shareholder firms is usually selected as the "lead" company of the new joint stock limited partnership at the time of the application. The senior staff of the new companies consists of personnel from the supporting companies. The research, though, can be carried out by a combination of research staff from the supporting companies or newly hired staff from other organizations such as universities or government laboratories. If, subsequent to the launching of the new firm, other firms wish to enter it, they must obtain the consent of the original firm. This event does occur; JKTC reports that firms both enter and leave the joint stock limited partnerships.

JKTC provides direct investment in the newly formed company for the expected life of the R&D project—typically a seven-year period. After that, the staff disperses (frequently returning to their home firms), leaving a small holding company that licenses the technologies it has developed. The income from such licenses and from sale of the project capital assets provides funding for the continuation of the holding company. Once a firm starts to earn net revenues, it pays dividends to the member firms and to JKTC. The firm also pays corporate taxes.

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[4] In 1995, JKTC changed its procedures to allow itself to make investments in projects having only one company. The first such example was a project with Canon Corporation.

[5] There is no direct investment by U.S. firms in JKTC firms, but the Japanese subsidiaries of U.S. firms invest in several JKTC R&D firms. Non-Japanese firms are reported as able to license the technologies following the same patent arrangements as they would for any other non-JKTC patent. JKTC hosts cited one such actual case.

Table 2.2
JKTC Capital Investments

Object of investment	Non-public R&D company. After JKTC's investment, its ownership of any public corporation must be less than 50%.
Investment ratio	Up to a limit of 50% of the expenditure eligible for investment. After investment, the ownership of JKTC must be less than 50%.
Term of investment	No more than 5 years from the first investment in the experimental and research project concerned.
Form of investment	Acquisition of shares in the company at the time of its allocation of new shares to a third party.
Diffusion of research results	Intellectual property rights, including patents obtained through the experiments and research in which JKTC invested, will be held by the company. However, since these companies receive government funding, the company must confer with any interested third party about granting licenses to the technologies it develops at an appropriate price.

Table 2.3
JKTC Investments for Fundamental or Comprehensive R&D

Object of Investment	Investment Ratio	Term of Investment
Corporations set up with capital from two or more companies with the object of carrying out research in key technologies executed from the basic or applied phase.	Up to a limit of 70% of the funds needed for research (excluding land costs).	No more than 7 years in principle (can be extended to 10 years for cases recognized as being of particular need).

Loan Services Program

The other mission of JKTC is to provide direct loans to individual companies for funds needed to obtain intellectual property rights to technologies, and for R&D projects carried out by companies, mainly for applied research. The loans reduce the risks and capital burden of R&D by subsidizing interest rate costs. Table 2.4 summarizes JKTC's loan conditions.

JKTC provides two types of loans: "A" loans, which are made to firms of all sizes; "B" loans, which are directed at firms with a capital of less than ¥10 billion.[6] The upper limit of the loan is 70% of the expenditure. Typically, loans are required to be repaid within 10 years after the end of the deferment period (R&D period). If a project is not going well, JKTC will reduce its interest rate on the loan. In the case of B loans, JKTC will reduce both the interest rate and the loan's principal.

The deferment period is the period up to the completion of the R&D (but in principle no more than 5 years). Collateral and guarantors are required for all loans. Upon completion of the R&D phase, the degree of success is appraised, and levels of loan interest and payment of part of the sales are decided as shown in rows (6) and (7) of Table 2.4.

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[6] JKTC officials stated that because of Japan's protracted economic downturn, many more small businesses have been applying to JKTC for loans.

Table 2.4
Loan Conditions

1. Expenditure eligible for loan	Expenditure on equipment & facilities, materials, commodities, labor, subcontracted work, and expenses.
2. Upper limit of loan	70% of the expenditure eligible for loan.
3. Repayment term	Within 10 years from the completion of the deferment period.
4. Method of repayment	In principle, split repayment twice a year.
5. Deferment period	The period up to the completion of the R&D (but in principle no more than 5 years).
6. Loan interest	No interest is payable during the deferment period. For the duration of the loan after the deferment period, the interest rate will be calculated taking the rate set at the time of the loan (Trust Fund Bureau Long-term Loan rate at the time of the loan) and, depending on the degree of success of the research, multiply it by either 1.0, 0.75, 0.5, 0.25, or 0. The degree of success is evaluated upon completion of the research.
7. Success remuneration	On the basis of the interest rate calculated as in (6) according to the degree of success, an amount equivalent to the interest calculated as simple yearly interest during the deferment period is remunerated at the time of repayment of the principle.
8. Collateral & guarantors	Required, in principle.

Based on the Japanese government's past experience of mixed success in funding private sector ventures, increased attention to financial standards, such as collateral for loans, is reported. JKTC representatives indicated that, in the future, they may be become more flexible on collateral requirements for venture business (apparently in response to Japan's current credit crunch).

OPERATIONS AND MANAGEMENT

Project Selection and Oversight

JKTC issues program announcements once or twice a year announcing the availability of funds. Projects are based on private sector initiatives rather than on stated JKTC priorities or solicitations by JKTC for R&D efforts in specific technological areas. JKTC sees its role as conducting reviews of the technical and business merits of the proposals it receives. Final decisions on the technological areas to be supported are based on JKTC's enabling legislation.

JKTC's project selection criteria include technical quality, the impact of R&D, the breadth of technical solution (its cross-field effects), and whether there is adequate R&D support in the private sector. No ex-ante allocation of funds is made across technical fields.[7]

Companies decide whether to apply for a direct investment or a loan. If it is an investment, typically they need to bring in a consortium of other companies to form a joint venture.

JKTC conducts an evaluation of the initial proposal, an interim assessment (usually in the third year), and also receives a final project report.

In conducting the initial review and selection process, JKTC relies on a technology analysis committee made up of 82 professors.[8] The committee is divided into eight technical subcommittees corresponding to the areas of major research; cross-category subcommittees are established for selected projects.

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[7] Interviews with MITI and selected firms indicate that considerable prior discussion occurs between firms and MITI concerning which types of projects are to be submitted to JKTC.

[8] Faculty members are appointed to the technology analysis committee for one-year terms. JKTC's chairman makes formal appointments to the technology analysis committee, but effectively appointment is based on recommendations of existing members of the committee. No industrial representatives are on the technology analysis committee.

JKTC policy has been to keep the names of committee members confidential because professors reportedly have been reluctant to have their names published. This is because of the risk of possible contact of committee members by participating firms. JKTC has recently changed its policy on the confidentiality of names. It was planning to make public the names of the 1998 committee members beginning in April 1999, thus moving to a policy of making known the names of the previous year's panel.

JKTC has set up a business feasibility committee and also employs an accounting firm to do business reviews of the proposals. JKTC representatives acknowledged that procedures and methods for conducting evaluations needed attention.

No data were provided by JKTC officials on the acceptance rate of proposals; however it appears from the interviews that this number approaches 100% for applications that are formally submitted. This high success rate is the result of an effective screening process in which technically poor and non-responsive proposals are eliminated prior to the formal stage.[9] This screening process is aided by MITI's basic industry bureaus. Companies contact these bureaus about the appropriateness of their proposals for MITI or JKTC funding. In this way, MITI's bureaus pre-screen proposals, at times acting as matchmaker in suggesting to a consortium of firms that additional firms be considered for partnership as a founding member of the new joint venture firm. Another informal mechanism affecting JKTC support involves meetings between MITI and firms that lead to the formation of a new joint stock limited partnership and the development of a proposal to be submitted for JKTC funding.[10]

JKTC describes itself as exerting little control over the management of funds once they are allocated to firms. Rather, it describes its role as that of a monitor of the performance of firms, employing a series of technical/business reviews.

Procedures for the third year review were described as follows: the R&D firm prepares a report, which it submits to the review panel. The committee holds hearings at which the firm's representatives respond to questions. The panel reports its findings on the technical progress of the project to JKTC. JKTC reviews the report, discusses internally how to present the findings to the firm and then provides feedback to the firm. No specific format for the assessment is reported. Once a project is funded, there is little likelihood that it will be terminated due to inadequate progress. JKTC reported no case of any project not passing its third year evaluation, although the third year evaluation was reported to have led to changes in the direction of a firm's R&D activities.

Performance Evaluation and Outcomes

MITI officials regard JKTC as a government "investment" program rather than as a subsidization of industrial R&D. MITI looks for returns on its investment in the form of dividends paid by the new firm from income received from its intellectual property rights. In aggregate financial terms, during its 13 years of operation (1985–1998), JKTC has "invested" ¥240 billion. As of 1998, revenue (income) returned by the firms was estimated at ¥2 billion (through the sale of licenses). MITI officials noted that "R&D always takes time;" suggesting expectations of increased license revenues over time. MITI officials also, however, noted that they are beginning to have doubts about the economic validity of this investment model.[11]

JKTC regards patents and published papers as the major outcome metrics and encourages firms to patent and publish results. JKTC officials noted that its projects have resulted in 4,226 patent applications (about 900

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[9] Officials noted that Japan's recession had led to a credit squeeze on both large and small firms, particularly the latter, and that as a result JKTC was receiving a larger number of technically poor proposals that essentially seemed to be attempts to acquire low-cost credit.

[10] Interviews with JKTC-supported firms support these accounts. Firms report that they frequently consult with MITI about the suitability of a project for JKTC funding and that MITI essentially pre-screens applications, effectively endorsing proposals to JKTC.

[11] "Strong encouragement" for JKTC firms to generate patentable findings is reported from both MITI and the Ministry of Finance. JKTC officials also report encouragement from the Ministry of Finance to show more income from licenses. Accordingly, JKTC officials note that they might have to modify the system to take into consideration exclusive licenses.

were granted) and over 16,000 technical papers and presentations over the past 13 years. This total was said to comparable to the number of patents originating in the approximately 15 other research institutes under the aegis of MITI's Agency for Industrial Science and Technology (AIST).

There have been few new business start-ups (focused on downstream production) resulting from JKTC-sponsored firms. However, MITI officials provided some specific examples of what they considered successful JKTC investment projects: [12]

- Protein Engineering Research Institute (PERI)—recently had five papers published in the international journal *Nature*.
- ATR—recently ranked fourth internationally as a telecommunications research institute by *Business Week*. Also, ATR developed a Japanese-English translator that has generated about ¥120 million thus far in copyright fees.
- Conditional Access Technology Incorporated (COATEC) developed scrambler-decoder technology for satellite television broadcasting which has produced about ¥500 million in royalty income thus far.

All JKTC projects are time-limited and are automatically finished after the agreed-upon term. This policy prevents funded projects from becoming "entrenched bureaucracies." JKTC has no method for tracking the flow (and impact) of knowledge after the R&D phase of the project has been completed.

JKTC recognizes the importance of the flow of knowledge from human capital as a mode of technology transfer. New venture companies may hire new people or transfer staff from the parent companies. JKTC officials noted that these joint ventures are useful as a technological training ground. However, JKTC does not attempt to track the careers of people who work on its projects.

Program Management/Evaluation

Compared to U.S. practices for evaluating government supported technological development programs, little novelty exists in the procedures, criteria, or methodologies used by JKTC to evaluate proposals or to assess the outcomes of JKTC-supported firms. No formal procedures for benchmarking the performance of centers were reported.

Future Program Evolution

Little variation during its 13 years of operations was reported in JKTC's formal policies. The changes that have occurred have flowed mainly from the practices of firms and the third year reviews. MPT officials said that there were no plans to review the Basic Law that established JKTC. The legislation that established JKTC set out basic principles and was not very detailed. JKTC changes its management procedures and policies through the screening procedures of related agencies. It believes that regulating details such as management procedures and policies by law will impede the flexible supply of efficient services.

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[12] These and other success stories are described in the JKTC brochure entitled *Research Results of JKTC Investment Projects.*

CHAPTER 3

REVIEW OF TECHNOLOGIES

OVERVIEW

JKTC projects can be divided into two broad categories: physical sciences[1] and biotechnology. An attempt is made to cover all technical areas of the JKTC projects, but the panel was only able to visit a small number of ongoing projects. We will give examples of projects and provide a general view of what was observed. A fuller description of the projects covered below can be found in the site reports in Appendix C, and a short description of all JKTC projects is presented in Appendix D[2].

All the projects visited were performing high caliber research. The staff was very competent and committed to achieving their research goals. The technical staff members were mostly at the Masters degree level, with many working on their industrial PhDs. Many researchers in the physical sciences or engineering projects admitted that this was their only way of obtaining a PhD short of leaving their company. This was less of an inducement in the biotechnology projects, since there appeared to be more PhDs working there.

Another novel aspect of JKTC projects is that they are created for a specific time, and then the research team and the laboratories are dismembered leaving only a shell company that lives off patent royalties and licensing of technologies developed by the company. Team members go back to their parent institutions and the equipment is sold to create a source of funding for keeping the shell company in business. The government is expected to regain its investment by in essence selling its shares in the companies to the private sector. To date the Japanese government has not had a significant repayment of its investment. This is in part due to the long term nature of investing in research and its inherent high risk.

The experience of the staff members and the effect on their careers has not been documented, but it does appear to be attractive experience from the point of view of the staff and the companies involved. An attempt to study the careers of past researchers working on JKTC projects might provide interesting data and possibly support for the investment made by the Japanese government.

The close collaboration between government and industry found in Japan differs from the more typical arms-length relationship between these sectors. The established time for the projects affects the type and style of the research, something that was observed in another Japanese program, called ERATO, which was studied by a previous WTEC panel (Gamota et al. 1996). Although funding is assured in the JKTC program, there is much more pressure to achieve a result since the end date is predetermined. In the United States the funding

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[1] By physical sciences we use a very broad definition which means all areas in science and engineering other than biotechnology.

[2] For an in-depth discussion of the individual projects, we refer the reader to the English copy of the *Research Results of Investment Projects* booklet published by the Japanese Key Technology Center (JKTC nd).

might not be as secure, usually the team and the research do not have a finite lifetime. As an example, although most funding for NSF science or engineering centers is also for 5 years, the projects can and usually do continue even if the NSF funding is not renewed.

The WTEC panel found that the quality of JKTC-funded researchers was quite high, and there appeared to be no lack of applicants to fill the ranks of staff in each project. Few university professors have participated in JKTC projects. We were told that in part this was due to the barriers set up between various Japanese government agencies. All faculty and students are under the Ministry of Education, Science, Sports, and Culture (Monbusho). To leave a position in the university was seen as damaging to a career, particularly if one wanted to go back to the university. We did encounter some post-docs in the JKTC projects, but they were foreigners. Some projects had industry–university partnerships, but it was not clear how they cooperated other then to meet occasionally and discuss results. We saw no such cooperation as one sees at the NSF science or engineering centers, or even as in the ERATO program, where some of the ERATO project directors have been university professors.

International participation varied between the projects. At ATR, there appeared to be many foreign researchers. The WTEC team members also learned that the Mixed Reality Systems Laboratory (MRSL) project (see Appendix C) collaborates with the MIT Media Lab, and U.S. students come to Japan to participate in the project. However, in most other projects there were no foreign researchers evident. Most project researchers took part in international meetings and made many presentations, and many published in English language journals, but the panel observed few foreigners among the staff.

Given the broad definition of physical science projects, these projects outnumber the biotechnology ones by a 3 or 4 to 1 ratio. For example, in 1985 there were 2 biotechnology projects out of 17 started. In 1995 one biotechnology project was started, among a total of 4 newly started projects. The physical sciences projects have always included a number of communications related projects, as well as electronics and materials. This emphasis follows the interests of the parent Japanese government sponsors, MPT and MITI. Additionally, due to the origins of the JKTC program, NTT and CRL were always heavily involved in all aspects of the selection and management of the program.

PHYSICAL SCIENCES

Physical science projects run the spectrum from basic research to advanced development. ATR laboratories represent the basic research end, while projects such as the Super Silicon or the YRP projects are in the advanced development stage. The latter two projects do engage in some basic research, but their goal is well established and their purpose is to develop technology in fast moving fields. The Super Silicon project has a goal of developing a 400 mm silicon wafer, something that all industry is expecting to be done because of the requirements imposed by continued integration of electronic components. The current state-of-the-art is 300 mm, and 400 mm is the next logical step. ATR laboratories are known worldwide as performing first class research in telecommunications, including visual and auditory research connected to communications. Projects are staffed by Japanese and foreign researchers, and there does appear to be more of an international flavor there than in other projects visited.

Physical science basic research projects typically are funded for 7 years and require 70% government funding. Advance development projects are funded for a shorter period and often are funded more heavily by industry, in some cases up to 49%. In all projects the government has at least a 51% share to ensure that it is the majority stockholder. However, even though the government is a majority stockholder, participating industrial partners hold responsibility for the conduct of the project's periodic review. Industrial sponsors also hold reviews on a regular basis, often quarterly. The industrial partner review is separate from the two reviews performed by JKTC, which are held at mid point and end of the project's life. A good example is the Mixed Reality (MRSL) program. The staff at MRSL all come from Canon, the industrial sponsor, but while at MRSL the staff's loyalty is to MRSL and not to Canon, so during reviews there is often a heated debate, and at the end, MRSL can make its own decision. Canon staff can only make suggestions but can not direct the MRSL researchers.

Over the years, a few projects have been in superconductivity. These have included some materials development as well as development of superconducting devices. A good example is Advanced Mobile Telecommunications Technology, Inc. (AMTEL). AMTEL's goal is the development of highly efficient mobile telecommunication systems utilizing high temperature superconductors for next generation land mobile telecommunications and mobile satellite telecommunications. This is a high risk project with competition around the world, and more importantly competition from other (non-superconducting) technologies. The superconducting filters being developed by AMTEL potentially have a large market, but due to the high risk, industry is only putting up 30% of the funding.

The process for project selection in the physical sciences area varies widely. Some projects are proposed to JKTC, such as those by ATR and YRP. However, the typical mode of operation is for JKTC to openly advertise opportunities and solicit proposals from industry. This was the case, for example in the creation of MRSL. JKTC openly sought proposals for this area, and only Canon Corporation responded with a proposal. JKTC still funded the project along with Canon on a 51%-49% basis. This was the first project funded with only one company. Such selection was permitted due to a change in the law creating JKTC, which previously stated that there had to be minimum of two companies funding a project. Another example is the HITS Laboratory. Its only industrial sponsor is the Victor Company of Japan.

Project selection also takes into account funding of areas by other agencies. The WTEC panelists are not sure how this coordination occurs, and at what level, but projects selected under JKTC often are in areas that there is little funding available from other agencies.

The projects are grouped into two major categories: mining and industry; and telecommunications, and further broken down by technology areas. Appendix D is a complete list of projects. The classification scheme is as follows:

- Mining, Industry
  - New Materials
  - Biotechnology
  - Machinery
  - Electronics
- Telecommunications
  - Communications processing
  - Network
  - Radio communications
  - Pictures/Transmission

For the last several years JKTC has emphasized projects related to information technologies, including technologies related to telecommunications and the entertainment industry. Most projects are also heavily software related and indicate the renewed effort on behalf of Japan to develop this field since it is key to almost any area of technology and business. In some of the newer projects, JKTC seems to try to overcome the U.S. lead by jumping ahead and working in fields that have yet to be shown to have applications, while other projects are directly applicable to such fields as accounting and billing. Leapfrogging might work in some areas where current technology has come to a "real" dead end, but as silicon technology, magnetic memory storage systems, and optical lithography have shown, a vast industrial investment in a particular technology makes it difficult for new methods to replace existing processes and manufacturing. A number of projects appear to be targeted at social issues. The HITS project seeks to anticipate the difficulty an aged population in Japan or elsewhere might have in handling new technologies dealing with wireless entertainment and communications equipment.

The return on investment in the form of licensing or patent sales on these newer projects is reportedly still years away, although the training and experimentation that the research staff gain during this period could be very important for Japan's future and to the investing companies. It is building a population of scientists and engineers who are growing up in and helping to foster a new research culture.

BIOTECHNOLOGY AND LIFE SCIENCES

Biotechnology, the controlled use of living organisms or cellular constituents for practical purposes, has been recognized worldwide as a critical technology. As such, Japan has pursued biotechnology in various modes including Japan's Key Technology Center (JKTC) program. To date, 10 corporate biotechnology centers have been established over the span of 13 years (since 1985). The centers, both past and present, are listed in Appendix D.

While not all current centers were visited, a selection was made that permitted visits to centers that are characterized as old (established) or new, small or large, and practical or fundamental science in nature. Additionally, some centers are more oriented toward economic development in addition to establishing a base of science and technology.

While generalizations are always subject to reality checks by exceptions, the following comments apply to the centers visited and to the JKTC program. In addition, information was gleaned from other sources such as technical information presented by the JKTC headquarters, discussions with others in Japan, or prior information released by a specific company center.

- The JKTC program has had and continues to have a good portfolio of significant company centers dedicated to cutting edge biotechnology topics that are being pursued in other countries including the United States. As an example, the early days were focused on protein engineering, recombinant DNA, and plant cell technology. Current company centers are focused on functional genomics, bioinformatics, biophotonics and biomolecular engineering. Bioinformatics is a topic that is being pursued in a number of centers (Helix Research Institute—HRI and Biomolecular Engineering Research Institute—BERI), reflecting an interest and realization in Japan that this area is a critical one in biology.
- The centers have a good mix of both pragmatic and fundamental research efforts reflecting the composition of the member companies and the founding management of those centers. More fundamental centers include HRI and BERI. More pragmatic centers include Environmental Immuno-Chemical Technology Co. (EIC) and certain aspects of BioPhotonics Information Laboratory (BIL). For example, HRI's orientation of genomics reflects the founding manager's philosophy of the criticality of incorporating cutting-edge science in a new technology area (Teruhisa Noguchi, former CEO) and the interests of the majority of the corporate members that are pharmaceutical companies. Like in the United States and elsewhere, functional genomics holds much promise for drug development and is being actively pursued by HRI.
- A genuine commitment to economic development was seen in at least one center visited, namely BIL in Yamagata Prefecture. This center is housed in a technology park and has the financial backing of local and prefecture organizations. Economic development interests were also evident in discussions with management at that center. On the other hand, other centers, while still having a programmatic charge for economic development, were not particularly directed toward that objective. The centers located in large cities were less oriented to economic development and more toward achieving credibility through quality research results.
- The biotechnology centers, like other JKTC centers, were oriented toward achieving significant research results to satisfy the needs of the academic reviewers along with peer-credibility and recognition, and toward patent filings to satisfy the needs of industrial sponsors. While these two indicators of productivity have shortcomings, they are the ones that are the driving forces for all centers visited.
- The more fundamental and cutting-edge science-based centers (HRI and BERI) now have active participation by academic scientists in the form of permanent employees (academic researchers who decided to leave academia and join a center), visiting scientists (meaning actual research performance at the center for a defined period), and collaborating faculty (where the scientists retains his academic affiliation but where there is active collaboration of research results and students). This exchange is relatively new but real. Reasons gleaned from conversations include: the recognition of the value of academic ties (as done in the West); the background of key managers and scientists at these centers

(many have been educated and trained in the United States and they like that model); and the need for ties in fast-moving areas of biotechnology such as genomics.

- The more fundamental and cutting-edge centers have a significant number of foreign (non-Japanese) scientists, especially in the form of postdoctoral fellows. This situation is a reflection of the need to bring in new and cutting-edge technology from abroad, in particular from the United States and Europe. Normally, the postdoctoral fellows stay for 2-3 years.
- The more fundamental and cutting-edge centers have significant publications in leading science and technology journals along with patents. As in the United States, both seem to be encouraged.
- One of the centers visited, BERI, was restructured successfully based on changing interests and needs of corporate sponsors and JKTC management. The original center, the Protein Engineering Research Institute, PERI, matured and was terminated by program dictates at the end of its time. However, BERI was then formed to pursue new directions in biomolecular engineering (that included not only proteins but also nucleic acids) as well as to take advantage of the large infrastructure of the established PERI laboratory facilities. The transition seemed to be quite positive and successful. Some personnel, however, were terminated at the end of PERI.
- While most JKTC centers visited have some similarity to other efforts being pursued in the United States in academic or industrial laboratories, BERI seems to have a unique distinction. First, BERI has an unequaled resource base in its laboratories and associated instrumentation and equipment all located in one place where interaction can easily occur. Second, BERI is focused on an important area—protein engineering—that is now getting renewed attention in the form of "proteomics," the study of relationships of proteins with genomics. Thus, BERI is well situated to make contributions to basic and applied areas coming from protein engineering that few other organizations could make. We are not aware of any other equivalent U.S. organization dedicated to biomolecular engineering that is so poised.

As with other JKTC centers, the biotechnology centers have some inherent differences from centers in the West that can be viewed as either an advantage or limitation, depending on one's perspective. These differences include:

- Commitment: Once a JKTC center is formed, it is a given that that center will exist until its time for termination. This condition imparts stability for the staff and solidifies the area of research to be conducted. In contrast, most centers in the West are given short time periods (at times one year) before a review may dictate changes in management, area and approach.
- Evaluation: JKTC centers have minimal review and evaluation (compared to what is currently being done in the United States with equivalent activities). Minimal evaluation reflects a greater confidence in staff and management and a recognition that significant scientific and technical issues cannot be solved in 2-3 years. On the other hand, minimal evaluation can bring on complacency and mundane research.
- Management: Most managers at JKTC centers are former executives from leading Japanese companies engaged in these centers. The benefits are that management is mature and seasoned for such positions. Management also knows the ultimate end results that can be beneficial to the participating companies. On the other hand, management without young "hot-shot" and career-advancing persons may not bring forth the drive that is needed to achieve world-class results given the highly competitive and changing nature of biotechnology.

In summary, the JKTC centers dedicated to biotechnology have and continue to represent different areas of science (from genomics, biophotonics to immunology), different end applications (biopharmaceuticals, medical diagnostics, and environmental screening of pesticides), and different end industries (pharmaceutical, medical imaging, and industrial and agricultural chemicals). New areas have definitely been recognized (genomics and bioinformatics) and represent major activities now being pursued. Other areas such as tissue engineering, bionanotechnology, or combinatorial biology do not yet have a dedicated company center nor was there any discussion on such possibilities dealing with these topics in the immediate future during the site visits. Given the nature of how centers are formed, like in the United States, a champion for a particular effort needs to be there to make it happen.

New JKTC centers, as well as those involved in cutting-edge science, have more academic interaction and foreign scientist participation, reflecting the reality that science is now global and that hot biotechnology areas such as genomics are highly competitive. Some centers, in fact, are starting to have discussions with foreign firms as an outlet for their technology but not necessarily as participating members. However, foreign companies operating in Japan can be members and some indeed are members.

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APPENDICES

APPENDIX A. PROFESSIONAL EXPERIENCE OF PANEL MEMBERS

Dr. Irwin Feller (Panel Chair)

Dr. Irwin Feller is director of the Institute for Policy Research and Evaluation and professor of economics at The Pennsylvania State University, where he has been on the faculty since 1963. Dr. Feller's current research interests include the economics of academic research, the university's role in technology-based economic development, and the evaluation of federal and state technology programs. He is the author of *Universities and State Governments: A Study in Policy Analysis* (Praeger Publishers, 1986) and over 100 refereed journal articles, final research reports, and book chapters, as well as of numerous papers presented to academic, professional, and policy audiences. He has been a consultant to the President's Office of Science and Technology Policy, National Aeronautics and Space Administration, the Carnegie Commission on Science, Technology, and Government, The Ford Foundation, National Science Foundation, and National Institute of Standards and Technology, among others. He is a member of the Panel on International Benchmarking of U.S. Research Fields—Immunology, National Academy of Sciences/National Research Council; Transportation Research Board, Research and Technology Coordinating Committee, National Research Council; NIST-Manufacturing Extension Partnership National Advisory Board; National Science Foundation Advisory Committee on Social, Behavioral, and Economic Sciences; and formerly chaired the American Association for the Advancement of Science's Committee on Science, Engineering, and Public Policy.

Dr. George Gamota

George Gamota is President of Science and Technology Management Associates, a technology consulting firm specializing in technology assessments, research and technology policy, and small business development. Dr. Gamota also serves as associate director of ITRI and advisor to its WTEC program, which assesses trends in international science and technology for the National Science Foundation (NSF), the Department of Commerce, the National Aeronautics and Space Administration, and various agencies of the Department of Defense. Dr. Gamota played a key role in the founding of the JTEC program in 1983 (WTEC's predecessor) and has been involved in its management ever since. He chaired WTEC's study of Japan's ERATO program in 1996. Dr. Gamota previously served as director of the Mitre Institute, Chief Scientist of the Mitre Corporation's Bedford Group, President of Thermo Electron Technologies Corporation, Professor of Physics and Director of the Institute of Science and Technology at the University of Michigan, Director for Research in the Office of the Secretary of Defense, Special Assistant to the President of Bell Laboratories, and member of the staff (MTS). He has also served as a consultant to Science Applications International Corporation (SAIC), Thermo Electron Corporation, JMAR Technology Corporation, and the National Academy of Sciences Committee on International Security and Arms Control. He was the 1995 national chairman for the National Conference on the Advancement of Research, and served as its program chair in 1993. Dr. Gamota holds a PhD in physics from the University of Michigan (1966) and an MS (1963) and BS (1961) from the University of Minnesota. Among the recognitions and awards Dr. Gamota has received are the Meritorious Civilian Service Award from the Department of Defense, Fellow of the American Association for the Advancement of Science (AAAS), Fellow of the American Physical Society (APS), and senior member of the IEEE. He is the author of over 100 articles and the author of or contributor to six books.

Dr. Richard E. Harris

Dr. Richard Harris is Chief of the Electromagnetic Technology Division of the National Institute of Standards and Technology, Boulder Laboratories. The division develops state-of-the-art standards and measurement technology for electrical and other measurements and provides measurement support for the magnetic data storage industry. The division has developed the series array Josephson voltage standard that is now used in about 50 laboratories worldwide; it supplies critical current standards for superconducting wire and artifact standards for magnetic force microscopy. The division also does advanced research on current standards, ac voltage standards, X-ray spectroscopy, microwave properties of high temperature superconductors, ultra-fast and ultra-dense magnetic recording, and magnetic imaging. It maintains a complete fabrication facility for superconducting and magnetic integrated circuits.

Dr. Harris received MS (1965) and PhD (1969) degrees in physics from the University of Illinois and a BS degree from the University of Rochester (1963). He became a staff member at United Technologies Research Center in 1969. In 1975 he joined the National Institute of Standards and Technology (then the National Bureau of Standards), Boulder, Colorado, becoming Group Leader of the Cryoelectronic Metrology Group in 1982. In 1993, he was appointed to his present position. In 1980 he was assigned for one year to the IBM Zürich Research Laboratories. In 1993, he served as a member of the City Council in Boulder, Colorado.

Mr. Paul Herer

Paul Herer is Senior Advisor for Planning and Technology Assessment for the Engineering Directorate of the National Science Foundation. He has directed strategic and long range planning, program development and technology assessment activities, such as WTEC. In addition, he has provided technical oversight for the Critical Technologies Institute, a federally funded center that supports the White House Office of Science and Technology Policy. He is currently on detail to the Office of the Director at NSF, where he is also involved in strategic planning. Mr. Herer has authored and co-authored many articles and reports dealing with technology assessment and policy, including the 1996 WTEC report on Japan's ERATO and PRESTO Programs. He has served on special long-term assignments to the Office of Management and Budget and to the Research and Development Corporation of Japan. He holds a BA degree in psychology and an MBA from the University of Maine. In 1997 he recently received NSF's highest honor, the Distinguished Service Award.

Dr. Patti O'Neill-Brown

Dr. Patricia O'Neill-Brown is Manager of the Japan Technology Program in the Commerce Department's Office of Technology Policy. She is responsible for tracking and analyzing Japanese scientific and technical developments and trends in science and technology policy. She is a key member of the U.S. government team that formulates bilateral agreements, principally the U.S.-Japan Science and Technology Agreement. One of her responsibilities is running the Machine Translation Center for Japanese Science and Technology Literature, put in place through an agreement with the Japan Science and Technology Corporation. Dr. O'Neill-Brown has a PhD from Georgetown University in linguistics with a concentration in computational linguistics. She reads, writes and speaks Japanese. Her professional interests include machine translation, intelligent information retrieval, agent technologies, computer assisted instruction, speech recognition and synthesis and multilingual computing. She develops software and is actively at work in the field of artificial intelligence (AI), publishing in the field and serving on conference committees. She was the co-organizer of a workshop on agents as part of the 5th Pacific Rim International Conference on Artificial Intelligence (PRICAI98) held in November 1998 in Singapore, and was on the conference committee for the 1998 Association for Machine Translation in the Americas (AMTA) conference.

Dr. Oskar R. Zaborsky

Dr. Zaborsky has extensive experience in science and engineering programs, administration and management, along with experience in R&D dealing with marine biotechnology, biological hydrogen production, environmental biotechnology, biocatalysis, and immobilized enzymes (having developed several patented methods). He has held positions in industry, government, non-profit organizations, and academia dealing with biotechnology, the life sciences and engineering. He joined the University of Hawaii in 1995, serving as the Williamson-Matsunaga FREE Scholar, and established the Marine Bioproducts Engineering Center (MarBEC) in 1998, an NSF Engineering Research Center. At NSF, Dr. Zaborsky was responsible for formulating the first government efforts dealing with recombinant DNA technology and renewable resources. At National Academy of Sciences, as Director of the Board on Biology, he was responsible for a number of significant studies including those on bioprocess engineering (*Putting Biotechnology to Work: Bioprocess Engineering*) and DNA typing technology (*DNA Technology in Forensic Science*). He has written more than 60 scientific articles and has authored or edited more than 10 books, including the series, Marine Biotechnology. He also launched a number of journals including *Enzyme & Microbial Technology*. Dr. Zaborsky received his education at the Philadelphia College of Pharmacy & Science, University of Chicago (E.T. Kaiser) and Harvard University (Nobel Laureate E.J. Corey). During the past few years, Dr. Zaborsky has been actively engaged in environmental biotechnology issues and served as co-chair of Environmental Biotech ‘96, a national conference and exhibition sponsored by the Biotechnology Industry Organization (BIO) and the National Science and Technology Council of the Office of Science and Technology Policy, White House. He has lectured widely, most recently in several major German and Japanese universities and biotechnology centers.

APPENDIX B. PROFESSIONAL EXPERIENCE OF OTHER TEAM MEMBERS

Mr. Hiroshi Morishita

Hiroshi Morishita, President, HMI Corporation, specializes in ultra-micro manipulation technology for microelectromechanical systems (MEMS). He founded HMI Corporation in 1991 to commercialize his ultra-micro manipulator system. He extended his interest and business to the field of archaeological excavating machines and to a new robot manipulator system to help bed-ridden persons. In 1994, he became a consultant to JTEC panel members concerning their study tours in Japan. He graduated from the University of Tokyo (BA, MA, mechanical engineering), and is in the final stage of preparing his doctoral thesis. He was a visiting researcher in Mechanical Engineering Department in 1992 and 1993, and at RCAST (Research Center for Advanced Science and Technology) of the University of Tokyo in 1994 and 1995.

APPENDIX C. SITE REPORTS

Site: **Agency of Industrial Science and Technology (AIST)**
Ministry of International Trade and Industry (MITI)
1-3-1 Kasumigaseki, Chiyoda-ku
Tokyo 100-8921, Japan
http://www.aist.go.jp/

Date Visited: 11 October 1998

WTEC Attendees: I. Feller, G. Gamota, P. Herer, R. Harris, P. O'Neill-Brown

Hosts: Kyuichiro Sano, Technology Promotion Division
Hiroki Ishigaki, Technology Promotion Division

The Japan Key Technology Center was described by MITI officials as a government "investment" program, not as a subsidization of industrial R&D. Returns on investment (in the form of dividends paid by the new firm from income received from its intellectual property rights) are expected from JKTC support. When JKTC was established (in 1985), it was the only government-funded R&D center program. Japan's new basic law on science and technology provides additional policy tools: additional center-like programs may be initiated by other agencies. Agencies also are seen as more likely to be receptive to allowing open competitions for research proposals. This new openness also may attract new R&D players. Also, the New Energy and Industrial Technology Development Organization (NEDO) has become an important sponsor of joint R&D ventures.

JKTC's funding is based on dividends flowing from the government's one-third holdings of NTT shares. These holdings follow from the law that privatized NTT. NTT's annual dividends are estimated at ¥78 billion. The government directs ¥26 billion (about one third of these dividends) to a special account to fund JKTC (which accounts for the relatively stable level of JKTC funding over time). The possibility exists that NTT's structure may again be changed, which in turn would affect its dividend policy. Such changes, in turn, might affect the base of JKTC funding.

Given this "formula" funding arrangement, MITI has only modest control over JKTC's annual budget. Its primary role in the allocation of JKTC funds (a role shared with the Ministry of Posts and Telecommunications—MPT) is in the broad allocation of funds among program areas, in the apportionment of JKTC funds between loans and investments and between type A and B loans.

During its 13 years of operation, (1985–1998), JKTC has "invested" ¥240 billion. Modest income from this investment has been recorded to date, although it was noted that "R&D always takes time."

Patent data were reported as follows: In 1991, JKTC centers applied for 4,000 patents; 900 were granted. In 1996, 435 patents were granted. This latter total was said to be almost the same as the sum of patents originating in the approximately 15 other research institutes under AIST's control. "Strong encouragement" for JKTC firms to generate patentable findings is reported from both MITI and the Ministry of Finance.

JKTC submits an annual report on its operations to MITI. MITI also approves JKTC's budget, as well as advising it on specific strategic directions (e.g., to increase the number of patents).

Little variation during its 13 years of operations was reported in JKTC's formal policies. The changes that have occurred have flowed mainly from the practices of firms and the third year reviews.

Originally, little purposeful effort was made to have JKTC investments promote regional economic development. JKTC projects, however, are now regionally dispersed, and thus may serve to stimulate regional economic growth.

Site: **Advanced Mobile Telecommunication Technology, Inc. (AMTEL)**
500-1 Minamiyama Komenoki-cho, Nisshin-sui
Aichi-ken 470-0111, Japan
http://www.denso.co.jp/NEWS/1999/0421a-e.html

Date Visited: 14 October 1998

WTEC Attendees: R. Harris, H. Morishita

Hosts: Masayuki Aoki, Managing Director, E-mail: aoki@ngo.amtel.co.jp
Yoshiki Ueno, Section Head, 1st Section, R&D Division
Seitoku Itou, Section Head, 2nd Section, R&D Division
Ryo Ishimaru, Senior Manager, Planning Division
Dr. Nobuyoshi Sakakibara, Chief Research Engineer, 1st Section, R&D Division
Hiroshi Kubota, Chief Research Engineer, 2nd Section, R&D Division
Mitsunari Okazaki, Section Head, Yokohama Laboratory, 1st Section, R&D Division

BACKGROUND

The headquarters of the Advanced Mobile Telecommunication Technology, Inc. project is at the Denso Research Laboratories in Aichi prefecture. A second site is the Yokohama Laboratory of Alps Electric Co., Ltd. in Kanagawa prefecture. Formed in 1994 with contributions from the Denso (15%), Alps (15%) and JKTC (70%) the company's mission is to "answer the demand for mobile telecommunications and to introduce new technology like high temperature superconductivity into practical applications. AMTEL's goal is "the development of highly efficient mobile telecommunication systems utilizing HTS as the next two generation systems: land mobile telecommunications and mobile satellite telecommunications." The company lists its capital as ¥2,857.25 million.

The Denso laboratory that this WTEC team visited is very elegant and spacious and not fully used. At this location there are 17 researchers and technicians. At Alps in Yokohama, 4 more researchers consider system design.

The company's work to meet market needs includes the development of both HTS filters and small cryocoolers.

INTERACTIONS WITH JKTC

In their original application to JKTC, AMTEL staff members noted that Denso had been studying HTS for 6 to 7 years and wanted to apply the base technology. Alps already had high frequency technology for cellular phones and wanted to advance its technology. A detailed business plan was submitted. Initial review of the plan was skeptical because it was not believed that such outstanding performance was possible. The application was presented to MPT, which is well aware of the limited spectrum available for cellular phones. Additional skepticism existed because the area of research was wide, and there was much work to do. There was a mid-term review, and there will be a final review. Each year, AMTEL sends a report to JKTC. AMTEL must control expenses but this is reported to be an acceptable requirement. JKTC increases AMTEL's capital three times a year, and each time a progress report must be submitted.

There are other internal reviews by an Engineering Promotion Committee and a Steering Committee. These reviews occur twice a year, using members from AMTEL, Denso and Alps. Both technical and management work are reviewed.

The mid-term review was two years prior to this visit, and AMTEL staff worked hard to prepare for it, submitting a thick report. The review itself lasted one hour with an additional hour for questions. The review was carried out by three professors. AMTEL's staff was not officially told the names of the professors in advance. In Japan if a professor were contacted before the review he would be obligated to try to do good things for the caller. That was deemed too much pressure, and the problem was solved by not revealing the names of the reviewers.

As of 1998, 37 patents had been issued of which 31 were for the cryocooler. A total of 140 patents had been applied for. In Japan patents are issued 2 to 3 years after application.

RECENT R&D RESULTS

Filters are composed of yttrium-barium-copper oxide (YBCO) superconducting films on MgO substrates. Four filters have been designed and tested:

	Filter 1	**Filter 2**	**Filter 3**	**Filter 4**
Poles	9	15	11	8
Freq. (GHz)	2.6	1.5	0.8	2.0

Filters 1 and 2 were fabricated for the demonstration samples at the mid-term review. Filter 3 is designed as a test for IS-95 cellular telephone base stations, but the tests will be carried out in the laboratory and not on telephone poles as some U.S. companies are doing.

The researchers use Hewlett-Packard design software. Filter 4 was fabricated in niobium as a conceptual test. A bandwidth of 5 MHz or 0.25% was achieved with 90 dB rejection. The passband slope was 30 dB/700 kHz. Responding to a direct question, the researchers compared it with results from the United States, characterizing it as better than those of Conductus or STI, but a little worse than Illinois Superconductor (which uses thallium films).

Filter 3 was demonstrated in a commercially available Stirling cycle refrigerator. AMTEL researchers indicated that in the future they might be more open to collaboration on refrigeration with other companies. They showed a coaxial lead with reduced heat leak because its very thin shield is made of vacuum deposited copper. They have used both MgO and LaO substrates with YBCO. The YBCO is sputter deposited on both sides of the substrate. They achieved a noise figure of 0.5 dB at 840 MHz, which they asserted is 2 dB better than room temperature copper and 1 dB better than copper at 77 K.

The cooler operates at 70 K +/- 0.3 K. A lower temperature would require a bigger cryocooler. The researchers have also developed a pulse tube refrigerator having a capacity of 1 watt, sufficient for 1 filter. They are developing a bigger refrigerator, which was first assembled four days before the visit. It is designed for a 7 watt capacity at 70 K. Compressor resonances were being evaluated at the time of the visit. The researchers acknowledged plans to miniaturize the refrigerator, reducing its size by about half to less than 20 kg. The overall size was about 30 x 30 x 20 cm. They stated that the refrigerator must be quiet to be located in an urban area, where people would object to the noise.

Deposition is carried out in a 4-target off-axis sputtering system having a base pressure of 1 x 10^{-6} T. The sputtering gas is a 1:1 mixture of Ar and O_2. The samples are exposed to air between depositions on the two sides of the substrates.

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Site: **Advanced Telecommunications Research Institute International (ATR)**
2-2 Hikaridai Seika-cho
Kyoto 619-02, Japan
http://www.atr.co.jp

Date Visited: 15 October 1998

WTEC Attendees: P. O'Neill-Brown, G. Gamota

Hosts: Wataru Tanaka, Vice President, Director, Liaison Division
Tatsuya Yamazaki, Senior Researcher, Department 1, ATR Adaptive Communications Research Laboratories
Dr. Shigeru Akamatsu, Head, Department 2, ATR Human Information Processing Research Laboratories; Guest Professor, Graduate School of Science and Technology, Kobe University
Dr. Bokuji Komiyama, President, ATR Adaptive Communications Research Laboratories
Roberto G. Lopez, Research Engineering Department
Dr. Seiichi Yamamoto, Senior Manager, Architecture, Research & Development, ATR Interpreting Telecommunications Research Laboratories

BACKGROUND

The purpose of Advanced Telecommunications Research Institute International (ATR) is to advance telecommunications R&D, with a particular focus on the design of applications that promote effective human-computer interaction. ATR has 140 shareholders.

ATR has four research divisions:

3. Media Integration & Communications Research Labs
4. Interpreting Telecommunications Research Labs
5. Human Information Processing Research Labs
6. Adaptive Communications Research Labs

The research budget for the 4 divisions is about ¥7.4 billion/year. The total number of staff is 305, of which 244 are researchers. Of those researchers, 116 come from shareholder companies. ATR has filed for 866 patents. The number of papers ATR has published domestically is 5,181 (2,303 internationally).

RESEARCH AND DEVELOPMENT

Following are brief descriptions of the research in each of the four research divisions.

ATR Media Integration & Communications Research Labs

- study of technologies for generating communication environments (the recognition and generation of human images)
- virtual reality research (3D display; haptic display; scene recognition and generation; thought-supporting agents)
- agent interface and design
- research into communications by mental image

- human communications science (interactive actors for understanding emotion)
- research on art and technology

ATR Interpreting Telecommunications Research Labs

- speech recognition and synthesis (spontaneous speech recognition, synthesis and prosody; speaker-independent speech recognition)
- research in language translation and dialogue processing (speech to speech translation; multi-language translation, dialogue management)
- multi-modal communication
- compilation of a linguistic database

ATR Human Information Processing Research Labs

- spoken language processing (speech perception and cognition)
- speech production mechanisms; cognitive and formative model of internal images in the brain; visual information generating mechanisms; visual scene analysis and object recognition
- mechanisms for information generation and integration (mechanisms for brain communications and evolution; mechanisms for integrating multi-module information)

ATR Adaptive Communication Research Labs

- architecture and control for adaptive communication systems (networks; design and control of complex adaptive systems)
- research in advanced wireless communications (intelligent antenna arrays based on multi-dimensional signal processing; microwave photonics technologies)
- advanced communication devices (quantum effect devices; dynamic function devices)

ATR is where the story of the Japan Key Technology Center begins. With the breakup of NTT in 1982, the Japanese government was concerned that NTT would move away from basic research. Therefore, to preserve a vital element of the nation's indigenous capacity for basic research, the Japanese government established the Japan Key Technology Center in 1985. The Key Technology Center's budget was (and is today) derived from the government's share of dividends from NTT stocks. In 1986, ATR was established by the Japan Key Technology Center as the first JKTC-funded project in Kansai Science City. ATR is a limited stock holding company that consists of 140 shareholders, including NTT, of course.

Japan has traditionally been weak in basic research, relying heavily on foreign sources of basic science. To correct this weakness, the Japanese government, especially recently, has been increasing funding for basic research and experimenting with new methods to encourage creativity. The Japan Key Technology Center brought ATR into being precisely in order to develop an indigenous capacity for technological innovation. An additional motivating factor that gave rise to the JKTC model was, as the panel discovered during its visit with MITI officials, the Japanese government's desire to contribute to the world's science base.

Without a doubt, ATR is contributing to the world's science base. Research taking place at ATR is cutting edge. In particular, ATR is a world leader in its efforts in face and object recognition. Face and object recognition techniques are key in the development of agent technologies. One of the world's hottest areas of research is in the area of agent technologies, whether they are realized anthropomorphically in computing environments, as robots in the physical world, or as purely software processes. The line of research that ATR is pursuing is a key element of what is called "adaptive agent technology." Adaptive agents are viewed as an important key to the information age.

In addition, the international way in which ATR operates clearly indicates that ATR is contributing to as well as gaining from the international scientific community. ATR's interactions with the world scientific community are significant. ATR's international cooperative activities include the following:

- participation in consortia and participates in and hosts workshops, symposia and conferences that involve the government, industry and academia of other nations
- inviting researchers from other nations as visiting researchers

The Japan Key Technology Center, and particularly through ATR, is attempting to contribute to the world's research base of knowledge through its framework for intellectual property rights (IPR) distribution emanating from JKTC-funded projects. The framework is set up such that there is a 50-50 split between the Japanese government and the limited stock holding company that is the recipient of JKTC funds. This is an attempt on the part of the government to see to it that not only do the direct recipients of the funding receive benefit from government funding of R&D, but also the nation at large benefits in very direct, immediate and concrete terms: any party has the ability to license technologies arising from JKTC funded projects. It is noteworthy to point out that the United States does not have an R&D funding policy of this sort.

The licensing policy has an international dimension. JKTC's licensing policy serves as a vehicle for contributing to the world community in its ability to be used for moving the R&D out of Japan's labs. Specifically, the WTEC panel inquired as to whether there is any JKTC policy that restricts foreigners in licensing technologies emanating from JKTC-funded projects. Panel members discovered that there do not appear to be any such restrictions. As an example, AT&T licensed some of ATR's speech technologies.

Japan has long used its policy of aggressive technology licensing to become one of the world's top technological producers. Since some U.S. companies also make technology licensing a key part of their business development plans, the JKTC licensing policy model affords the potential for U.S. companies to leverage into Japan's research base.

In short, the JKTC model, through ATR, represents an effort to meet important policy objectives of the Japanese government—that is, as a key mechanism for "home-growing" Japan's basic research capacity, dispersing the benefits of government funded research widely, and contributing to the world's basic store of knowledge.

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Site: **Biomolecular Engineering Research Institute (BERI)**
6-2-3 Furuedai, Suita
Osaka 565-0874, Japan
http://www.beri.co.jp

Date Visited: 13 October 1998

WTEC Attendees: O.R. Zaborsky

Hosts: Jun-ichi Sugai, Representative Managing Director
Kyozo Tsukamoto, PhD, General Manager, Research Coordination Department

BACKGROUND

The mission of the Biomolecular Engineering Research Institute (BERI) is to clarify the structures and functions of proteins, nucleic acids, and other biological molecules of importance to life processes. It is hoped that BERI will provide an understanding of the mechanisms for molecular recognition and refine the methodology for the rational design of biomolecules with novel or more efficient functions that then will have applications in the environmental, energy, industrial and medical fields. For understanding the mechanism of life, research is being carried out to clarify the character of signal receptors, enzymes, and genes, and attempting to make biomolecular research useful for mankind.

BERI was established on March 28, 1995 with the participation of 18 companies. BERI is an 8-year program, with a planned funding of about ¥15 billion, with 70% being derived from the Japan Key Technology Center (JKTC) under the direction of MITI and 30% from the participating companies. The total number of employees is close to 80 (except students).

BERI is a new organization but one that had a precursor activity, the Protein Engineering Research Institute (PERI). PERI was a 10-year program focused on protein engineering, lasting from 1986-1996, with about ¥17 billion in funding by JKTC and 14 companies.

Current management includes M. Furukawa, President (Chairman of Mitsubishi Chemicals), and Y. Shimura, Research Director (Professor Emeritus of Kyoto University). BERI, according to discussions, is managed by industry, with all intellectual property rights belonging to the institute.

RESEARCH AND DEVELOPMENT

Department of Molecular Biology

This department is focused on the analysis of the mechanisms of molecular interactions. Current research is focused specifically on: (1) the structure and function of the receptors for neuronal signaling molecules; (2) cloning and analysis of signaling molecules for growth factors; (3) analysis of the control mechanisms of gene expression during differentiation, and (4) identification of DNA polymerases and nucleases. These enzymes are important for DNA replication and recombination. An interest in extreme thermophiles is being pursued in the department. The current personnel associated with this department include 13 research scientists, four postdoctoral fellows, and 10 research assistants.

Department of Bioorganic Chemistry

As the name implies, this department is focused on bioorganic chemical interests dealing with enzymes, receptors, and innovative materials. It specializes in the restructuring of biomolecular systems into lower molecular weight substances and the creation of materials with new functions. This department is conducting research to understand biology and then use the information to produce new biomolecules that will have application to medical problems and industry. A strategy for efficiently mimicking and controlling the evolutionary process in vitro has been developed to create a new class of biomolecules with desired functions. In addition, this department analyzes the structure and function relationships of "natural" biomolecules and reproduces their functions in compounds of much smaller size. By combining chemical and biological technologies, it is stated that this department opens new paths to design and synthesize innovative materials. In keeping with the chemical focus, this department's philosophy is that "everything in biology or medicine has a chemical basis." The personnel associated with this department include seven research scientists, one postdoctoral fellow, and five research assistants.

Department of Structural Biology

This department is focused on determining the structures of many important biomolecules by using the most advanced technologies in X-ray diffraction, atomic force microscopy, cryo-electron microscopy, and nuclear magnetic resonance (NMR) spectroscopy. It is hoped that knowledge about these structures at an atomic level significantly enhances the understanding of biomolecules and how they function. This knowledge, in turn, is essential for rational design of novel molecules, such as inhibitors or activators that will solve environmental and medical problems. To date, this department has elucidated the 3-dimensional structures of proteins essential for DNA replication and repair, photoenergy conversion, and signal transduction in cells. The current personnel associated with this department include 10 research scientists, three postdoctoral fellows, and seven research assistants.

Department of Bioinformatics

This department is focused on a relatively new but important field, namely bioinformatics, which harnesses computers to analyze complex and vast databases in biology. Research is focused on computational analysis of genetic and structural databases that will advance the understanding of the interdependence of structure, function, and evolution. This department is also interested in how molecules are able to recognize and interact with each other. A major objective of research is to establish basic techniques and theories and set the foundation for general application of bioinformatics to many medical and industrial problems. The current personnel associated with this department include eight research scientists, one postdoctoral fellow, and one research assistant.

The interrelationship of these four departments is shown in Figure C.1.

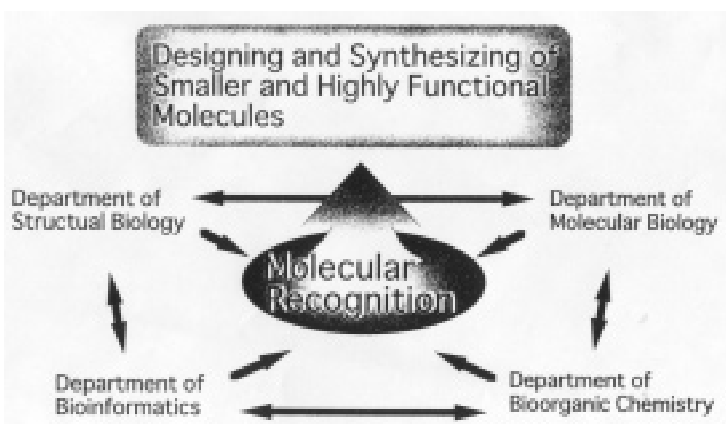

Fig. C.1. Research departments at BERI.

BERI research can be divided into three major research themes: (1) analysis of the mechanisms of biomolecular interactions (molecular recognition), (2) restructuring of biomolecular systems into lower molecular substances and the creation of materials with new functionality, and (3) development of biomolecular engineering core technology. The latter includes structural analysis and analysis of molecular recognition and theoretical and database analysis.

The full complement of personnel also includes 18 scientists from industry (included in the above department count), 14 graduate students, and an administrative staff of 13. Twenty of the research scientists are permanently employed by BERI. Foreign postdoctoral fellows are from the United States, Russia, China and France. Graduate students collaborate with BERI staff and come from local universities (e.g., Osaka University).

CORPORATE PARTICIPATING ORGANIZATIONS

Corporate participating organizations include the following:

- Ajinomoto Co., Inc.
- Asahi Chemical Industry Co., Ltd.
- Fujitsu, Ltd.
- Hitachi, Ltd.
- Japan Tobacco, Inc.
- Kaneka Corporation
- Kirin Brewery Co., Ltd.
- Kyowa Hakko Kogyo Co., Ltd.
- Mitsubishi Chemical Corporation
- Hoechst Marion Roussel, Ltd.
- Sankyo Co., Ltd.
- Shionogi & Co., Ltd.
- Suntory, Ltd.
- Takeda Chemical Industries, Ltd.
- Tanabe Seiyaku Co., Ltd.
- Toray Industries, Inc.
- Toyobo Co., Ltd.
- Yamanouchi Pharmaceutical Co., Ltd.

OBSERVATIONS

BERI research has been quite productive as judged by its appearance in some of the best journals: *Nature*, *Science*, *J Am Chem Soc*, *Cell*, and *J. Molecular Biology*.

Management has recognized the dual nature of research satisfying industry and also the university reviewers. BERI's objective is to produce results in the form of patents and also peer-reviewed publications in well recognized journals.

BERI has exceptional resources for conducting research derived from its physical facilities (laboratories, support structures, advanced instrumentation and equipment), partly acquired from its predecessor organization, PERI.

BERI has attracted some solid young university professors desiring to conduct quality research in an institute setting (as opposed to staying in a university). This is due to the students' belief that they can accomplish more in a shorter time even though the risk is higher (less employment certainty due to the termination of BERI in a few years).

BERI's current management is experienced and comes from the chemical and pharmaceutical industries. As such, it is quite knowledgeable about research and the time required for its translation into commercial results.

Site: **Biophotonics Information Laboratories, Ltd. (BIL)**
Yamagata Prefecture Advanced Technology R&D Center
2-2-1 Matsuei
Yamagata 990-2473, Japan

Date Visited: 15 October 1998

WTEC Attendees: O.R. Zaborsky

Hosts: Dr. Masaichi Shinoda, Executive Director, President
Hideo Sekiguchi, General Manager, Technical Administration

BACKGROUND

The mission of the Biophotonics Information Laboratories, Ltd. (BIL) is to understand the various states of life through information gleaned from biophotonics, the study of light-biological interactions. BIL is an element of the “Life Support Technology Plan” of Yamagata Prefecture and is intended to develop the Tohoku region as a center of excellence in science and technology.

The project’s objective is the development of life support technologies through technologies for non-invasively measuring the functions and structures of living systems at high speed using light. Expected results include the following:

- Defining the characteristics of biophoton phenomena of cancer cells.
- Studying the active oxygen generating mechanisms of leukocytes. When completed, the applications are expected to include treatments of patients with diseases caused by insufficient active oxygen generation.
- Measurement of light scattering through coherent detection imaging technology based on optical heterodyne technology. Optical computer tomography (CT) images of hard tissue (teeth and bones) have been obtained that can then be used in medical diagnostics. With the hand as the model biological system, optical images have revealed structural details about the joints, bones and some of the blood vessels. A high-quality image has been achieved in terms of resolution and contrast.

BIL was founded in March 1993 by 13 firms and several Yamagata Prefecture organizations and foundations. It is a 6-year joint research project terminating in 1999, with a planned fund of ¥3.45 billion of which 70% is invested by the Japan Key Technology Center (JKTC) and 30% by participating companies.

Management at the time of this WTEC visit included Michio Fujisaki, CEO (Fujitsu), Dr. Masaichi Shinoda, Executive Director and President (Fujitsu Ltd.) and Mr. Hideo Sekiguchi, General Manager, Technical Administration. Strong motivation for this project came from Professor Humio Inaba, Tohoku Institute of Technology, also a Director. Senior technical staff includes K.P. Chan, B. Devaraj, M. Kobayashi, and J. Miyazaki.

RESEARCH AND DEVELOPMENT

BIL’s research is focused on biophotonic phenomena that include the following:

- Biophoton emission—spontaneous ultra weak light emission emanating from all living cells, the result of ongoing biological processes.
- Biological fluorescence—the absorption of light at a certain wavelength with a re-emittance at a longer wavelength.
- Optical absorption—specific light absorption characteristic of structure and chemical composition. Differences in absorption can be used to determine the states of living systems.

- Optical scattering—scattering of light in various directions caused by the complex and heterogeneous nature of biological systems. Information provided by scattered and reflected light can be used to identify structural differences.

Research and development work has been focused on the following:

- Sensing and imaging technology for ultra weak light emitted from biological substances in the visible or near infrared region. In particular, the focus has been on the characteristics of light emitting sources and their modeling, light detection, spectroscopy, and imaging. Research on hardware has covered InGaAs photodiode light receptive elements, polychrometers, acoustic optical tuning filters, and signal processing technologies such as photon statistics and correlations.
- Optical heterodyne technology and coherent detection imaging technology for the measurement of the functions and structures of living systems. Research in this category includes performance improvement and functional enhancement, relation between measuring wavelength and biological functions, computer tomography imaging technology and applications. Solid state variable wavelength lasers have been included as a generic technology component.

BIL consists of three laboratories with 21 researchers. The three laboratories are as follows:

1. Biophoton Laboratory
2. Device Development Laboratory
3. Bio-Imaging Laboratory

In addition, BIL is advised by three committees:

4. Technical Evaluation Committee, which convened at the start of the project and at the end of year 2 and within JKTC
5. Technical Advisory Committee, which convenes annually and consists of experts in relevant technology fields
6. Technical subcommittees, which convene when required and consist of technical specialists from participating organizations

COMPANIES SUPPORTING BIL

The companies supporting BIL are the following:

- Fujitsu, Ltd.
- Yamagata Technopolis Foundation
- Shimadzu Corporation
- NEC Corporation
- Fuji Film Co., Ltd.
- The Tohoku Intelligent Cosmos Promotion Council
- Tohoku Electric Power Co., Inc.
- Hitachi Cable, Ltd.
- Fujikura, Ltd.
- The Furukawa Electric Co., Ltd.
- Sumitomo Electric Industries, Ltd.
- Toshiba Corporation
- Indeco, Inc.
- Kawasaki Electric Corporation

- Kojinkai Hospital
- Tohoku Electronic Industrial Co., Ltd.
- Topcon Yamagata Co., Ltd.
- The Yamagata Bank, Ltd.
- Yonezawa Hamari Chemicals, Ltd.

OBSERVATIONS

BIL is dedicated to biophotonics, one of two such organizations formed by JKTC.

BIL's focus on optical imaging of tissues seems to have been well placed, and results are quite impressive in that fine details not available by magnetic resonance imaging can be seen (e.g., structural details of the joint region, bones and blood vessels).

BIL, while relatively small in terms of personnel, has achieved good results in technology developments in the biomedical imaging field and also in publications. The results and data described in the visit have been published and presented at some leading U.S. meetings (e.g., Gordon Conference).

The motivation for establishing BIL came from a leading local university professor, Humio Inaba, who also has been instrumental in providing key researchers to this effort (e.g., Dr. Kimpui Chan, Dr. B. Devaraj).

The application of biophotonics to biomedicine is receiving highest priority, but applications are also being pursued in agriculture, an area of local interest (farmers).

Economic development is a major objective of this project, more than other JKTC projects in the biotech area visited. BIL is part of a larger industrial park, the Yamagata Prefecture Advanced Technology R&D Center.

Site: **Digital Vision Laboratories (DVL)**
Place Canada, 3-37, Akasaka
7-chome, Minato-ku
Tokyo 107, Japan
http://www.dvl.co.jp/

Date Visited: 16 October 1998

WTEC Attendees : P.O'Neill-Brown, G. Gamota, I. Feller, P. Herer

Hosts: Hitoshi Aoike, Senior Vice President, Chief Technical Officer
Masaru Tomochika, Vice President, Operations
Yasushi Nishimura, Senior Manager, Digital Media Viewer, R&D
Kunio Hane, PhD, R&D Technology Executive
Tatsuji Igarashi, R&D Technology Executive and Senior Manager, Client Server, Research and Development
Minoru Ashizawa, Senior Manager, Architecture, Research and Development
Yutaka Ohyama, Senior Manager, Script Research and Development
Emiko Kezuka, Senior Engineer, Research and Development

BACKGROUND

Digital Vision Laboratories (DVL) is set up as a limited stock holding company, as are the other businesses established by the Japan Key Technology Center. The shareholders of DVL are Japan Key Technology Center, ASCIII Corporation, Sony Corporation, NEC Corporation, Matsushita Electric Industrial Co., Ltd., Toshiba Corporation, Hitachi, Ltd. and Fujitsu, Ltd. The planned period of test research is from March 1995 to March 2000. Support from JKTC will cease at the end of the five year project period. At the end of the project period, at the member companies' own expense, DVL will remain in business to manage the licenses that it will grant. DVL will license its technologies to its member firms, and as required under the terms of the JKTC grant, to any other party wishing to license the technologies. Member firms do not have first refusal rights—DVL can license its technologies to anyone in any order.

DVL's goal is to establish an international digital standard for data manipulation, including storage, retrieval and interchange across electronic devices. DVL is said to have competitors who are seeking to have their protocols for these procedures adopted as digital standards.

The operating cost of DVL for the five-year period is ¥6.1 billion (~$61 million), with ¥4.27 billion (~$42.7 million) from the Japan Key Technology Center. The staff members are sent to DVL by the member companies, and after the project is completed, they will return to their host organizations. DVL has a steering and a technical committee, upon which a representative from JKTC and MITI sit. DVL has applied for 150 patents in the United States and Japan, of which 40–50 are U.S. applications.

DISCUSSION

Interviewees implied that the sponsor firms joined together to form DVL and then approached MITI about support for the new firm. MITI then directed them to JKTC.

DVL is developing software specifications and protocols to enable efficient data handling and the sharing of data across a variety of electronic devices. These software specifications and protocols are as follows:

- MMB, Machine Understandable Metadata Broadcasting, to allow data interchange between computing and consumer electronic devices.
- MMF, Multi-Schema Metadata Format, and MMP, Metadata Mediation Protocol, for data storage and retrieval for use in networked electronic commerce systems. MMF and MMP have been submitted to the World Wide Web Consortium for approval as standards.

- DMV, Digital Media Viewer, an application programming interface (API) for creation of software for DMV compliant platforms. The API provides access to the operating system, graphics and sound hardware, input devices, network (Internet) and audio visual devices (such as VCRs); and middleware, called GCP, Global Computation Platform, which allows for distributed object programming, asynchronous message-passing and concurrent execution, message evaluation scheduling for real-time control demand, flexible object space management for openness and scalability, and which can handle multimedia data structures.

JKTC reviewed DVL's activities at the end of the company's third year of operation. DVL prepared a 100 page report on its technical work, patents, and papers and provided demonstrations of its technology to an evaluation committee. The technical reviews were conducted by university professors. DVL reports that JKTC's committee was favorably impressed by its accomplishments. DVL also submitted a business plan for an independent, third party review. The review comments were also favorable on the business plan; accordingly, JKTC gave its permission for DVL to proceed with its research and business activities.

DVL's shareholders can be grouped into four categories:

7. government (Japan Key Technology Center)
8. Japan's premier consumer electronic device companies (Sony Corporation and Matsushita Electric Industrial Co., Ltd.)
9. Japan's leading computer hardware/software companies (NEC Corporation, Toshiba Corporation, Hitachi, Ltd., Fujitsu, Ltd.)
10. a publisher of computer and game-related magazines and books, marketer of multimedia products and developer of game software (ASCII Corporation)

This combination of stakeholders creates an interesting and important dynamic. DVL managers described the company as somewhat of a novelty within JKTC, as the one software firm in a program essentially designed to support the development of key hardware technologies. However, while DVL may appear to be a novelty in the JKTC program, if viewed in the context of how the Japanese historically have approached software development, DVL turns out to be not so novel after all.

The panel was told that the member firms of DVL came together because each expected to achieve something that they could not develop on their own. In particular, the objective was to ensure that the software specifications being designed would be supported in the hardware. This has been a classic approach to Japanese software development.

The fact that hardware and software companies are cooperating with consumer electronic device companies to develop software specifications for data sharing and handling across these devices means that the software specifications will have strong support on the devices intended for them to run on. NEC, Toshiba, Hitachi and Fujitsu are what Smith and Cusumano term "classic software producers" (Smith and Cusumano n.d.). Classic producers are also the makers of the hardware and link development of the software they create intimately with the hardware intended for it to run on. For the classic producers, the support of hardware is a significant factor driving the content and schedule of a release. This release structure and strategy policy of the "classic software producers" is contrasted with that of the "PC software developers," who are not as strongly driven by issues of hardware support.

No similar effort in the United States is conceived of in this way. There are no instances of hardware manufacturers and software developers getting together, forming a new company, receiving government funding, and working together to develop digital standards.

In addition to developing digital standards, DVL is creating applications that implement the specifications and protocols the company is developing. For instance, MMF and MMP are implemented in an e-commerce system being deployed on InfoSeek Japan. Clearly, the deployment of this e-commerce system is more than a foray into the buying and selling of goods. It is also, and perhaps even more importantly, a proving ground for the partner companies to test the viability of the specifications and protocols they are developing.

The vision is that after the five-year period, what will be created are Japanese, and perhaps even international, standards that will enable the development of new technologies designed to run across a variety of media, including electronic commerce, education, and gaming applications.

DVL is working with JKTC to try to eliminate some of the administrative barriers that it faces as a software firm. DVL noted that there is a “linear” process in hardware development, in which a firm progresses from R&D to manufacturing, and then to marketing its products. By way of contrast, the software development and release life cycle is concurrent: R&D, manufacturing and marketing need to all occur at once. JKTC does not provide funds for marketing support. DVL is working with JKTC to try to see that this policy is changed.

The environment created by this limited stock holding company motivates and maintains the interest of researchers. The researchers WTEC panelists interviewed said that they enjoy the work they are doing at DVL more than the work they had been doing at their home companies. Their enthusiasm is most likely due to the fact that they are directly involved in the creation of the supporting mechanisms that will enable the growth and development of cutting-edge technologies, and they have their eyes directed towards the day when they can create their own applications based on these standards back in their own home labs.

Unlike the *keiretsu* model in which shareholders in a firm are held together by a bank, in the case of DVL the shareholders are tied together through government funding. However, there is a key distinction between the Japanese government funding DVL and a bank as a source of funding. The Japanese government has set itself up as the major shareholder in all of the companies funded by the Japan Key Technology Center in an attempt to ensure that the fruits of the research and development will be distributed on a wide basis. Thus, the role that the government has carved out for itself is to (a) support standards development and (b) ensure that the standards will be made available to any Japanese company that plans to support or develop products of this sort. A bank does not have and would not take on such a mission.

As the Japanese look into the crystal ball and see their digital future, DVL pops up as a vivid image. It is clear that the JKTC policy objective here is to see to it that member companies of DVL are not the only beneficiaries of this project, but Japanese industry at large as well as the consumer/citizen. The vision is surely that DVL’s contribution to the “digital scene” will be to enable any company to develop new products and services based on the protocols and specifications it establishes.

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Site: **Environmental Immuno-Chemical Technology Co., Ltd. (EIT)**
Satte Office
1134-2 Gongendo, Satte-Shi
Saitama-Ken 340-01, Japan

Date Visited: 14 October 1998

WTEC Attendees: O.R. Zaborsky

Hosts: Tetsuya Zemba, Chairman, COSMO Research Institute
Mikio Yoshida, General Manager, General Affairs Department
Magaro Hayashi, Research Manager, R&D Division
Yojiro Yuasa, General Manager, R&D Division
Yasuo Iwamiya, Dir. and General Manager, New Products and Technology Laboratory
Hiroki Kamiyama, Managing Director, COSMO Research Institute

BRIEF DESCRIPTION

The mission of the Environmental Immunochemical Technology Co., Ltd. (EIT) is to develop a rapid and highly sensitive analytical method for identifying environmental pollutants. In particular, the objective is to develop immunoassays for detecting chemicals released into the environment. To date, the major focus of efforts has been on screening for pesticide residues in food and water. EIT was established in 1994 with the participation of 6 companies covering the spectrum from chemical raw material supplier to pesticide producer to analytical instrumentation manufacturer. EIT is a 5-year joint research project, with planned funding of $10 million of which 70% comes from MITI through the Key Technology Center program and 30% from participating companies.

At the time of this visit, management included Mr. Tetsuya Zemba, Chairman, Cosmo Research Institute, Mr. Yojiro Yuasa, General Manager of R&D Division, and Dr. Masaro Hayashi, Research Manager of R&D Division.

EIT, which has its headquarters in Tokyo, is divided into six divisions, with each private company having a division. The companies involved, with division responsibilities, respectively, are the following:

- Kumiai Chemical Industry Co., Ltd., a manufacturer and seller of pesticides (Division 1, located in Shizuoka)
- Ohtsuka Chemical Industry, Co. Ltd., a manufacturer and seller of pesticides, Division 2, located in Tokushima
- Cosmo Research Institute, Ltd., a subsidiary of Cosmo Oil Company and the lead organization of this effort (Division 3, located in Saitama)
- Iatron Laboratories, Inc., a manufacturer and seller of clinical diagnostic equipment (Division 4, located in Chiba)
- Nihon Millipore, Ltd., a subsidiary of Millipore Corporation and seller of biotechnology equipment and instruments (Division 5, located in Tokyo)
- Toray Research Center, Inc., a subsidiary of Toray and active in analytical services (Division 6, located in Kanagawa).

RESEARCH AND DEVELOPMENT

Major research areas (with divisional responsibilities) are as follows:

- molecular design and synthesis of analyte (hapten) derivatives (divisions 1 and 2)
- production of antibodies—monoclonal antibodies (divisions 3, 4 and 6)

- establishment of immunoassays (divisions 3, 4 and 6)
- validation (all divisions)

Flutolanil (a,a,a-trifluoro-3 isopropoxy-o-toluanilide), regulated in Japan in more than 130 different farm products with maximum residue levels of 1-2 ppm, is being used as the model pesticide to develop the technology. Flutolanil is used on golf courses and rice fields. Monoclonal antibodies are also being developed for 10 other pesticides. Flutolanil is a small molecule, and hence there needs to be a spacer arm for antibody formation.

EIT currently is composed of 21 researchers, five of whom have PhDs. Disciplines included are chemistry, molecular biology, and analytical biochemistry. EIT is also starting to work with some academic institutions (e.g., Kobe Medical School) as well as agricultural and analytical institutes (not named) to disseminate immunoassay technology in Japan.

OBSERVATIONS

EIT is an effort dedicated to a very specific technology, i.e., immunoassays for pesticides. As such, it is the most dedicated effort within the biotech centers this WTEC panel visited.

EIT was planned to take advantage of its participating member firms that had some background technology, especially the Cosmo Research Center, the lead firm. This objective has been achieved.

Research results have led to the formulation of a test for flutolanil, a broad-spectrum fungicide using a competitive enzyme-linked immunosorbent assay (ELISA test). Other tests are being developed, but no timetable was given for their completion or commercialization.

EIT represents a good example of a very pragmatic group of companies and researchers dedicated to a very tangible and realistic goal, namely to achieve a more cost-effective bio-based screening system for pesticides in soil, water, and food. Commercialization of the immunoassay had not yet been achieved at the time of this visit.

Research results are starting to be disseminated through publications and through presentations at meetings (e.g., Association of Official Analytical Chemists, AOAC).

Site: **Helix Research Institute, Inc. (HRI)**
1532-3 Yana, Kisarazu-shi
Chiba 292-0812, Japan
http://www.hri.co.jp/english/home_e.html

Date Visited: 12 October 1998

WTEC Attendees: O.R. Zaborsky

Hosts: Yasuhiko Masuho, PhD, Managing Director
Kenji Nagahari, PhD, Director of Research Strategy Dept.

BRIEF DESCRIPTION

The mission of the Helix Research Institute (HRI) is to develop effective technologies for identifying new biologically important genes and evaluating their functions. HRI was established on March 28, 1996 with the active participation of 10 companies, mostly involved in pharmaceutical research. HRI is a 6-year joint research project, with a planned fund of ¥6.6 billion of which 70% comes from MITI through the Key Technology Center program and 30% from participating companies.

Current management includes Mr. Osamu Nagayama, President (CEO of Chugai Pharmaceutical Co., Ltd.), Dr. Yasuhiko Masuho, Managing Director (Yamanouchi Pharmaceutical Co., Ltd.), and Mr. Hitoshi Watanabe, Director of Administration (Fujisawa). The past president and inspirational founder of HRI was Dr. Teruhisa Noguchi, formerly associated with Yamanouchi Pharmaceutical Co., Ltd. and Suntory. Dr. Noguchi is now president and CEO of two new institutes, Tenox Institute and Medico Frontier Institute.

DEPARTMENTS AND LABORATORIES

HRI is divided into three major departments or laboratories.

Genomics Laboratory

The Genomics Laboratory is focused on establishing methods for high-throughput cloning of complete full length cDNA and identifying gene function using new core technologies, such as the use of electro-optical devices for effective measurement of expression profiles. This laboratory is supported by the Bioinformatics Laboratory, which performs sequence analyses and functional predictions of new genes. The Biological Technology Department is linked to the work of this Genomics Laboratory by developing experimental methods for evaluating gene function using techniques such as gene expression profiles. The current personnel associated with this department include one principal scientist, one senior scientist, one scientist, and six technicians.

Bioinformatics Laboratory

The Bioinformatics Laboratory is focused on providing integrated bioinformatics service to HRI's Genome Laboratory and conducting research and development on new tools for bioinformatics. The current personnel associated with this department include one principal scientist, five senior scientists, and three systems engineers.

Biological Technology Laboratory

The Biological Technology Laboratory is focused on the functional analysis of full-length cDNAs generated and characterized within the Genome and Bioinformatics Laboratories, respectively. HRI staff members strongly believe that high throughput analysis of gene function will be the key technology in the next generation of genomic research, and HRI's ultimate goal is to create a system for screening gene function.

This unit is also interested in secreted proteins and signal transduction molecules in neuronal cell function. HRI's aim is to narrow down genes of important biological function that may potentially be targets for new drug discovery. The current personnel associated with this department include one principal scientist, five senior scientists, three scientists, three postdoctoral fellows, seven technicians, and five visiting scientists.

The interrelationships of these departments or laboratories and their major current research areas are shown in Figure C.2.

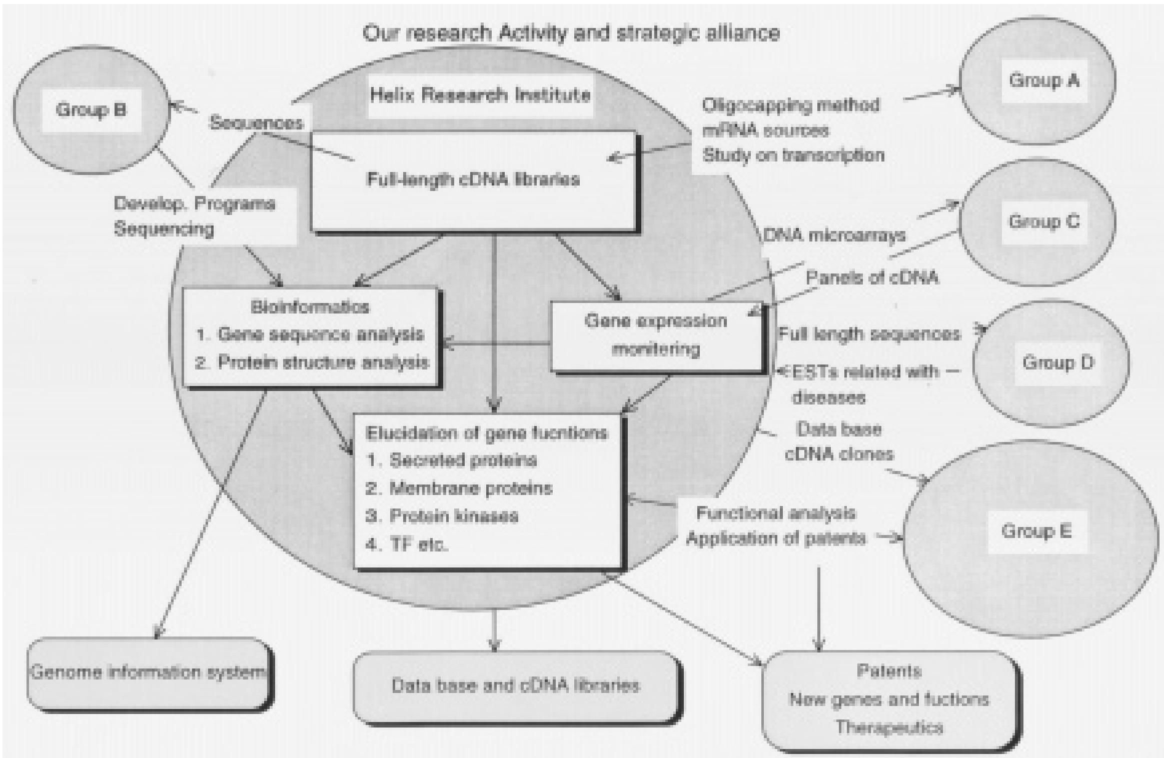

Fig. C.2. HRI research activities and alliances.

In terms of collaboration with others, the most significant activity currently in place is with Dr. Sugano, Tokyo University, who developed an efficient cloning method for obtaining complete, full-length cDNA using an oligo-cap method. The method has been described in a publication (Maruyama and Sugano, Gene 138, 171-174, 1994). The full-length enriched cDNA libraries from cultured cells and tissues are constructed using his method, as is a mammalian expression vector for direct application to functional analysis in biological assays. As a result, HRI is trying to clone new genes efficiently, particularly those related to human diseases associated with the central nervous system. In addition, HRI has an interest in monitoring the coordinated expression levels of genes in order to decipher the logic for gene regulation.

The 10 companies supporting HRI are as follows:

- Kyowa Hakko Kogyo Co., Ltd.
- Sumitomo Chemical Co., Ltd.
- Taisho Pharmaceutical Co., Ltd.
- Chugai Pharmaceutical Co., Ltd.
- JAFCO Co., Ltd.
- Hitachi, Ltd.
- Fujisawa Pharmaceutical Co., Ltd.
- Mitsubishi Chemical Co., Ltd.

- Yamanouchi Pharmaceutical Co., Ltd.
- Yoshitomi Pharmaceutical Co., Ltd.

OBSERVATIONS

HRI's founder (Dr. Noguchi) and current managers are experienced individuals coming from the research-savvy pharmaceutical industry who have connections in the United States. For example, Noguchi was associated with Rockefeller University.

HRI is a relatively new organization tackling a major area in which Japan is behind (at least five years as stated by several investigators and managers). However, HRI has excellent resources (the latest and best in DNA technology equipment and instrumentation) and is actively engaged with several companies (especially Hitachi) to pursue niche opportunities in genomics. Hitachi is particularly active in bioinformatics technology developments.

HRI management has recognized that collaboration is a key to success in this fast-moving area and has initiated such interaction with Japan's scientists. There is also recognition that international collaboration is good, especially in the form of visiting scientists from Europe and the United States.

Site: **Japan Society for the Promotion of Science (JSPS)**
4F, Yamato Building, 5-3-1, Kojimachi
Chiyoda-Ku Tokyo 102-0083, Japan
http://www.jsps.go.jp/

Date Visited: 15 October 1998

WTEC Attendees: I. Feller, P. Herer

Hosts: Kimio Muranatsu, Head, Research Promotion Division
Yasuyuki Tamaki

JSPS is a quasi-government agency. It operates under the auspices of the Ministry of Education, Science, Sports, and Culture (Monbusho). Its major activities include international scientific cooperation, such as scientific exchange of researchers and joint seminars with the United States, France, Great Britain, and several other countries, and fellowships for young researchers. JSPS reports a close relationship with the National Science Foundation, the National Institutes of Health, and the National Cancer Institute in the United States.

One of the objectives of JSPS is to foster collaboration between researchers in private industry and universities. Recent steps taken in Japan in this regard include government support of joint activities between private sector institutions and national universities. At Hokkaido University, for example, the government will lend the private sector land on campus to set up a laboratory at which industrial researchers will conduct cooperative research with the faculty and research staff of the university.

Some private universities are now reported to have established contractual ties with companies. In the past, government relations have limited the ability of national universities to work with industry. It was seen as unfair if national universities were to serve the interests of one or another firm. A compounding factor limiting university-industry collaboration has been the “mentality” of universities that they need to retain their independence in conducting research and not be restricted by industrial priorities. Furthermore, universities and industry have traditionally vied for supremacy between their basic research programs.

Improved cooperation is emerging as the boundaries between basic research and applied research become blurred. In addition, what research universities term basic is in fact becoming more applied, and what industry terms applied is becoming more basic. Thus, the gap between the two is narrowing. Both parties understand that these changes are occurring, and are seeking new opportunities to work together more closely.

In the past national universities were for elites; now they are becoming more open and democratic, which has led them to accept the need to work more closely with industry. Attitudes are changing, and university leaders have come to realize the need to work synergistically with industry for the betterment of society.

Site: **Japan Key Technology Center (JKTC)**
Ark Mori Building, 16F, Akasaka 1-12-32
Minatoku, Tokyo 107-6016, Japan
http://www.jktc.go.jp/

Date Visited: 12 October 1998

WTEC Attendees: I. Feller, G. Gamota, R. Harris, P. Herer, P. O'Neill-Brown, O.R. Zaborsky

Hosts: Mr. Toshiuki Yazaki, Director, General Affairs Division, General Affairs Department
Ryuko Fujii, Director, Loan Department
Hitoshi Funamachi, Director, General Affairs Department
Mr. Ikeda

BACKGROUND

The Japan Key Technology Center (JKTC) was established under a special law in 1985. It is financed jointly by the government and private industry for the purpose of promoting research and development on "fundamental key technologies of private industries." JKTC's main activity is to provide loans for R&D by private concerns and investment capital to joint R&D companies set up by private concerns. From an economic perspective, JKTC support reduces the financial risks that firms face as they pursue technological advances.

The center also provides other services such as coordinating arrangements for joint research with national research institutes, inviting overseas researchers, disseminating research data held by national research institutes, government-affiliated bodies, and carrying out various surveys related to key technologies. Since its establishment, the center has assisted more than 360 research and development projects.

JKTC has a staff of 54. Its annual budget for capital investment and loan services is roughly ¥28 billion, largely derived from the Japanese government's holdings of shares in Nippon Telegraph and Telephone Corporation (NTT). Dividend income from these shares provides JKTC's core annual revenues (of about ¥26 billion).

JKTC funds are used provide direct investments and loans to the private sector and to finance its own operations. JKTC provides up to 70 percent of the R&D funds through loans and up to 70 percent through direct investment; the private sector firms provide the balance. JKTC provided no statistics on the distribution of investments or loans by size of firm.

JKTC is analogous to a government-operated venture capital fund. (JKTC representatives noted that there was little venture capital in Japan for "upstream activities," such as R&D start-ups. Venture capital is, however, said to be available for "downstream" activities such as improving manufacturing capacity).

LOANS

JKTC provides loans for funds needed to obtain intellectual property rights to the results of the R&D and for R&D projects carried out by companies, mainly from the applied research phase. Two types of loans were described to the visiting WTEC delegation: "A" loans, which are made to firms of all sizes; and "B" loans, which are directed at firms within a capital of less than ¥10 billion. In the case of loans, if the project is not going well, JKTC will reduce the interest rate it charges. In the case of B loans, JKTC will reduce both the interest rate and the loan's principal. Typically, loans are required to be repaid within 10 years from the completion of the deferment period (R&D period).

JKTC officials stated that because of the economic downturn, many more small businesses have been applying to JKTC for loans.

DIRECT INVESTMENT

In the case of direct investment, JKTC and the participating companies hold appropriate shares of stock in the new venture company. JKTC reports that one of the shareholder firms is usually selected as the "lead" company. Note that investment support typically involves a number of firms (although the number can be as low as one). At the time of application, the firms effectively set up a new joint venture. If other firms want to enter subsequent to the launching of the new firm, they must enter into agreement with the original firm. JKTC reports that no new entries have been refused: firms both enter and leave the joint venture.

Direct investment financing is provided for the expected life of the R&D project (typically 7 years). At the end of the R&D term, the R&D firm completes its activities and becomes instead the company (or corporate shell) to manage the intellectual property holdings (if any) flowing from its research findings. Once a firm starts to earn net revenues, it pays dividends to the member firms and to JKTC. The firm also pays corporate taxes.

Since its inception, JKTC has funded 74 investment projects. Forty-seven projects have been completed; 27 were ongoing at the time of this visit. Although as a private firm, the R&D venture could presumably move into production, JKTC reports no case of this development.

JKTC describes its objective as improving the level of Japan's key technologies. Management representatives stated that JKTC does not exist to make a profit, although they also report pressure from the Ministry of Finance to increase the number of patents from the firms JKTC helps create (and presumably, therefore, the license income stream).

Projects are based on private sector initiatives, not on JKTC priorities or solicitations by JKTC for R&D efforts in a specific technological area. JKTC's role is to conduct an assessment of the technical and business merits of the proposals it receives. Final decisions on the technological areas to be supported are based on JKTC's enabling legislation, which emphasizes the major areas of telecommunications, electronics and biotechnology (JKTC brochure).

JKTC issues program announcements once or twice a year announcing the availability of funds. Project selection criteria, which are listed on JKTC's homepage, include technical quality, the impact of R&D, the breadth of the technical solution (its cross-disciplinary effects), and whether the R&D system is appropriate. No ex-ante allocation of funds is made across technical fields.

JKTC describes itself as exerting little control over the management of funds once they are allocated to firms. Rather it describes its role as that of a monitor of performance, employing a series of technical/business reviews.

JKTC's review procedures were described as follows: it conducts an evaluation of the initial proposal, an interim, third-year assessment, and receives a final report. Japan's recession has led to a credit squeeze on both large and small firms, particularly the latter; as a result, JKTC has received a large number of proposals from small- and medium-sized companies. JKTC is not planning to change its review procedures to accommodate these proposals.

Once a project is funded, there is little likelihood that it will be terminated for inadequate progress. JKTC reported no case of any project not passing its third year evaluation. The third-year evaluation was reported to have led to changes in the direction of a firm's R&D activities and to both increases and decreases in JKTC funding levels.

Procedures for the third year review were described as follows: the R&D venture firm prepares a report, which is submitted to the technology analysis committee. The committee holds hearings at which the firm's representatives respond to questions. The committee reports its findings on the technical progress of the project to JKTC. The review is said to include an assessment of what has been accomplished. JKTC reviews the report, discusses internally how to present the findings to the firm and then provides feedback to the firm. No specific format for the assessment is reported.

JKTC describes itself as lacking the staff to conduct its own evaluations of the technical and business progress of projects. Instead, project evaluation relies on a technology analysis committee made up of 82 professors. The technology analysis committee is divided into eight technical subcommittees corresponding to the major categories of research, and some cross-category subcommittees are established for selected projects.

JKTC officials declined to disclose the review criteria form or the names of the 82 faculty members of the technology analysis committee. JKTC policy has been to keep these names confidential because professors reportedly are reluctant to have their names published. This is because of the risk of possible contact of assessment committee members by participating firms. JKTC has recently changed its policy on the confidentiality of names. Beginning in April 1999, it was scheduled to make public the names of the 1998 committee members, thus moving to a policy of making known the names of the previous year's panel.

Faculty members are appointed to the review panel for a one-year term. Formal appointment to the technology analysis committee is made by Mr. Toyoda, JKTC's chairman. However, effective appointment is based on recommendations of existing members. No industrial representatives are on the technology analysis committee.

JKTC has set up a business feasibility committee and also employs an accounting firm to do business reviews of the proposals. JKTC managers acknowledged that procedures and methods for conducting evaluations needed attention.

No data were provided on the acceptance rate of proposals, although it appears from the interview that this rate is very high.

The interim evaluations can lead to changes in the project and to budget changes including both increases and decreases.

There is no direct investment by U.S. firms in JKTC firms, but the Japanese subsidiaries of U.S. firms have invested in several JKTC R&D firms. Non-Japanese firms are reported as able to license the technologies following the same patent arrangements that would be used for any other non-JKTC patent. One such actual case was cited.

There are no explicit criteria related to local or regional economic development. MITI has its own programs to support regional economic development.

The metrics on impact evaluation do not take into account the quality of the research. No formal procedures for benchmarking the performance of centers were reported.

JKTC officials strongly encourage firms to patent and publish results and refer to patents and papers as the major outcome metrics. It was noted that over the past 13 years JKTC projects have resulted in 4,226 patent applications and over 16,000 technical papers and presentations. There have been a few new business start-ups (focused on downstream production).

As of 1998, revenue from the licenses to JKTC has been modest—only ¥2 billion has resulted from investments totaling ¥240 billion. JKTC officials report encouragement from the Ministry of Finance to show more income from licenses. Also, they see the need to take into consideration exclusive licenses.

JKTC officials noted that it was very difficult to judge projects. Again, they referred back to the flow of knowledge to the firms, but they have no way of tracking the flow (and impact) of knowledge after the R&D phase of the project has been completed.

JKTC officials recognize the importance of the flow of knowledge from human mobility as a mode of technology transfer. (New venture companies may hire new people and/or transfer staff from the parent companies.) They also note that joint ventures are useful as technological training grounds.

WTEC's JKTC hosts noted that they are thinking about a more general evaluation of R&D cooperation in Japan. This project presumably will be undertaken by MITI's Agency for Science and Technology, which has responsibility for several government–industry cooperative R&D programs.

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Special loan services for R&D companies (one page description) and image figure of special loan services.

Descriptions of investment projects, 1995-97.

Japan Key Technology Center (brochure).

Law for the facilitation of research in fundamental technologies.

Site: **Ministry of Posts and Telecommunications (MPT)**
Communication Industry Finance Planning Division
Communication Policy Bureau
Kasumigaseki, Chiyoda-ku, Tokyo, Japan
http://www.mpt.go.jp/outline/compoli.html

Date Visited: 12 October 1998

WTEC Attendees: I. Feller, P. Herer

Hosts: Mr. Masahiko Kitamura, Deputy Director, Communications Industry Finance Planning Division
Mr. Nozaki
Mr. Kobayashi

MPT, along with MITI, supervises JKTC. Beyond the guidelines contained in JKTC's enabling legislation, MPT neither specifies the technical areas that JKTC is to support nor provides budgetary support to supplement JKTC's core budget (from pass-through of NTT dividends). MPT's oversight role of JKTC primarily consists of checks on the overall composition of its projects, although, as noted, MPT doesn't set specific R&D areas for JKTC to support. The basic philosophy of the JKTC program is that if the private sector determines an R&D project is necessary then MPT, through JKTC, will support it (as long as it fits the general guidelines of the enabling legislation).

Evaluation of JKTC projects is done by a panel of academics in the third year of each project's life.

JKTC supports private sector R&D. It is highly valued by MPT for its work in telecommunications.

No plans were contemplated to review the basic JKTC law, even though JKTC had been in existence for 13 years. The enabling legislation set out basic principles and was not very detailed. Thus, JKTC's management procedures and policies can be dealt with flexibly, without changing the basic law.

Based on the Japanese government's past experience in funding private sector ventures, the need for financial standards, such as collateral for loans, has become apparent.

MPT officials do hope that the centers and related R&D projects will provide the basis for regional economic growth. ATR, for example, is located in "academic city" based on the Silicon Valley model.

WTEC's MPT hosts expressed the view that it is a good idea to provide B loans to small- and medium-sized firms (B loans are considered one type of support to venture firms).

MPT, on occasion, may suggest to firms that they consult with other MPT bureaus before going to JKTC, and there are occasions where MPT may recommend that the firms involved in a JKTC proposal contact other bureaus.

Site: **Mixed Reality Systems Laboratory, Inc. (MRSL)**
6-145 Hanasaki-cho, Nishi-ku
Yokohama 220, Japan
http://www.mr-system.co.jp/index_e.html

Date Visited: 14 October 1998

WTEC Attendees: G. Gamota, P. O'Neill-Brown

Hosts: Toshio Kitamura, Advisory Director
Juji Kishimoto, Director

BACKGROUND

Mixed Reality Systems Laboratory, Inc. (MRSL) is one of the newer JKTC projects, and it is unique in that it has only one investor from the private sector, Canon Corporation. The project was approved in FY1996 and established on January 31, 1997. The duration of the project is 4 years and 3 months (making it one of the shorter JKTC projects).

JKTC investment is 50.1%, while Canon investment is 49.9%. Total investment is ¥5.409 billion. The company is run by a Board of Directors; the members are all Canon executives. The staff consists of 32 researchers, most of whom are from Canon. The exceptions are those with special skills needed for the planned research. Those people work under contracts. Foreign participation is encouraged: a specialist is being invited from the United States to spend a year or more, and two students from MIT Media Lab work at MRSL. MRSL also has joint research activities with the University of Tokyo, University of Tsukuba and Hokkaido University

The genesis of this project began when JKTC advertised for proposals in this area of research. Canon, admittedly little known in this area of technology, saw an opportunity to go into a new area with a possible long term benefit in identifying new product areas. By merging government support with its own resources Canon saw a way of strengthening its own future with support from the government. MRSL will offer patents and licenses to all interested parties, but Canon will have first rights of refusal to any discovery.

RESEARCH

The aims of the research are as follows:

- Develop technologies for building a composite environment model from geometric and radiometric structures of the real world, using 3-D graphics measurement and recognition technologies.
- Develop technologies that enable the seamless and real-time fusion of the physical space and a cyberspace (3-D spatial synthesis).
- Comprehensively evaluate a mixed reality system equipped with 3-D display technologies.

3-D imaging and display technologies for mixed reality systems require the following:

- Develop both a compact and lightweight head-mounted display and a high-luminance wide-angle 3-D display device without glasses. The aim is to achieve a mixed reality system that incorporates state-of-the-art optics design theory.
- Establish methods for quantitative measurement, evaluation, and analysis of the impact of 3-D displays on people as well as obtaining physiological information for preventing and minimizing hazardous effects. Such results will be fed back into the design of displays and other equipment toward the research and development of imaging and display equipment that reflect such considerations as safety and physical comfort.

OBSERVATIONS

It is clear that Canon managers are quite happy about this arrangement since it not only allows its researchers to pursue high risk areas, but also provides a way for the researchers to develop close ties to universities in Japan and abroad. This is lacking in most Japanese companies and even in the United States. As in other projects, there is an internal review held by Canon staff and an external one held by JKTC. In addition to this, an intermediate project review was also performed at the end of 1998 by 8 experts—4 are professors from universities and 4 are from JKTC. MRSL, while a part of Canon, is actually completely separated from Canon in all of its functions and administration. MRSL will offer patent and licenses to all interested parties, but it is necessary to have suitable consultation with shareholders (JKTC and Canon). The priority right to utilize the research developed by MRSL is a subject under discussion between JKTC and Canon.

Site: **New Energy and Industrial Technology Development Organization (NEDO)**
Sunshine 60, 29F
1-1, 3-Chome, Higashi-Ikebukuro
Toshima-Ku, Tokyo 170-6028, Japan
http://www.nedo.go.jp/3color-e/index.html

Date Visited: 13 October 1998

WTEC Attendees: I. Feller, G. Gamota, P. Herer, P. O'Neill-Brown

Hosts: Hirokazu Date, Deputy Director General, Industrial Technology Department
Toru Yamauchi, Dir., International Joint Research Div., Industrial Technology Dept.

BACKGROUND

NEDO supports R&D in new energy sources and energy conservation technology, primarily through direct contracts ("entrustment") with private sector firms and consortia. NEDO describes itself as supporting R&D that the private sector can't do because it's too risky or too long term (the basic market failure model). NEDO has no R&D laboratories or facilities of its own. Rather it supports private sector R&D. (NEDO also has an international joint research program, including some projects with NIST.)

SUPPORT FOR R&D ACTIVITIES

The framework for NEDO's activities is as follows: for basic R&D, it uses the entrustment model in which 100 percent of the cost is paid by NEDO. If findings emerge from R&D, NEDO then moves to a direct subsidization of follow-up activities. The exception to this practice is international joint research. Here, projects are supported on a grant basis, which NEDO officials consider a form of donation. Approximately 90 percent of NEDO's budget goes for the entrustment model. NEDO's support is directed at personnel costs, with the firms providing facilities.

The R&D thrust areas are determined by MITI and NEDO. NEDO's total budget is ¥100 billion. NEDO officials invite proposals from firms to do work on R&D priorities that NEDO has set. The organization also invites proposals from firms on industrial technology or for the development of industrial research teams.

The contracts with firms are not competitive, but they are negotiated on a sole source basis. Increased use of open-ended program solicitations is being initiated. A new mechanism initiated about three years ago involves thematic program announcements inviting applications for awards of up to ¥100 million for three years. No specific allocation of funds by research area is specified in the announcement; "creativity" is reported to be the main selection criterion. (NEDO considers universities as research institutes, not as training facilities. Thus, the impact of university-based research on graduate education is given little weight.)

NEDO's project selection committee consists primarily of academics. NEDO has ¥5 billion for special programs. The success rate on applications for this new program is about 10 percent. Applications come from firms, universities, and national laboratories. New permission has been granted to universities to participate in NEDO-supported projects, and more flexible arrangements to allow joint university–industry proposals have been instituted. NEDO is the first agency to have a mechanism for allowing open competition among universities, industry, and others. This approach is now being tried by other agencies.

No formal committee in NEDO or MITI exists to set R&D priorities. Rather, informal discussion occurs among these agencies, firms, and others, including informal input from academics.

NEDO evaluates project applications as follows: applications are first read by one or two staff members; the applications are then forwarded to a review committee comprised of the top faculty in the relevant field and the best experts from the private sector. Review committee members serve two year terms.

NEDO officials expect the projects they support to be commercially viable, and also to produce royalty income for NEDO (although they describe this objective as more of a hope and a wish than as a reality).

Data on the size distribution of the recipients of NEDO contracts were not available to the panel, but most awards, in fact, are described as going to large firms. One reason offered for NEDO's predominant interaction with large firms is that MITI has a separate institute on small- and medium-sized enterprise corporations which funds R&D by small- and medium-sized firms.

Little relationship between NEDO and JKTC was reported. Both organizations, however, are under MITI, which is charged with coordination. JKTC projects were described as short-term and geared to commercialization, whereas NEDO was described as supporting longer-term, more basic R&D projects.

Site: **Sumitomo Electric Industries, Ltd.**
1-1-1, Koya-kita, Itami
Hyogo 664-0016, Japan
http://www.sei.co.jp/

Date Visited: 13 October 1998

WTEC Attendees: R. Harris, H. Morishita

Host: Hideo Itozaki, Manager, Department of Electronic Materials,
Itami Research Laboratories

BACKGROUND

Present work at Sumitomo Electric Industries is a partial result of JKTC support of the Superconducting Sensor Laboratory (SSL). The SSL project ran from March 1990 to March 1996, at a total cost of ¥5,700 million, of which ¥3,990 million was from JKTC. JKTC officials describe the project as "advanced biomagnetic field measurement system (SQUID) research and development" which included "studies and development of fundamental technologies related to super high-sensitive magnetic field measurement of living body (brain) activity non-invasively, and analysis and image-processing of brain information." The project was a joint effort amongst Hitachi, Yokogawa Electric, Sumitomo Electric Industries and seven other companies.

Mr. Itozaki gave a complete explanation of the history of Japanese funding for superconducting electronics since the discovery of high T_c superconductivity. Much of this history is in the previous WTEC report on electronic applications of superconductivity in Japan (Rowell et al. 1998) and is not reported here.

At the end of the SSL project the equipment, primarily the large multichannel SQUID system, was donated to Tokyo Denki University for a project under Professor Kotani, who has since become President of the University. The fabrication line is still in the buildings constructed for the SSL. Tokyo Denki University has loaned it to ISTEC-SRL. It is supported by some new NEDO funding.

After the SSL project ended, the researchers returned to their home companies, which are now working separately and competitively to make commercial SQUID systems. Tokogawa, Hitachi, Daikin, Shimadzu and the Seiko Institute are working on low T_c SQUID systems. The latter two are developing applications in non-destructive evaluation. Commercial systems have been announced by Yokogawa and Shimadzu in 150 and 20 channel varieties. The Yokogawa work takes advantage of a joint research project with the Kanazawa Technical Institute (KIT).

The SSL still exists as a patent controlling company using 0.1 staff-years of administrative support. For the first two years, administration was handled by Hitachi. For the next two years Sumitomo will be responsible.

INTERACTIONS WITH JKTC

Originally SSL was funded 60% from JKTC and 40% from member companies. Most of SSL's assets were in its buildings, which have been donated to KIT. The remaining SSL funds came from its sale of some equipment to participating companies and from license royalties. Since there is a small royalty stream to SSL, JKTC has requested that all its original funding be returned, even though there was no original expectation in the view of the participating companies. Some companies are very upset with this request.

A projection of SSL's continuing income has been made which shows royalty funding asymptotically approaching ¥100 million per year and a payback period of 15 years. At present the royalty stream is ¥1.2 million per year. This is highly unusual among the completed JKTC projects. Only a few of the 50 or so projects exhibit any royalty stream. Nevertheless, there is no guarantee that the projected royalties for SSL will materialize.

During the SSL funding period only Sumitomo was interested in HTS SQUIDs, and it performed only about 10% of the total work. The HTS work was physically located at Sumitomo. At the end of the SSL project, Sumitomo bought all the equipment at its site.

The SSL did go through the mid-term and final evaluations. Each evaluation team was made up of four to five professors, and they were different for the two evaluations. The researchers did not know the members of the team until the actual "hearing." There was quite a buzz as the staff recognized the team members. WTEC did not ask the identity of any team members, and the information was not volunteered.

SSL passed the evaluations easily. It was very successful. Its goals were not just research but to construct a building and to demonstrate equipment. Both the building and the working 200 channel instrument, as projected, were tangible signs of success. Subsequently, even a royalty stream has resulted, although small.

Supporting the royalty stream, Sumitomo already has modest sales. Moreover, about ¥40 million comes from Daikin, Hitachi, and Shimadzu, the latter two of which have sold improvements of the original system to Tokyo Denki University.

This year or next Sumitomo may sell some systems to hospitals.

Two and a half years after the end of the project, the companies still feel pressure to contribute to the royalty stream. But the biggest pressure is on the people who are trying to market equipment. The WTEC panelists presume this means that if you don't sell anything you aren't providing any royalties at all, so there is no pressure.

RECENT R&D RESULTS

Dr. Itozaki was the sole host for the WTEC visit. He received his PhD from Northwestern University in the early 1980s. There are three professional staff members working on this project, Itozaki with a PhD and two MS people. There are one or two technical support staff members. All funding is from Sumitomo.

The entire focus of the Sumitomo program is on HTS SQUIDs, which provide high-resolution measurement of magnetic fields. The use of liquid nitrogen is a big advantage over LTS SQUIDs. Sumitomo is trying to generate a new field of interest, especially in non-destructive evaluation. It is a big field overall. More generally Sumitomo managers have no specific market in mind and know they must make a market.

The simple SQUID system Sumitomo sells is designed to stimulate buyers to create markets. It is hoped the buyers will use the SQUID, not do research on it. The SQUID demonstration system is similar to Mr. SQUID, produced by Conductus in the United States. For example, there is a geographic survey project coming up. WTEC panelists presume this is something like the magnetotellurics work John Clarke once did. In addition, big companies may want to detect iron particles on the production lines for copper wire, an application that may interest Sumitomo itself. Dr. Itozaki explained that the sale of about 20 of the HTS magnetometers was highly important in establishing and maintaining the credibility of the HTS SQUID project within Sumitomo. He has no funding except from Sumitomo.

The Sumitomo SQUIDs have a noise level of 10 $fT/Hz^{1/2}$ compared with 8 from the University of California at Berkeley. The best commercial niobium SQUIDs are 5-10 $fT/Hz^{1/2}$, and the best ever is less than one. On the other hand, it is expensive for Sumitomo to make the best HTS SQUIDs, so its simple system is specified at about 1000 $fT/Hz^{1/2}$. Extremely high sensitivity is very difficult for end users, so for now low sensitivity is better.

The WTEC team was given a complete lab tour beginning with a clean room, about Class 10,000, with two lasers for laser ablation. The lasers were stacked on top of each other. Another clean room contained a third laser. During the SSL the first two lasers were owned by SSL but located at Sumitomo. The third was owned by Sumitomo and kept separated from the other two. Now they are located near the other labs. The Sumitomo group makes its own targets, providing better opportunity for changing composition and materials compared with buying commercial targets.

In addition, a better clean room for lithography is available solely for the HTS SQUID operation. Its contents include a contact printer, an asher and a resist oven.

Sumitomo SQUIDs are made from HoBCO, primarily for historical reasons.

The WTEC team was shown a cardiography system with a 32 SQUID array detector. It has been in operation for three years. Detectors are individually encapsulated (0.5 cm diameter) and plugged into a PC card. The patient lies in a horizontal, three-layer mu-metal tube of approximately one meter in diameter. The SQUIDs are cooled by N_2 flowing through an uninsulated plastic tube. Electronics consisted of a rack of control cards for the SQUIDs, coupled to a computer. Dr. Itozaki explained that by using the array researchers have seen anomalous behavior from one part of the heart but not other parts.

Dr. Itozaki explained that the technique for finding iron inclusions in copper wire has not been further developed. To be useful in production, the system would have had to be further engineered with a refrigerator and software for fully automatic operation. No funds were provided by the Sumitomo production facility. Inclusions only occur once or twice a year. When they do, there is chaos, but apparently it is felt that the diagnostic ability made possible by the SQUID system is not essential.

There was no evidence of the 64 channel HTS SQUID mentioned in the Rowell report.

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Sendai International Center. 1998. 16 ch high T_c SQUID MCG system. *Biomag 98*. August 28th to September 2nd. Sendai, Japan.

Site: **Super Silicon Crystal Research Institute (SSi) Corp.**
555-1, Nakanoya, An-naka
Gunma 379-0125, Japan
http://www.super-si.co.jp/

Date Visited: 12 October 1998

WTEC Attendees: G. Gamota, P. O'Neill-Brown

Hosts: Masao Imakita, Senior Managing Director
Kiyoshi Takada, Director, General Manager
Dr. Teruoki Misawa, Manager, Planning Department

BACKGROUND

Silicon is the main element used for most electronic components. For this purpose, silicon is made in form of wafers, and with the push for greater integration of components on single wafer, there is a need for super-large wafer diameters. The present standard for wafers is 200 mm, and this effort is to create high quality 400 mm diameter wafers. Larger silicon wafers are critical to the realization of each new generation of semiconductors. The 300 mm wafer is well on the way to becoming the choice of the next generation substrate, so work on the 400 mm wafer is critical, and Japan hopes to be in the lead for its development.

To achieve such a goal, a number of semiconductor manufacturing companies came together and proposed to the JKTC a 5 year project whose purpose is to develop the technology for 400 mm diameter wafers.

The stockholder companies are the following:

- Japan Key Technology Center
- Shin-Etsu Handotai Co., Ltd.
- Sumitomo Metal Industries, Ltd.
- Komatsu Electronic Metals Co., Ltd.
- Mitsubishi Materials Silicon Co., Ltd.
- Toshiba Ceramics Co., Ltd.
- NSC Electron Corp.
- Showa Denko K.K.

SSi was established on March 29, 1996, and is to run until January 2001, or four years and 11 months (one of the shorter JKTC projects). The total capital for research is ¥13.4 billion (or approximately $100 million). Fifty percent comes from JKTC and the remainder from the companies. SSi employs 36 people, including 28 researchers. Almost all employees come from the stockholding companies.

SSi is organized traditionally, with a Board of Directors made up entirely from the private sector and a steering committee. The steering committee is made up of company employees who review progress four times per year and provide guidance. There are three subcommittees, one each for the three departments: Crystal Technology, Wafer Technology, and Epitaxial Technology.

RESEARCH APPROACH

SSi's research program is laid out in four phases.

- 1996: Pilot Research
  - machine concept design, fluid analysis and metrology trends
  - setting up the laboratory and finalizing research staff and management structure
- 1997-1998: Key Technology Research
  - manufacture crystal puller, wafer shaping machines, and finalizing design and manufacture of epitaxial furnace; additionally, fundamental experiments were being conducted to solve some underlying problems
- 1999-2000: Improvements & Verification of Key Technologies
  - improvements on all machines
  - experimentation verification
  - coupling with metrology
- Finish (second half of 2000): Integration of wafer shaping process
  - total evaluation of wafer qualities
  - wafer evaluation through device processes

CURRENT STATUS

Research has progressed on target, and as of October 1998, during the panel's visit, wafer diameter of 400 mm had been achieved. A wafer demonstration "World Premiere" was made at the SEMICON West conference '98. This was quite an achievement, and the Japanese researchers acknowledged that while it was their program that put it all together, much of the credit for specific technologies came from overseas, starting with work of Czochralski in 1917, Bardeen, Brattain and Shockley in 1948-49, and Siemens in 1955. Basically it was excellent engineering work putting things together to push the state of technology.

Current challenges include increasing the crystal weight from 100 kg to 400 kg; reducing flatness from 0.35 micron to 0.13 micron; reducing particle size from 0.12 micron to 0.04 micron; reducing metal impurity from less than 10^{10} to 10^{8} atoms per cm^{2}; reducing epi layer thickness from 2–5 microns to 1–3 microns; and finally reducing epi layer uniformity from less than 4% to less than 1%.

INTERNATIONAL COOPERATION

SSi's approach is to cooperate with worldwide companies interested in this technology, including manufacturers of equipment. It utilizes machines from the following sources:

- crystal growth puller made by Germany's Leybold Systems
- surface grinder made by Japanese Disco Corporation, Toshiba Machine Co., and Academy
- double side polisher by Peter Wolters from Germany
- surface inspection tools from ADE Corp., from the United States
- CVD and XPS systems from JEOL, Ltd., of Japan
- epitaxial furnace from Moore Epitaxial, Inc, of the United States

OBSERVATIONS

The company staff members were open in their appreciation for a JKTC type program and felt that it can be a big asset for pushing world technology. Even though the stockholding companies will not have any priority in technology licensing, staff experience in working in this environment is very important to the companies. The laboratory was well equipped, and the staff seemed very motivated and interested in sharing results.

Site:	**Teratec Corporation** **2-11-13 Nakacho, Musashino-shi** **Tokyo 180, Japan**
Date Visited:	16 October 1998
WTEC Attendees:	R. Harris, H.M. Morishita
Hosts:	Ryuichi Ishikawa, General Manager, General Affairs Department Yukio Kasahara, PhD, General Manager, R&D, Dept. 5 Yoshihide Miyagawa, General Manager, R&D Dept. 2 Kensuke Kobayashi, General Manager, R&D Dept. 1 Haruo Chiba, General Manager, R&D Dept. 3 Haruo Hosomatsu, General Manager, R&D Dept. 1

BACKGROUND

The WTEC visitors were received by Mr. Ishikawa, Manager of the General Affairs Department. At the time of the WTEC panel visit the director, Mr. Hisao Nakamura, was in the hospital. Mr. Nakamura had spent a year at NIST in Gaithersburg, MD, about a decade earlier. Many of the managers of the various R&D departments traveled from Teratec's other locations to the meeting.

Teratec is a joint project running from March 1992, to March 2001, with an expected total capital of ¥7.5 billion. Participants and their fractional investments follow:

Japan Key Technology Center	70%
Yokogawa Electric Corporation	10%
Advantest Corporation	4%
Ando Electric Co., Ltd.	4%
Anritsu Corporation	4%
Hewlett-Packard Laboratories Japan	4%
Iwatsu Electric Co., Ltd.	4%

The focus of Teratec is "research and development on fundamental technology such as micro-probe technology, sampling technology and so on, to realize signal waveform measuring systems for ultra high-speed devices and systems that are essential for future high-speed information processing and transmission."

Many of these companies are manufacturers of superb commercial high-speed test equipment. Their cooperation in forming Teratec seems natural.

The general areas of work of Teratec and their departmental locations are as follows:

• ultra-high-speed optical sampling technology	departments 4 and 5
• ultra-high-speed A-to-D and D-to-A conversion technology	departments 1 and 5
• ultra-high-speed signal conversion technology	departments 1, 2, 3, and 5
• high performance semiconductor process technology	department 1

Departments 1 and 5 are on the site of Yokogawa Electric in Musashino. Departments 2, 3, and 4 are in three other locations. Teratec also does joint research with the Plasma Research Institute at Tsukuba University and the Nuclear Fusion Research Institute in Nagoya.

INTERACTIONS WITH JKTC

The process by which Teratec was founded first involved joint meetings in which the participants agreed on research objectives. Subsequently they worked with the major shareholder, JKTC, to get final agreement. Their objective is to develop measurement techniques up to a few hundred GHz. They are working in the range of 50 to 100 GHz so far.

One method used by Teratec to evaluate its work is outside the JKTC review. Like the JKTC review, this one is also organized by professors. This internal review is held once a year, as recommended by JKTC.

JKTC officials desire a high return on their investment. Working with JKTC requires a great deal of time. Many meetings are held to set objectives. So far more than 100 patents have been applied for, but, of course, one cannot be certain whether they will provide adequate return. JKTC will evaluate Teratec every two years, rather than the original JKTC plan for reviews every three years.

The early evaluations primarily concerned technology, but now they are turning more to financial return. Some of the professors doing the reviews are famous and are known to the researchers. The economic evaluations were done for the first time in 1997. Instead of using an academic panel, the firm Nomura was used. Nomura has developed a long-term projection of the company's results.

Teratec provides partial early technical disclosures to its shareholders, not to encourage commercialization, but to ask member companies to evaluate commercial possibilities.

When asked for an explanation of why Teratec could not remain in business at the end of the JKTC funding to produce and market its ideas, the researchers indicated that Teratec's participants are competitors so that a joint commercial company would be difficult.

Teratec has proposed methods many times for improving its relationship with JKTC. Particularly troublesome is that funds are transferred to Teratec four times per year with attendant strict auditing. Transfers two times a year would be more efficient in the opinion of Teratec managers.

RECENT R&D RESULTS

The WTEC panel was shown a 450 m^2 clean room which was superbly appropriate for the developmental research being undertaken. It included molecular beam epitaxy, deposition of SiN and SiO_2 and other integrated circuit materials. Lithography was done with a Canon multimask i-line stepper manufactured in 1992. Heterojunction bipolar transistors (HBT) fabricated in the facilities play a frequent role in Teratec's developments. The facility is run by three staff members, but appears to be operated as an open shop by Teratec scientists, a practice that is more common in U.S. laboratories and is helpful in stimulating creativity and achieving results rapidly.

The WTEC team was also shown impressive microwave test equipment, but limited time prevented a detailed explanation of its use. The underlying technical requirement is based on the need to design and manufacture ultra high speed integrated circuits with electrical connections that transmit radiation rather than merely static voltages.

Teratec has developed a scanning force optoelectronic microscope (SFOEM), which offers state-of-the-art positioning capability through piezoelectric positioners and ultra-fast time resolution through laser-driven optical switches. Much of the apparatus is integrated into the tiny probe tip of the microscope. Teratec has measured time resolution as small as about 2 ps and can produce false color plots of the propagation of signals in transmission lines.

Other projects of Teratec, all at ultra-high-speed, are optical sampling techniques, analog-to-digital and digital-to-analog conversion, circuit technology for micro-probes, multiplexing and demultiplexing, and optical-to-electrical signal conversion.

All of these projects are aimed at very important measurement technology for future integrated circuits. It was not clear whether the projects are sufficiently timely compared with inevitable commercial demands. Neither was it clear whether the integrated circuit manufacturers can wait for such measurement technology to be developed outside their own organizations. The presence in Teratec's membership of active primary players in the new technology will hopefully ensure adequately prompt results followed by rapid commercialization of test instruments.

REFERENCES

Numerous reprints.

Teratec Corporation. Materials Received.

Future Technology for Measurements. n.d. Teratec Corporation.

Information on Scanning Force Optoelectronic Microscope. n.d. Teratec Corporation.

Teratec. 1998. Answers to WTEC questions (in Japanese).

Site: **University of Tokyo**
Department of Applied Chemistry
Department of Superconductivity
Hongo 7-3-1, Bunkyou-ku
Tokyo 113-8656, Japan
http://www.appchem.t.u-tokyo.ac.jp/labs/kitazawa/superconductivity/index.html

Date Visited: 15 October 1998

WTEC Attendees: I. Feller, R. Harris, P. Herer

Hosts: Professor Koichi Kitazawa

This was a fairly wide-ranging interview about the structure of Japanese universities and university–government relationships. Little information directly relevant to JKTC was provided. In fact, Professor Kitazawa noted he had very little knowledge of JKTC.

According to Prof. Kitazawa, Japanese universities are changing. Research funds for basic research in universities have increased significantly. The government, recognizing the need to stimulate the economy, has been increasing expenditures. Previously, it had relied heavily on public works construction to stimulate the economy. One of the supporting arguments for this change in policy apparently is that public works expenditures had little stimulatory impacts because most of the funds went to purchase land, and thus were really income transfers to already wealthy land holders who had high propensities to save, whereas if the money were spent on R&D, it would pass through to faculty, who were "poor" and have high propensities to consume. The government has made a major commitment to increase funding of academic R&D. Also, the increased academic R&D would stimulate purchases of high technology goods, which would help resolve a balance of trade controversy.

Ten years ago, Japanese politicians were concerned about two political issues in their relationships with the United States and other industrial countries: the trade imbalance and Japan's alleged lack of contribution to basic research. The government thus wanted to solve two problems with one stone. Increased spending on high technology/basic research programs would lead to a high percentage of the purchases going to the United States.

The government's new research policy promised ¥17 trillion—or approximately a $170 billion expenditure—between 1995 and 2000. So far the government has been very generous with its increased research support. Professor Kitazawa's new funds come from the Japan Science and Technology Agency (JST). Prof. Kitazawa's colleague gets funds from NEDO, a subsidiary of MITI. JST, NEDO, and the Japanese Society for Promotion of Science (JSPS) are becoming increasingly important sources of university R&D funds. Professor Kitazawa also mentioned that the JSPS program is run by the Ministry of Education, Science, Sports, and Culture (Monbusho).

The funding environment for academic R&D has improved dramatically. Prof. Kitazawa's annual laboratory budget was about $200,000 a year, mostly from Monbusho, until he started to receive JST support. It is now five times larger. Also, increased flexibility has been allowed in the use of the funds. However, the university is also taking part of the award. There appears to be a 15 percent levy against the grant, 10 percent of which goes to the university, and 5 percent to central administration of the School of Engineering. These funds are then used to provide support to faculty who don't receive grants. Prof. Kitazawa described this as a form of redistribution. The research fund can be used to hire postdocs, but the students' scholarships are supported independently by Monbusho.

Prof. Kitazawa's research support is based upon peer review. He estimated that there are from 300 to 400 groups now doing research under the new system, with each group involving about 10 faculty. There has been no change, however, in faculty salaries because they are paid independently from the government. The impacts of this new research funding have been largely on purchases of equipment and increased hiring of postdocs. Until about five years ago, only JSPS had provided support for postdocs, and then only for a small number of them. Now postdocs have become increasingly important members of research laboratories—to the total of more than ten thousand by now—although Prof. Kitazawa himself still has only one postdoc.

Little relationship exists between the increased funding of academic research and support of graduate students. Graduate students are supported by fellowships from the government. (There seems to be little direct comparison to the U.S. model of using research support to provide graduate assistantships.) In response to questions on interdisciplinary research, Prof. Kitazawa noted that the Japanese university system is more pure in terms of its disciplinary focus. His lab is described as atypical in the breadth of its research disciplines and faculty.

Despite the increase in government funding for academic research, Dr. Kitazawa expressed concerns about the efficiency of the Japanese university system and the ability of government policies to promote the needed pace of change. The Japanese system of higher education was based, he noted, on upon a design imposed by the United States in the immediate post-World War II period, and although this system contributed to democratic decision-making, it also was ineffective when rapid changes were needed. Adding to the slow pace of change, in his view, were the fragmentation of responsibilities among government bureaus and the emphasis on consensus in governmental policy-making.

Prof. Kitazawa felt that insufficient national attention is given to the inefficiencies of Japan's higher education system. There is a looming shortage of human resources in science and technology in Japan, which currently is muted by the economic recession. Over time, he sees Japan as having to compete with the United States for the brain drain of the Chinese and Indian graduate students and researchers in science and technology, but Japan is less than one tenth the size of the United States.

Prof. Kitazawa observed that in Japan even basic research proposals were designated as applied research. In order to get government funding, the national research institutes and the universities disguise the basic research intent of their proposals to emphasize applied research in order for the proposals to get through. Consequently, national data on the distribution of basic vs. applied research are skewed towards applied research.

Prof. Kitazawa described the biggest problem, as well as the advantage of the Japanese university system, as lifetime employment in a government institute. Thus, lab directors never fire their research associates, who are PhDs. The University of Tokyo, for example, has a rule that if a research associate is not promoted in five years, he is advised to leave the university. However, a research associate need not leave as long as he stays in the same position. Thus it is not easy to adjust the skills of the research team to accommodate changing needs in a research project or to conduct interdisciplinary research. It's also very difficult to change research directions. For example, the University of Tokyo is seen as having two or three departments in engineering that are no longer needed.

Two approaches followed in Japanese universities to deal with the issue of rigidities in the personnel system are to merge departments and to endeavor to retool faculty in new disciplines. However, these are seen as very slow and incomplete processes. The size of departments (in terms of students and faculty) is fixed by the government. To change these numbers requires major efforts proposed by the department, approved by the university and then by Monbusho. For example, one of the largest faculties in the University of Tokyo is the Faculty of Agriculture, which reflects the orientation of the university approximately 100 years ago when Tokyo still had a surrounding agricultural region.

Faculty responses to this new competitive grant mechanism vary. At the University of Tokyo, many faculty members are involved in this new big grants mechanism. Several of the other former imperial universities also have adapted to it, although none to the degree of the University of Tokyo. Only a small percentage of faculty members at the non-imperial universities are involved. An effort is being made to provide for a broader distribution of awards to the non-imperial universities. Along these lines, Prof. Kitazawa noted, based on his experiences as a member of peer review committees, that at the margin of proposal selection, if it became a matter of selecting a proposal from a "have" or "have-not" institution, the committee would try to give it to the latter. Funding for academic research is on the PI, or essentially laboratory director, model. There are few center proposals.

Prof. Kitazawa noted that in Japan it is difficult to motivate faculty by the prospect of large grants. A bigger fund to a field does not lead to a bigger number of researchers in the field since they have secure faculty positions. In contrast, U.S. universities are described as being motivated by budgets from externally funded research proposals.

With all these changes, it is still too early to gauge how Japan's university system will respond to the new system of funding academic research.

Prof. Kitazawa is very much concerned that Japanese society is changing too slowly. He made similar observations about the pace of change in firms. They cannot fire people as changes are occurring. He noted that in the United States, it might be difficult for individuals to change but that they do change as they join different organizations that require them to change. Lack of mobility in Japan reinforces the conservatism of individuals. If change is to occur, it is likely that it will happen through the growth of the postdoctoral system. Several national research institutes are beginning to hire postdocs, who are more mobile. This may lead to change taking place, but not for several years.

The Japanese government wants to facilitate improved university-industry-national research institute cooperation. Several changes in laws have been adopted toward this end. For example, faculty members, who as employees of national universities are essentially public sector civil servants, can now spend some time as consultants with private companies. Still, many restrictions exist on this practice. For example, faculty members must get permission from the university president to be consultants. This process can take several months. In most of the cases, the length of time and the tedious processes are discouraging to those who wish to initiate these activities.

Japanese companies were described as giving more funds to U.S. private and state universities than to Japanese universities. Prof. Kitazawa explained this in terms of Japanese firms getting very little from Japanese governmental universities (in the form of technical reports or opportunities to place most of their people in university laboratories for retooling), whereas American universities (MIT was cited repeatedly) have been making big efforts to give Japanese firms something in return.

Private Japanese universities were presented as more responsive to the needs of industry and to changing opportunities, because they had fewer government restrictions on faculty activity. Keio University was cited as having a public image of strength in information technology. This reputation has attracted good students and, in turn, industrial support. The university, however, was not seen as competitive for research grants as much as major governmental universities.

Prof. Kitazawa reported energetic efforts by MITI, JST, and more recently Monbusho to stimulate the formation of small- and medium-sized firms and particularly to emphasize entrepreneurship. Still, he saw the launching of a small firm related to materials technology as very difficult in Japan. Cultural differences between Japan and the United States were emphasized in this regard. Particular emphasis was placed on lifetime employment practices. Small firms cannot find good researchers, because if the researchers are good, they are already employed by stable, larger firms. In terms of spin-offs from academic research, Prof. Kitazawa knew of only one example, that of a former national research institute researcher who had started his own firm to manufacture crystal growth systems.

Site: **YRP Mobile Telecommunications Key Technology Research Laboratories Co., Ltd. (YRP Key Tech Labs)**
Ichibankan, 6F
3-4 Hikari-no-oka
Yokosuka 239-0847, Japan
http://www.kokusaidenki.co.jp/yrp/index.html

Day Visited: 14 October 1998

WTEC Attendees: G. Gamota, P. O'Neill-Brown

Host: Yoshihiko Ishikawa, Senior Vice President, Executive Manager
Dr. Takehiko Kobayashi, Head of the Communications System Dept.
Mitsuhiko Mizuno, Dr. Eng., Head of the Radio Transmission Dept.
Koji Takeuchi, Head of the Planning Dept.

BACKGROUND

Yokosuka Research Park (YRP) is located about one hour outside Tokyo. The objective is to create a new science city in this part of Japan, with YRP and its wireless communications technology being the centerpiece attracting many companies interested in this technology and business area. YRP's future is in the area of "International Mobile Telecommunications–2000" (IMT–2000). Many such systems are being developed around the world, and YRP Key Tech Labs is developing technologies critical to the second generation of IMT–2000 services. YRP Key Tech Labs is concentrating on the following research areas:

Radio Transmission Department

- code division multiple access (CDMA) technologies
- multipath countermeasure technologies

Communications Systems Department

- switching networks
- radio networks
- radio propagation

YRP Key Tech Labs is a seven-year project started on March 28, 1995 and is to be finished by March 2002. A total of $40 million was invested in the project, with JKTC providing 70% of the funding, and the investment companies providing 30%.

YRP Key Tech Labs has a 30 person full time staff, of whom 27 were transferred: 25 from the investment companies and two from the MPT's Communications Research Laboratory. The company research staff members expect to work there two, three or four years, whereas the remaining few might stay the whole seven years. The policy is to rotate, mix training and research. Some people use the time to obtain a doctor's degree based on the research done at YRP Key Tech Labs. Reviews are held internally twice a year by staff from investment companies; an external review is performed by JKTC during the midpoint of the project.

The Ministry of Posts and Telecommunications (MPT) was critical in pulling this effort together. Together with the investment companies, MPT helped prepare the proposal and worked on it for two years to get it funded.

The investors, other than JKTC, are all Japanese companies including the following:

- NTT Mobile Communications Network, Inc.
- Oki Electric Industry Co., Ltd.

- Sony Corporation
- Toshiba Corporation
- NEC Corporation
- Hitachi, Ltd.
- Fujitsu Limited
- Matsushita Communication Industrial Co., Ltd.
- Mitsubishi Electric Corporation
- Kokusai Electric Co., Ltd.
- Sanyo Electric Co., Ltd.
- Sharp Corporation
- Sumitomo Electric Industries, Ltd.
- Toyo Communication Equipment Co., Ltd.
- Victor Company Of Japan, Limited
- Japan Radio Co., Ltd.
- Hitachi Denshi, Ltd.
- The Furukawa Electric Co., Ltd.
- Fujikura Ltd.

Collocated within YRP is the CRL's Yokosuka Radio Communications Research Center, with other companies quickly occupying adjoining space.

FUTURE ACTIVITIES

Areas for research include the following:

- broadband and high quality transmission
- different media and different bit rate transmission
- transmission to high speed vehicles
- frequency bands (3–10 GHz) development usable for mobile communication

CONCLUDING REMARKS

The YRP Key Tech Labs managers pointed out that they have a free hand to pursue the research that is the most important to the future of their companies. Activity was only limited by funding. The area YRP chose to build its laboratory has the beginnings of a large new techno-park, somewhat reminiscent of Tsukuba Science Center.

YRP activities include a wide range of efforts with foreign countries. This is done via exchanges with overseas researchers, including participating at National Science Foundation workshops; training staff at overseas facilities; and participating and hosting conferences and seminars. The YRP acts as an information center.

APPENDIX D. JAPAN'S KEY TECHNOLOGY CENTER PROGRAM SUMMARY INFORMATION

NEW MATERIALS

- Non-oxide Glass, Tokyo (1985)
    - research and development of non-oxide glasses
    - Nippon Sheet Glass, HOYA
- Research Institute for Metal Surface or High Performance Ltd. (RIMS), Tokyo (1985)
    - development of high-performance surface metallic materials
    - Nippon Kokan, Ishikawajima-Harima Heavy Industries, Kawasaki Steel, Sumitomo Metal Mining and 13 other companies
- Colloid Research Institute Co., Ltd., Kanagawa (1986)
    - research and development of manufacturing technology of high performance ceramics from controlled colloidal solution
    - Nippon Steel Co., Nippon Steel Chemical Co., NGK Spark Plug Co, Kurosaki Refractories Co.
- Rheo-Technology, Ltd., Tokyo (1987)
    - research and development of semi-solid processing
    - Kawasaki Steel, Kobe Steel, Sumitomo Metal Industries, Nippon Steel, and 13 other companies
- Alithium, Ltd., Tokyo (1988)
    - research and development of high specific strength alloys (Al-Li alloys)
    - Sumitomo Light Metal Industries, Kobe Steel, Furukawa Electric, Showa Aluminium and 3 other companies
- Next Generation Catalyst Research Institute, Co, Ltd. (NGC), Kanagawa (1992)
    - research and development on technologies for next generation lean de-NO_x Catalysts
    - Toyota Motor, Petroleum Industry Technology and Research Institute, Nissan Motor and 12 other companies

MACHINERY

- Space Technology Corporation (STC), Tokyo (1985)
    - materials research using space environment
    - Ishikawajima-Harima Heavy Industries, Toshiba, NEC, Hitachi, Mitsubishi Electric
- Advanced Combustion Engineering Institute Co., Ltd. (ACE) (1986)
    - advanced combustion engineering research
    - Hino Motors, Isuzu Motors, Nissan Diesel Motor, Mitsubishi Motors and 8 other companies
- The Frontier Aircraft Basic Research Center Co., Ltd. (FARC), Tokyo (1986)
    - research and development of advanced propulsion system
    - Ishikawajima-Harima Heavy Industries, Sumitomo Precision Products, Kawasaki Heavy Industries, Mitsubishi Heavy Industries and other 30 companies

- Food Machinery Key Technology Research and Development Co., Ltd., Tokyo (1986)
  - research and development of intellectualized food processing technology
  - Rheon Automatic Machinery, Mayekawa MFG, Samy Shinagawa Machinery Works and 25 other companies
- Three-D Composites Research Corporation
  - research and development concerning 3-D fabric composites
  - Mitsubishi Electric, Nippon Steel, Toyoda Automatic Loom Works, Mitsubishi Rayon, Arisawa Mfg.
- Research Institute of Advanced Material Gas-Generator Co., Ltd., Tokyo (1992)
  - research and development of key technologies for gas-generator using advanced materials
  - Ishikawajima-Harima Heavy Industries, Kawasaki Heavy Industries, Mitsubishi Heavy Industries and 11 other companies
- Advanced Technology Institute of Commuter-Helicopter Co., Ltd., Gifu (1993)
  - research and development of advanced technology for commuter-helicopter
  - Kawasaki Heavy Industries, Shimadzu Corporation, Tokyo Aircraft Instrument, Teijin Seiki, Japan Aircraft Mfg.

ELECTRONICS

- Optoelectronics Technology Research Corporation, Tokyo (1985)
  - generic research for optoelectronic integrated circuits
  - NEC, Oki Electric, Sumitomo Electric, Toshiba and 9 other companies
- Japan Electronic Dictionary Research Institute, Ltd., (EDR), Tokyo (1985)
  - research on electronic dictionaries for natural language processing
  - Fujitsu, NEC, Hitachi, Sharp and 4 other companies
- Interactive Basic Information System Development Corporation (IBIS), Tokyo, (1985)
  - research on advanced information processing-type image information systems
  - Sumitomo Electric, Fujitsu, Matsushita Electric
- Optical Measurement Technology Development Co., Ltd. (OMTEC), Tokyo (1985)
  - research of measurement technology for coherent light communication
  - Yokogawa Electric, Advantest, Ando Electric, Anritsu, Iwatsu Electric
- SORTEC Corporation (SORTEC), Tokyo (1985)
  - research and development of synchrotron radiation application technologies
  - Mitsubishi Electric, Toshiba, NEC, Hitachi, Fujitsu and 8 other companies
- AI Language Research Institute, Ltd. (AIR), Tokyo (1987)
  - research and development on high-level AI language for system description
  - Mitsubishi Electric, Oki Electric, Fujitsu, Sharp, Toshiba and 6 other companies
- Amorphous Magnetic Device Laboratory, Ltd., Miyagi (1987)
  - research on amorphous magnetic materials and magnetic devices
  - Mitsubishi Heavy Industries, Tohoku Electric Power, Nippon Steel, Hitachi and 24 other companies

- GTC Corporation, Tokyo (1988)
  - research and development of advanced technologies for large-area TFT circuitry
  - Hitachi, Mitsubishi Electric, Oki Electric, Sumitomo and 8 other companies
- Superconducting Sensor Laboratory, Chiba (1989)
  - advanced biomagnetic field measurement system (SQUID) research and development
  - Hitachi, Yokogawa Electric, Sumitomo Electric and 7 other companies
- Free Electron Laser Research Institute, Inc., Osaka (1990)
  - research and development on free electron lasers for industrial use and its applications
  - Mitsubishi Electric, Sumitomo Electric, Kansai Electric Power Co., Mitsubishi Heavy Industries, Hitachi and 8 other companies
- Teratec Corporation, Tokyo (1991)
  - fundamental research on ultra high-speed electronic measuring technology
  - Advantest Corporation, Ando Electric, Anritsu Corporation, Hewlett-Packard Laboratories Japan, Iwatsu Electric, Yokogawa Electric
- Biophotonics Information Laboratories, Ltd.
  - research and development of new sensing and imaging technology for biophotonic phenomena
  - Fujitsu, Yamagata Technopolis Foundation, Fuji Photo Film, NEC, Shimadzu Corporation and 14 other companies
- Digital Vision Laboratories Co., Tokyo (1994)
  - Research and development of middle-ware for interoperable HD multimedia
  - Matsushita Electric, NEC, Sony, Hitachi, Toshiba, Fujitsu, ASCH
- Super Silicon Crystal Research Institute Corp., Nakanoya (1995)
  - R&D on crystal growth technology, wafer shaping technology and development of a 400 mm diameter wafer
  - Shin-Etsu Handotai Co., Ltd., Sumitomo Metal Industries, Ltd., Komatsu Electric Metals Co., Ltd., Mitsubishi Materials Silicon Corp., NSC Electron Corp., Toshiba Ceramics Co., Ltd., and Showa Denko K.K.

COMMUNICATIONS PROCESSING

- ATR Auditory and Visual Perception Research Laboratories, Kyoto (1985)
  - research on auditory and visual perception
  - Sharp, NTT, ATR and 136 other companies
- ATR Interpreting Telecommunications Research Laboratory, Kyoto, (1985)
  - basic research for automatic telephone interpretation
  - KDD, NTT, ATR and 136 other companies
- ATR Communication Systems Research Laboratory, Kyoto (1985)
  - basic research on intellectual communication system
  - Matsushita Electric, NTT, ATR, and 136 other companies
- Japan Database Network Laboratory Co., Ltd. (JDNL),Kumamoto (1985)
  - research and development of a speech input/output system that stores information associatively, communicates with other machines, and works on personal computers
  - Carry Labo., T&E Soft, Micro Cabin, M.A.C., Thinking Rabbit

- Telematique International Research Laboratory, Tokyo (1986)
  - research and development of telematique library system
  - ASCII, Tokyo Electric Power, Canon, KDD, and 19 other companies
- The Conditional Access Technology, Inc. (COATEC), Tokyo (1986)
  - research and development of conditional access technology
  - Japan Satellite Broadcasting, NHK, Toshiba, NEC, Matsushita Electric
- ATR Auditory and Visual Perception Research Laboratories, Kyoto (1991)
  - research on human communication mechanism
  - Sharp, NTT, KDD, NHK, Matsushita Electric, and 3 other companies
- ATR Optical and Radio Communications Research Laboratory, Kyoto (1992)
  - basic research on advanced speed translation communication technology
  - NTT, ATR, KDD
- ATR Media Integration & Communications Research Laboratories, Kyoto (1994)
  - basic research on intellectual image information communications
  - Matsushita Electric, NTT, KDD, Sanyo Electric, Sharp and 4 other companies
- Electromagnetic Compatibility Research Laboratories Co., Ltd. (EMC Lab), Sensai (1995)
  - R&D on ways of avoiding interference between various networks, electrical devices, and communications systems
  - Sony Corp., Sanyo Electric Co., TDK Corp., Tokin Corp., and 19 other companies
- HITS Laboratories, Inc., Kanagawa (1997)
  - R&D on wireless multimedia home network systems. Focus is on the elderly to make it easier for them to handle connections between various multimedia equipment
  - Victor Company of Japan, Ltd.
- Cyber Net Communications Inc., Mie (1997)
  - Research and development on quantitative methods of billing for communication and information: time spent on access and the quantity of information obtained from its access
  - CTY Co., Ltd, Toyotsu Initiative Japan, Inc., Nissho Iwai Co., and 8 other companies

NETWORKING

- Callnet Inc., Tokyo (1985)
  - research and development of basic technology to build joint back-up communication network
  - Carry Laboratories, T&E Soft, Micro Cabin, M.A.C., Thinking Rabbit
- Future Building Systems Ltd., Tokyo (1985)
  - development of integrated information and communication system for future buildings
  - Fujitsu, Taisei Corporation, Shimizu Corporation
- Cable Television Key Technology Research Corporation, Tokyo (1987)
  - experimental research into the application of integrated digital communications technology to cable TV networks
  - Mitsubishi Electric, Oki Electric, Fujitsu, Sharp, Toshiba and 6 other companies

- Advanced System Research Organization Ltd., Tokyo (1987)
  - research on different computers and operating systems to bring about compatibility for future generation languages
  - CSK, Sumitomo Trust and Banking, NK EXA and 5 other companies
- Advanced Intelligent Communication Systems Laboratories, Ltd., Miyagi (1989)
  - basic research to achieve higher reliability and optimal operation of large scale communication systems
  - Hitachi, Tohoku Electric Power, NTT, Oki Electric and 8 other companies
- Software Research Laboratory, Hokkaido (1990)
  - Tests/research on advanced individual learning information systems
  - SCC, Hokkaido SE, Hokkaido Electric Power, Hokkaido Business Automation and 4 other companies

RADIO COMMUNICATIONS

- ATR Optical and Radio Communication Research Laboratory, Kyoto (1985)
  - basic research on photoelectric wave communications
  - Sanyo Electric, NTT, ATR and 136 other companies
- Space Communications Research Corporation (SCR) (1986)
  - research and development on satellite communications and broadcasting payload technologies in the geostationary platform era
  - Toshiba, NTT, KDD, NHK and 6 other companies
- Robotech Laboratory Co., Ltd., Chiba (1987)
  - tests/research on remote monitoring/controlling system using millimeter waves
  - Yamazaki Construction, Meisei Electric, Nikko Electric
- Small Power Communication Systems Research Laboratories, Miyagi (1987)
  - basic research on low-power high-speed communications
  - Tohoku Electric Power, NTT, Sumitomo Electric, Toshiba and 22 other companies
- Mobile Communications Technology Development Co., Ltd., Kanagawa (1989)
  - tests/research on public personal and mobile communication systems
  - NEC, Matsushita, Oki Electric, Fujitsu, and 3 other companies
- Advanced Millimeter Wave Technologies Co. Ltd., Kanagawa (1990)
  - research and development on very small millimeter wave communication systems
  - NEC, Fujitsu, Ohbayashi Corporation
- Advanced Space Communications Research Laboratory, Tokyo (1993)
  - research and development on advanced mobile satellite communications and digital audio broadcasting
  - NEC, Mitsubishi Electric, Toshiba, NHK, Hitachi, Fujitsu, KDD and 8 other companies
- Advanced Mobile Telecommunication Technology, Inc., Aichi (1993)
  - development of highly efficient mobile telecommunication systems
  - Nippondenso, Alps Electric

- YRP Mobile Telecommunications Key Technology Research Laboratories, Kanagawa (1994)
  - theoretical/experimental research on high quality mobile communication basic technologies
  - NTT, Oki Electric, Sony, Toshiba, NEC, Hitachi and 13 other companies
- ATR Adaptive Communications Research System, Kyoto (1995)
  - research on communication systems which can autonomously adapt to complex and unpredictable changes in communication environments, and reliably support huge varieties of communication services
  - Sanyo Electric, NTT, KDD, Sharp, Matsushita Electric, and another 63 companies
- Advanced Mobile Telecommunications Security Technology Research Laboratories Co., Ltd., Yokohama (1996)
  - R&D on advanced security technology for mobile communications systems
  - NEC, Matsushita, Mitsubishi Electric
- YRP Advanced Mobile Communication Systems Research Laboratories Co., Ltd., Kanagawa (1997)
  - research on key mobile communications systems for VHF and UHF bands, with goal of increasing communications channels, realizing multimedia networks, and enhancing reliability
  - Toshiba, Hitachi, Matsushita, Mitsubishi Electric, Asahi Chemicals, Oki Electric, Optowave Laboratory Inc., Kokusai Electric Co., NEC, Japan Radio Co., Hitachi, Fujitsu

PICTURES/TRANSMISSION

- Graphics Communication Technologies, Tokyo (1986)
  - research and development of high speed processing architecture for digital mobile picture communication systems
  - ASCH, Hitachi, Iwatsu Electric, Ohikura Electric and 6 other companies
- High Definition Television Engineering Corporation, Kanagawa (1988)
  - tests/research on generating, transmitting and displaying system of HDTV images
  - NEC, Seiko Epson, Meitec, NHK, Tetsudo Sogo Gijutsu Kenkyusho
- Graphics Communication Laboratories, Tokyo (1992)
  - research and development on visual media integrated transmission processing system
  - ASCH, Hitachi, Victor Company of Japan, NTT
- Advanced Digital Television Broadcasting Laboratory, Tokyo (1994)
  - research and development on next generation terrestrial digital television broadcasting systems
  - Toshiba, NEC, Hitachi, Matsushita Electric, Sony and 6 other companies
- Mixed Reality Systems Laboratory Inc., Yokohama (1996)
  - experimentation and research to realize “mixed reality systems” by seamless fusion of physical space and cyberspace, including a realistic 3-D display
  - Canon
- Information Broadcasting Laboratories, Inc., Tokyo (1996)
  - research on distributed information management technology for information broadcasting systems
  - Sony, Matsushita, Ricoh, Japan Broadcasting Corporation, Fuji Television Network, Inc.

ELECTRONICS/NETWORKING

- Ultra-High Speed Network and Computer Technology Laboratories, Tokyo (1993)
  - tests/research on ultra-high speed network/computer integration technology
  - NEC, Fujitsu, Hitachi

BIOTECHNOLOGY CENTERS

- Protein Engineering Research Institute (PERI), Osaka (1985)
  - protein engineering; design and synthesis of proteins for practical applications; enzymes, antibodies, hormones
  - Kyowa Hakko Kogyo, Takeda Chemical Industries, Mitsubishi Chemical
- M & D Research Co., Ltd., Tokyo (1985)
  - new chemical synthesis; DNA recombinant technology; biologically active peptide production
  - Daicel Chemical Industries, Meiji Seika Kaisha
- PCC Technology Co., Ltd., Tokyo (1986)
  - plant cell technology; large-scale production technology; production of useful chemicals
  - Kirin Brewery, Kyowa Hakko Kogyo, Mitsui Toatsu Chemical
- Biomaterial Research Institute Co., Ltd, Yokohama (1986)
  - bioactive materials; tissue engineering
  - Sumitomo Electric, Toray, Sumitomo Bakelite
- Bio-Polymer Research Co., Ltd. (BPR), Kawasaki (1991)
  - production of fibrous biopolymers (cellulose); microbial production
  - Ajinomoto, Shimizu Corporation, Nakano Vinegar
- BioPhotonics Information Laboratory, Ltd., Numagi (1992)
  - new sensing and imaging technology for biophotonic phenomena; detection of ultra-weak light emission from biosamples
  - Fujitsu, Fuji Photo Film, NEC, Shimadzu Corporation
- Laboratory of Molecular BioPhotonics, Tokyo (1993)
  - detection of biomolecules useful for optical filters, lenses, biosensing systems; fluorescent reagents for labeling
  - Hamamatsu Photonics, Nikon, Chugai Pharmaceutical
- Biomolecular Engineering Research Institute, Osaka (new name for follow-on activity to PERI) (1994)
  - engineering of biomolecules for new and desired functions; applications in environment, chemicals and medicine
  - Kyowa Hakko Kogyo, Takeda Chemical, Mitsubishi Chemical, Fujitsu, Sankyo, Toray
- Environmental Immuno-Chemical Technology Co., Ltd., Tokyo (1994)
  - immuno-chemical methodology for environmentally important substances; environmental monitoring systems for conservation of global environment
- Helix Research Institute, Chiba (1996)
  - technologies for identifying new genes and evaluation of function; bioinformatics; functional genomics
  - Yamanouchi Pharmaceutical, Fujisawa Pharmaceutical, Mitsubishi Chemical, Kyowa Hakko Kogyo, Sumitomo Chemical