Assessment of Technical Strengths and Information Flow of Energy Conservation Research in Japan

Volume 1 — Executive Summary

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ASSESSMENT OF TECHNICAL STRENGTHS
AND INFORMATION FLOW OF ENERGY
CONSERVATION RESEARCH IN JAPAN
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(a) Global Competitiveness Council

PREFACE

This study was completed for the Office of Energy Systems Research (ESR) in the Department of Energy. The primary goal of ESR research programs is to provide a solid technology base in areas related to energy storage, energy conversion, energy end use, and the transmission and distribution of electrical energy. These programs serve as the foundation for the energy end-use offices in the DOE Conservation and Renewable Energy Program as well as for those in private industry. The specific objectives of ESR are:

1. to develop the technology base required to achieve improvements in the efficiency and fuel flexibility of future energy conversion, storage, transmission, distribution, and utilization in all end-use sectors.
2. to improve the energy efficiency of technologies having application in a variety of industries.
4. to provide technology options that will enhance the reliability of the nation's future electric network under normal and emergency situations.

To aid in achieving these objectives, in 1981 the ESR staff established the Technology Analysis and Evaluation Project, which is conducted from the Pacific Northwest Laboratory.^(a) This project assists ESR in planning and managing its research program by conducting technical program evaluations, program information management, technology characterization and assessments, and international technology monitoring.

This document is a concise report of a study performed to build the groundwork for ESR international monitoring efforts. The study explores the status of research and technology developments in Japan and the ability of U.S. researchers to keep abreast of Japanese technical advances. Ten technology areas that can be applied to improving the efficiency of energy use and that

(a) Pacific Northwest Laboratory (PNL) is operated for the Department of Energy by Battelle Memorial Institute.

are relevant to ESR research programs were examined. The details of this investigation are published in a supporting document.(a)

(a) Hane, et al. 1984. Assessment of Technical Strengths and Information Flow of Energy Conservation Research in Japan: Background Document. PNL-5244, Vol. 2, Pacific Northwest Laboratory, Richland, Washington

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EXECUTIVE SUMMARY

The history of technology development in Japan is marked by a remarkable effectiveness in combining national expertise with international developments and research results. Japan's significant advances in technology have caused concerns about the ability of the U.S. technical community to keep abreast of these activities. Problems of language, culture, and physical distance have aggravated the lack of U.S. understanding and made this deficiency in our ability to monitor Japanese R&D increasingly apparent. These concerns have been recognized by many groups, including the U.S. Congress, which held a subcommittee hearing on this topic in March 1984.^(a)

These concerns have become increasingly important as the levels of research activity in Japan continue to rise. In 1970 the investment in R&D in Japan as a fraction of the gross national product (GNP) was ~1.8%, compared with 2.6% in the U.S. By 1981 the Japanese commitment to R&D had increased to ~2.4%, approximately equaling the U.S. percentage. Total R&D spending as a percent of GNP over the years 1970 to 1983 is shown in Figure 1 for Japan, U.S., West Germany, Britain, and France. Because of the increasingly specialized nature of defense and space R&D, excluding R&D spending for these areas provides a more direct measure of efforts relevant to economic growth and social goals. The ratio of this nondefense, nonspace R&D to GNP is shown in Figure 2. This figure shows that Japan has significantly outpaced the U.S. since the late 1960s, having a ratio of 2.2% in 1981 compared with 1.7% in the U.S.

Through the perceptions of U.S. researchers, this study evaluates the researchers' strengths and comparative status of Japanese work in their respective fields, as well as their perceptions of the quality of information transfer to the U.S. technical community. Researchers were identified and interviewed in ten technology areas:

- Amorphous Metals
- Biotechnology

(a) House Committee on Science and Technology, Subcommittee on Science, Research and Technology, March 6 and 7, 1984.

FIGURE 1. Ratio of Total National Research Investment to GNP
(National Science Foundation. 1983. Science Indicators - 1982. National Science Foundation, Washington, D.C.)

- Ceramics
- Combustion
- Electrochemical Energy Storage
- Heat Engines
- High-Temperature Sensors
- Heat Transfer
- Thermal and Chemical Energy Storage
- Tribology.

FIGURE 2. Ratio of Research Investment (Excluding Defense and Space Research) to GNP (National Science Foundation, 1983. Science Indicators - 1982. National Science Foundation, Washington, D.C.)

These technology areas were selected because they generally can be applied in promoting the more efficient use of energy and because they are relevant to programs within the Office of Energy Systems Research in the U.S. Department of

Energy (DOE), which supported this effort. Of particular interest in the study was the longer-term, basic and applied research. Basic research typically involves investigating the fundamental behavior of processes, and applied research typically addresses particular applications or technologies and improvements in their performance.

This study is therefore intended to provide a preliminary indication of the status of important technical research in Japan and the ability of researchers to follow these areas. Although the researchers' perceptions are generally qualitative, they nonetheless provide technically-based assessments of overseas technical progress at the earliest stages of development. Their comments on the quality of information transfer provide indications of the ability of U.S. researchers to benefit from research results and developments in Japan, as well as the ability of U.S. research managers to develop their plans with an international perspective.

GENERAL PERCEPTIONS OF THE STATUS OF JAPANESE RESEARCH

Analyzing the comments offered by researchers in the various fields reveals several consistent observations about research in these areas in Japan.

A summation of researchers' estimates of the comparative status of research in Japan is provided in Table 1. The columns in the table describe the status of the basic and applied research efforts, as well as changes in programmatic emphasis toward more basic research and the "momentum" of the basic or applied research effort. The perceptions of the status of the basic and applied research efforts are rated in the table as either very strong, strong, moderate, or weak.

"Very strong" work is generally excellent and at the leading edge of the technology, with significant aspects perceived as superior to the U.S. "Strong" work is of high quality and generally comparable to work in the U.S. "Moderate" work is good but still apparently several years behind U.S. efforts. "Weak" work is not very significant, with the U.S. having a far greater research capability.

The table shows that significant technological challenges to the U.S. are perceived in the areas of amorphous metals, biotechnology, and ceramics. Also,

TABLE 1. General Perceptions of the Status of Basic and Applied Research in Japan

Research Fields	Researchers Interviewed	Basic Research			Applied Research	
		Status	(Momentum)	(Recent Emphasis)	Status	(Momentum)
Amorphous Metals	11	***	(0)	(+)	****	(+)
Ceramics	16	***	(0)	(0)	****	(+)
Combustion	15	***	(+)	(+)	***	(+)
Tribology	13	***	(+)	(+)	***	(0)
Heat Transfer	7	***	(0)	(0)	***	(+)
Biotechnology	6	**	(0)	(0)	****	(+)
Heat Engines	10	**	(0)	(0)	***	(+)
Electrochemical Energy Storage	9	**	(0)	(0)	***	(+)
Thermal and Chemical Energy Storage	6	*	NA	NA	**	(+)
High Temperature Sensors	8	NA	NA	NA	**	(NA)

Symbols

**** very strong
 *** strong
 ** moderate
 * weak

+ positive emphasis
 0 no significant emphasis
 - activity decrease
 NA information not available

significant R&D momentum was noted in the area of stationary Stirling engine development. The researchers' observations on the strengths of research in Japan are summarized in the technology-specific discussions below.

Amorphous Metals

This study focused on research addressing the magnetic properties of amorphous metals. Although opinions were somewhat mixed, most researchers noted that fundamental work in the U.S. currently appears to be superior to research in Japan in both the extent of high quality research and the work of the top individuals. In particular, the work of Egami and Graham at the University of Pennsylvania is noted for its excellence.

The Japanese effort in amorphous metals was noted for its strength in the applied development of the materials and production techniques for a wide range of applications. Several researchers noted that researchers in Japan will test hundreds of materials to find those with the desired characteristics or to derive rules empirically. The materials development is then applied to a wide range of end uses. Currently the areas receiving the greatest amount of attention are power transformers and consumer electronics. The first major government-supported amorphous alloy program is a five-year effort that began in 1981 to develop power transformer cores. In addition to the development of power transformers, electronics firms are exploiting the unique magnetic properties of these materials and have already produced the first magnetic recording heads manufactured by a double-roller quenching technique. This technique results in recording heads with performance characteristics that are superior to those previously available.

However, just as significant as the applied work supported by the government is the very recent emphasis on long-term R&D. A three-year, government-supported program to establish a fundamental research base was completed in 1983. Additional research that will be performed by private and public organizations is currently being coordinated by the government, although the details are not publicly available.

Biotechnology

Biotechnology is being targeted by the Japanese government as one of the major high-technology industries of the future. As a result, there is a great deal of interest and activity in this area within the Japanese research community. As with the development of most other new technologies in Japan, the emphasis of the initial activity is on the applied development of this science. In the fundamental sciences of microbiology and genetic engineering, the consensus among the researchers interviewed is that the U.S. clearly has a superior research capability. However, Japanese industry has applied biotechnology on an industrial scale (in the form of fermentation technology) for example, and has gained extensive process engineering experience. In a recent study of international biotechnology development, the Office of Technology Assessment noted that the Japanese government spends a large portion of its \$60 million for biotechnology on processing aspects, while as little as \$6.5 million of the billion dollar U.S. budget is spent on industrial processing techniques. Given the Japanese capability, history, and governmental focus on bioprocess engineering, the U.S. most likely will be severely challenged in this technology in the near future.

Ceramics

Ceramics has also been targeted by the Japanese government as one of the high-technology industries of the future. The R&D emphasis again appears to be on the applied development of the technology, processing techniques, and a wide variety of end uses. In material characterization research, the general consensus is that Japan and the U.S. are at a rough parity. It was also noted, however, that there is a substantial amount of momentum in Japan. For example, several researchers noted that for every one researcher working on a technical problem in the U.S., there are frequently five to ten working on the same problem in Japan.

The main thrust of the Japanese effort, however, is perceived to be toward expanding the applications of ceramics and developing processing techniques. There is a strong consensus that Japan has already surpassed the U.S. in both aspects by producing materials with greater uniformity and reliability and by integrating computer controls more extensively in their processing.

Combustion

The general consensus among the combustion researchers interviewed is that Japan's efforts focus far more on applied areas than the U.S. efforts. Researchers note that the basic combustion research work in the U.S. is much more broadly based and at the leading edge of the science. However, it was felt that combustion activity in general was increasing in Japan and that the momentum currently building is likely to create a substantial challenge to the U.S. in the future. Research in Japan was noted to excel in the applied aspects; particularly noted were the efforts underway in adiabatic diesel engine combustion and coal combustion. Also, Japanese work is perceived to be superior in the use of instrumentation and microprocessor controls for combustion.

Electrochemical Energy Storage

Assessing the overall field of electrochemical energy storage is hampered by the wide variety of electrochemical systems. The Ministry of International Trade and Industry (MITI) is currently in the fourth year of an 11-year program to develop electrochemical energy storage technology for utility load leveling. The batteries being studied are sodium-sulfur, zinc-chloride, zinc-bromine, and redox types. Comments offered indicate that the work in Japan is somewhat behind that of the U.S. However, the significance of this national program should not be ignored because other national efforts often have resulted in the state-of-the-art balance tilting in Japan's favor. Other battery technologies identified in which Japanese development is superior include manganese-dioxide, lithium-magnesium, and lithium-CFx batteries. These technologies are less well publicized because they are not part of the MITI program.

Heat Engines

Unlike most of the other technologies covered in this study, researchers noted that much of the technical research published in Japan concerning the Stirling engine is fundamental, rather than applied. While the work is expected to contribute to a substantial data base, researchers could not identify areas in which this would create a technical disadvantage for the U.S. However, although details are sparse, significant work is generally thought to

be underway in the applied development of this technology. For example, the six-year, \$44.4 million MITI-sponsored project to develop a residential/commercial size heat pump is considered to be significant. In gas turbine development, an MITI-sponsored project in combined-cycle technology was also noted, as well as the development of low emissions technology that is considered superior to U.S. technology. Overall, however, researchers indicated that the U.S. has an edge in Stirling engine and gas turbine development.

Heat Transfer

There was an unusually high level of agreement among the researchers in this field on the strengths and comparative development of the work in Japan. In the fundamental study of heat transfer the efforts in the two countries are perceived to be comparable, with a slightly broader effort in the U.S. The strength of the work in Japan is considered to be in the applied areas, with particularly notable work in enhanced surfaces, boiling, condensation, high temperatures, and heat transfer in electronic components. Products of these technologies have already been demonstrated to be superior to those offered elsewhere. This is clearly considered an important technology area in Japan and again one in which significant advances are occurring in the applied development areas.

High-Temperature Sensors

A definite lack of comprehensive information hampered the assessment of Japanese efforts in high-temperature sensors. No comments were offered on the fundamental research aspects. Researchers did comment that the ability to apply the sensors appears to be superior in Japan. Again, it is in the process-related characteristics that Japanese work is particularly notable. In the more applied aspects, increasing Japanese interest was noted in fiber optic high-temperature sensor technology, but the U.S. is still considered to lead in this area.

Thermal and Chemical Energy Storage

Assessments of the thermal and chemical energy storage field were also severely hampered by a lack of available information. Researchers noted that before the late 1970s Japan did not appear to have much interest in this field.

However, lately researchers have sensed a rapid increase in activity but find that activity difficult to define. Areas in which research effort is apparently being accelerated include phase-change technology, clathrates for low-temperature energy storage, and metal hydrides. In each of these areas there is some feeling that technology in Japan is comparable to and is even surpassing development in the U.S.

Tribology

Perceptions of Japanese efforts in tribology were the most marked by the significant variation in opinions offered. One group of researchers felt that the work in Japan still generally lags behind that of the U.S., while a second group claimed that the program in Japan has greater depth and scope and is shifting toward a greater emphasis on fundamental studies. This possible shift is evidenced by the tribology facility newly opened at Japan's National Mechanical Engineering Laboratory. Researchers who noted the strength of the Japanese effort pointed to several contributing characteristics, including a stronger capability in the analysis of the chemical component of tribology, less division of research along academic disciplines, and a greater depth in the secondary and tertiary university research facilities.

Overall Analysis of Researcher Perceptions

From the comments offered by researchers in the various fields surveyed, a number of common perceptions about R&D in Japan were identified. These include observations regarding the Japanese emphasis upon applied rather than basic research, the occasionally greater degree of cross-training in Japan, the greater use of empirically-based R&D approaches, the coordination among researching organizations, and the longer-term commitment to research. These observations are discussed below.

Researchers noted almost unanimously that the strength of the Japanese effort is in applied research rather than basic work. Researchers in several fields noted that efforts in Japan have often relied on results from basic research performed elsewhere, although it was observed by several researchers that the Japanese will repeat another nation's work to establish their own data base. These observations seem consistent with the popular perception of a general tendency in Japanese technology development to borrow concepts or

technologies initially developed elsewhere and then improve on them. These improvements are especially evident in commercialization steps beyond applied R&D: the Japanese excellence in processing and manufacturing was noted in all ten of the technical areas reviewed.

In several fields, however, researchers noted that there is currently a redirection toward a greater emphasis on basic research. This redirection marks a significant shift in Japanese research from the previously strong bias toward applied work. These fields include tribology, amorphous metals, and combustion.

Researchers in a variety of fields also noted some differences in the way research generally is conducted in Japan as compared with the U.S. It was noted that researchers in Japan are typically less restricted by academic disciplines than those in the U.S. In tribology, for example, a Japanese researcher will often apply to his research aspects of hydrodynamics, chemistry, and possibly even surface science, which are typically more differentiated disciplines in the U.S. Similarly, Japanese engineers in biotechnology will combine work in process engineering and fermentation in a more developed manner than U.S. researchers.

A second notable difference in research in Japan is the heavily empirical approach often used in finding a material or organism with desired characteristics. In biotechnology researchers observed that their Japanese counterparts will frequently screen hundreds of organisms to find one with the desired characteristics, rather than attempting to create one using genetic engineering techniques. Similarly, researchers in amorphous metals noted that their peers in Japan will often process a hundred different materials to derive rules of behavior and to find a material with the desired properties. This work is typically performed well and thoroughly but is very unlike the typical approach in the U.S., where researchers strongly prefer to work in areas that differ significantly from those of their peers.

The structure of research in Japan also appears to differ from that of the U.S. A substantial level of coordination of research efforts was noted by researchers in many of the fields studied. It was often remarked that although efforts in the U.S. are typically more broadly based than those in Japan, they

are also typically much less well coordinated. This level of coordination applies not only to the long-term efforts, but also to applied and developmental work. University-industry cooperation was also frequently mentioned as being much more significant in Japan. For example, in tribology it was noted that any university program lacking close industrial ties is considered to be a secondary program. Also, although the government financial contribution to research areas is recognized to be small to moderate, the coordination made possible by their guidance is viewed as significantly beneficial.

Researchers commented that both public and private agencies in Japan are more willing to commit resources to a research area over the long term and that this longer-term commitment fosters an ability to mix long-term and short-term efforts. Laboratories in Japan often do not distinguish between long-term and short-term work but perform the mixture of these elements that suits their technical needs. This commitment minimizes disruptions caused by changes in government administrations or by short-term fluctuations in private sector planning.

INFORMATION TRANSFER TO U.S. RESEARCHERS

The second major issue of concern addressed in this study is the quantity and quality of the technical information on Japanese research available to U.S. researchers. The researchers were asked about their methods for following developments in Japan as well as their judgments of the effectiveness of these means. In particular, researchers were asked to comment on the literature, conferences, and other mechanisms for interaction. In this section general comments on the various information sources are given first, followed by comments on a few specific technology areas. Finally, some overall concerns regarding information transfer are discussed.

Information Sources

Researchers commented that journals are the most useful and relevant in fundamental fields of study in which the state of the art advances slowly. Researchers in heat transfer and combustion noted that the two-year delay typical of journal articles does not often pose much difficulty. In the more end-use oriented fields, such as ceramics and amorphous metals, this two-year delay

can be the difference between the laboratory work and commercialization. In these sectors, researchers review the literature for the fundamental work but otherwise use it only as a supplementary source of information.

Major national or international conferences provide a good forum for interaction and are generally well attended by Japanese researchers. Conferences are typically viewed as being more timely than the journal literature. These conferences are also highly valued for their ability to provide contacts with researchers from Japan.

Smaller, more topically focused meetings often attract significant attendance from both the U.S. and Japan, such as the binational seminars sponsored by the National Science Foundation. Many researchers noted that these small seminars are among the most effective means of exchanging information because they provide an informal setting for interaction as well as an environment for technically detailed discussions.

The quality of these avenues for information transfer in each of the technology areas is summarized below.

Quality of Information Transfer in Various Technical Areas

Information dissemination in heat transfer is clearly superior to any other field covered in this study. In many ways, this field provides a model of information transfer that other fields would benefit from emulating. The field has good international journals and a service that translates selected articles from Japan. This service, which is published by Pergamon Press, screens articles written in Japanese and then translates them into English. This field also has conferences that are well attended by Japanese researchers and has periodic binational seminars. For example, the National Science Foundation has sponsored several binational seminars in heat transfer in the past few years.

A second set of technology areas is considered to have moderate information transfer from Japan. There are typically a few good international journals and a few good international conferences in these areas that combine to provide the primary formal sources of information on Japanese work. Fields

that fall into this category include amorphous metals, biotechnology, combustion, ceramics, and electrochemical energy storage.

The next lower step in the quality of information transfer involves those fields in which the international literature and conferences provide a sparse and incomplete picture of work in Japan. There are no major journals in these fields in which the Japanese regularly publish nor are there major conferences at which their work is well represented. These fields include biotechnology, heat engines and tribology.

Finally, in a few areas the information transfer is obviously poor. Neither the international literature nor the conferences provide more than very sparse coverage of work in Japan. These fields include high-temperature sensors and thermal and chemical energy storage. The incompleteness of the information transfer is reflected in the inability of U.S. researchers to identify notable aspects of Japanese research in these fields or to offer comments on Japan's comparative position.

Overall assessments of the quality of the information sources available in each of the fields are shown in Table 2. The assessment of the quality of the English language journals in the various fields is divided into U.S. and international journals, and Japanese journals or articles translated into English. An "excellent" rating indicates that generally researchers feel the material is comprehensive, sufficiently detailed, timely, and representative of the significant work under way. A "good" rating indicates that significant journals exist, but are lacking in timeliness, comprehensiveness, or in the detail of the research reported. "Fair" indicates that the journal coverage is very limited in comprehensiveness or detail on the Japanese work presented. Finally, a "poor" rating indicates that the material available is generally cursory, providing only very occasional information on developments in Japan. Conferences are rated in Table 2 on the same basis as the journals. Small meetings, which are generally regarded as being highly effective, are simply noted on the basis of how often they occur. An "excellent"-rated conference needs little improvement, and a "good" rating signifies that there are a few deficiencies detrimental to U.S. understanding of the material. The contribution of personal contacts to the information transfer process is not included

TABLE 2. Quality of Technical Information Transfer to U.S.

Research Field	Researcher Interviewed	Journals		Conferences	Other Meetings	Overall Rating
		International and United States	Japanese Translation			
Amorphous Metals	11	***	***	***	0	***
Ceramics	16	**	**	***	0	***
Combustion	15	***	**	***	0	***
Tribology	13	**	**	**	--	**
Heat Transfer	7	****	****	***	+	****
Biotechnology	6	**	**	**	0	**
Heat Engines	10	**	*	**	--	**
Electrochemical Energy Storage	9	***	**	***	0	***
Thermal and Chemical Energy Storage	6	*	*	*	--	*
High Temperature Sensors	8	*	*	*	--	*

**** excellent
 *** good
 ** fair
 * poor

+ meetings occur periodically
 0 meetings have occurred once or twice
 -- no such meeting

in this overall rating. This is not to discount their importance, as many researchers use contacts as a primary means of monitoring developments in Japan, but they are omitted because access to this resource varies greatly among individuals and is not a generally available source.

Common Concerns Regarding Information Transfer

During the interviews, several common concerns arose regarding shortcomings in the transfer of technical information. These concerns centered on the quality of accessible technical information and the level of interaction with Japanese researchers. In all the fields, except for heat transfer, researchers have only very limited access to Japanese publications. The researchers contacted who are able to read or otherwise gain access to the Japanese technical literature found the information to be more useful than the international literature in several ways:

- The Japanese literature is more timely.
- The Japanese literature is often more detailed, describing experimental details often left out of the international literature.
- The Japanese literature does not duplicate material in international literature and offers useful additional insight to the work.
- The Japanese literature is more comprehensive than the international literature. Many researchers in Japan publish principally or solely in Japanese.
- The Japanese literature contains more information on applications of the research and on industrial research. The international literature is often principally academic.

Researchers also noted that the U.S. generally does a poor job of monitoring patents submitted in Japan. In contrast, there is an office in the Japanese government specifically assigned to monitor foreign patents.

Technical information services are not used very extensively because of the effort required to identify significant articles. Researchers in many fields noted that Japanese technical literature is not as thoroughly reviewed as U.S. technical literature. Consequently, the quality of the literature

varies widely, and sifting through the literature for the useful articles is frequently not considered to be worth the time required. Thus, translation of these articles alone is not sufficient. Researchers emphasized the need to provide screening service along with translation service, as performed in the field of heat transfer.

In addition to the inability to monitor much of the Japanese literature, it was frequently noted that relatively few U.S. researchers attend conferences in Japan or visit Japanese facilities. Again by contrast, Japanese technical people are very aggressive about attending U.S. conferences and visiting U.S. facilities. Therefore, visits of Japanese researchers to U.S. facilities are a major component of research interactions with the Japanese. U.S. researchers frequently noted that visiting research facilities in Japan has several advantages over relying upon Japanese visits to the U.S.:

- Visits allow detailed interchange about work underway at the facility in Japan.
- The facilities provide an indication of the approach and limitations of experiments in Japan, which are not always evident in the literature.
- The visits allow interaction with researchers in Japan who do not get to travel frequently to the U.S.

The importance of this personal interchange is suggested at two levels: formal exchanges and visits to research facilities and conferences in Japan.

A large percentage of the researchers interviewed recommend that exchanges be encouraged to give graduate students, faculty, and other members of the research community the opportunity to work in Japan. It was emphasized that these should be substantive scientific exchanges involving research in Japanese laboratories. In addition to developing an intimate familiarity with research methods used in Japan, these exchanges would have the more permanent benefit of allowing the development of close personal and professional contacts with researchers in Japan. Interviews have made it clear that the U.S. has been overly delinquent in promoting this type of exchange.

Many researchers also commented that visits to conferences in Japan and to research facilities should be encouraged rather than restricted. Restricting travel only aggravates the problem of unidirectional information flow because few researchers are able to visit the experimental facilities in Japan to discuss technical details.

With the current restrictions on overseas travel imposed by many private organizations and the government, some researchers have relied heavily on the trip reports of those who do travel. While these trip reports can be valuable sources of information on current activities in Japan, they are limited by the researcher's interests and reasons for the visit. Trip reports also tend to be limited to the small group of researchers who are aware of them. No mechanism is available for making these reports known to the general community.

When discussing the need to encourage more visits to Japan, several caveats were offered by U.S. researchers who have had extensive experience in this area. These researchers noted that it is important to make a commitment to developing technical relationships: merely passing through facilities once may produce a very superficial view of the work. Secondly, it is important to develop an understanding of the structure of research in Japan. Researchers unaware of the differences, such as the organization of laboratories or the other facilities available, are likely to develop a distorted view of the work underway. Therefore, although visits are needed, the most meaningful rewards in information exchange are reaped through long-term contacts, which can only be developed by making a commitment to establishing and continuing technical relationships.

In summary, several steps can be taken to improve binational information transfer and provide both researchers and research managers with better insight into efforts in Japan. This study has revealed that in fields in which significant research is being performed in Japan, mechanisms of binational information exchange can be significantly improved. The principal components identified include:

- screening and translating technical material published in Japan

- promoting binational seminars or workshops, in conjunction with organizations such as the National Science Foundation
- encouraging the development of professional relationships through research exchanges and by easing international travel restrictions.

BENEFITS OF MONITORING JAPANESE RESEARCH: RESEARCH PLANNING

As international technology developments continue to advance, the inability of U.S. technology planners to utilize these developments will become increasingly significant. The potential penalties of not improving the current poor ability to keep abreast of R&D in Japan range from the inefficient repetition of R&D in the U.S. to the decreased competitiveness of U.S. industries.

By studying research overseas, both the researcher and research planner can increase the efficiency and effectiveness of their work. Researchers can benefit from international information exchange by exploring alternative insights that can be found overseas and by avoiding the repetition of costly experiments. Research planners can use information regarding international developments in their programmatic decisions, decisions that may bear directly upon the international competitiveness of U.S. technologies. This information would provide insight to the research planner regarding the comparative position and future developments in the field, and alternative emphases in technology development.

Comparative positions and future developments can be discerned by tracking R&D, since R&D is a predecessor of advances in commercial technology. For example, surface scientists note that the advanced semiconductor technology that has recently emerged in Japan was made possible by the significant long-term commitment made to this technology in the early 1970s. This commitment involved a heavy investment in surface science tools and their application to semiconductor materials at a notably more significant level than in the U.S.

Reviewing overseas activities can also shed light on alternative ways to organize the research approach in a technical field. For example, tribology research in Japan is conducted by intermixing chemical and mechanical components. By contrast, research in the U.S. tends to be conducted according to

more sharply defined disciplines, with a heavy emphasis on the mechanical aspects. A second example occurs in biotechnology, in which Japanese government-supported research focuses upon process engineering. By contrast, process engineering is a very minor part of the government-funded effort in the U.S.

Research managers are faced with the problem of acquiring a comprehensive understanding of binational research activities in the various fields. Sorting through the abundance of technical material would quickly become an unmanageable chore. Yet this study has demonstrated the importance of monitoring the comparative positions of U.S. and Japanese developments. Thus it is recommended that researchers who closely follow work in Japan meet periodically to share and summarize their perceptions of the status of Japanese R&D. These researchers could provide a valuable resource for a more comprehensive and technically detailed study of specific fields in Japan. Such studies are necessary to effectively understand the full extent, scope, and status of the potential challenge to U.S. research and technology development, and to ensure that U.S. research maintains its position at the leading edge of science and technology.

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