JTEC/WTEC ANNUAL REPORT AND PROGRAM SUMMARY 1993/94

Geoffrey M. Holdridge, Editor

March 1994

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* **Boldface indicates new summaries from 1993/94 reports.**

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† **Published in final form for the first time in this volume**

LOYOLA COLLEGE IN MARYLAND

Director's Letter

Loyola College in Maryland

March 1, 1994

It is a distinct pleasure to deliver to our readers this summary of studies and a report of recent activities at the Japanese Technology Evaluation Center (JTEC) and the World Technology Evaluation Center (WTEC). Briefly stated, the mission for JTEC/WTEC has been to inform R&D policymakers in government, industry and academe concerning the current status and trends in high technology abroad. To that end we are happy to report the completion of five studies in 1993 and progress on five more, which will be published soon.

By all measures, the JTEC/WTEC program has achieved significant improvement in dissemination in the past year, generating more public interest in the results of its studies. The increasing attention being paid to JTEC and WTEC studies in the industrial research and manufacturing communities is evidenced by their growing representation among our workshop attendees (now about fifty percent) and by their requests for copies of the reports. Over a thousand persons attended JTEC/WTEC workshops in the time period covered by this summary, and over a thousand more have heard secondary presentations of study results in other forums. In addition, 5,000 full reports and 4,000 executive summary reports have been distributed. In calendar year 1993, 33 expert panelists visited eleven different nations to research the state of the world's high technologies.

It was exciting in three of these studies to observe the excellence of science and engineering in Russia, Belarus and Ukraine and to have active participation in our workshops by 11 outstanding scientific representatives of those countries. Many opportunities for international cooperation were brought to light in these and other studies.

The JTEC/WTEC program owes appreciation to numerous people for their support of the past year's activities -- Paul Herer and many others at the National Science Foundation, sponsors from numerous agencies, superb panelists who contributed the quality information, and an excellent staff, led by Geoff Holdridge, that published and distributed about 1.5 million pages. Special thanks are due to Duane Shelton, currently director of the International Technology Research Institute, who brought the JTEC/WTEC organization up to operational speed and passed it over to me in early 1993.

I hope that you will find value in this information and will offer us your suggestions for the future course of JTEC and WTEC.

Michael J. DeHaemer
Director, Principal Investigator

FOREWORD

The National Science Foundation has been involved in funding technology assessments comparing the United States and foreign countries since 1983. A sizable proportion of this activity has been in the Japanese Technology Evaluation Center (JTEC) and World Technology Evaluation Center (WTEC) programs. We have supported more than 30 JTEC and WTEC studies over a wide range of technical topics.

As U.S. technological leadership is challenged in areas of previous dominance, such as aeronautics, space, and nuclear power, many governmental and private organizations seek to set policies that will help maintain U.S. strengths. To do this effectively requires an understanding of the relative position of the United States and its competitors. The purpose of the JTEC/WTEC program is to assess research and development efforts ongoing 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 pre-competitive research.

Many U.S. organizations support substantial data gathering and analysis efforts directed at 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. That is, they provide enumeration of 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 technical fields. The National Science Foundation staff includes professionals with expertise in a wide range of disciplines. These individuals provide the technical expertise needed to assemble panels of experts that can perform competent, unbiased, technical reviews of research and development activities.

Specific technologies, such as telecommunications, biotechnology, and nuclear power, 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 assessment is sponsored by two to four agencies. In the first few years of the program, most of the studies focused on Japan, reflecting concern over Japan's growing economic prowess. Studies were largely defined by a few federal mission agencies that contributed most of the funding, such as the Department of Commerce, the Department of Defense, and the Department of Energy.

The early JTEC methodology involved assembling a team of U.S. experts (usually six people, from universities, industry, and government), reviewing the extant literature, and writing a final report. Within a few years, the program began to evolve. First, we added site visits. Panels traveled to Japan for a week visiting 20-30 industrial and research sites. Then, as interest in Japan increased, a larger number of agencies became involved as co-sponsors of studies. Over the 10 year history of the program, 15 separate branches in six agencies of the Federal Government (including NSF) have supported JTEC and WTEC studies.

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. These most recent WTEC studies have focussed on identifying opportunities for cooperation with researchers and institutes in Russia, Ukraine, and Belarus, rather than on assessing them from a competitive viewpoint.

In the past four years, we have also begun to considerably expand dissemination efforts. Attendance at JTEC/WTEC workshops (in which panels present preliminary findings) increased, especially industry participation. Representatives of U.S. industry now routinely number 50% or more of total attendance, with a broad cross section of government and academic representatives making up the remainder. JTEC and WTEC studies have also started to generate increased interest beyond the science and technology community, with more workshop participation by policymakers and better exposure in the general press (e.g., *Wall Street Journal*, *New York Times*). Publications by JTEC and WTEC panel members based on our studies have increased, as has the number of presentations by panelists at professional society meetings.

The JTEC/WTEC program will continue to evolve in response to changing conditions in the years to come. We are now considering new initiatives aimed at the following objectives:

- o Expanded opportunities for the larger science and technology community to help define and organize studies. This may be accomplished through a proposal competition in which NSF would invite universities and industry (preferably working together) to submit proposals for JTEC and WTEC studies. These would then be peer reviewed much as NSF reviews research proposals.

- o Increased industry sponsorship of JTEC and WTEC studies. For example, NSF recently funded a team organized by the Polymer Science & Engineering Department at the University of Massachusetts (Amherst) to visit Japan for two weeks studying biodegradable plastics and polymers R&D there. Twelve industrial firms put up over half of the funds.

- Including a broader policy and economic context to our studies. This is directed at the need to answer the question, "So what?" that is often raised in connection with the purely technical conclusions of many JTEC and WTEC panels. What are the implications of the technical results for U.S. industry and the economy in general? We will be adding an economist to an upcoming JTEC study on optoelectronics in Japan as a new effort to address these broader questions.

In the end, all government funded programs must answer the following question: *How has the program benefitted the nation?* I would like to point out a few of the benefits of the JTEC/WTEC program:

- JTEC studies have contributed significantly to U.S. benchmarking of the growing prowess of Japan's technological enterprise. Some have estimated that JTEC has been responsible for over half of the major Japanese technology benchmarking studies conducted in the United States in the past decade. Our reports have also been widely cited in various competitiveness studies.

- These studies have provided important input to policymakers in federal mission agencies. JTEC and WTEC panel chairs have given special briefings to senior officials of the Department of Energy, the NASA Administrator, and even the President's Science Advisor.

- JTEC/WTEC studies have been of keen interest to U.S. industry, providing managers with a sense of the competitive environment internationally. Members of the recently completed study on satellite communications have been involved in preliminary discussions concerning the establishment of two separate industry/university consortia aimed at correcting the technological imbalances identified by the panel in its report.

- JTEC and WTEC studies also have been valuable sources of information for both U.S. and foreign researchers, suggesting potential new research topics and approaches, as well as opportunities for international cooperation. One JTEC panelist was recently told by his Japanese hosts that, as a result of his observations and suggestions, they have made significant new advances in their research.

- Not the least important is the educational benefit of the studies. Since 1983 over 170 scientists and engineers from all walks of life have participated as panelists in the studies. As result of their experiences, many have changed their viewpoints on the significance and originality of foreign research. Some have also developed lasting relationships and ongoing exchanges of information with their foreign hosts as a result of their participation in these studies.

As we seek to refine the JTEC/WTEC program in the coming years, improving the methodology and enhancing the impact, we will still be operating from the same basic premise that has been behind the program from its inception: the United States can benefit from a better understanding of cutting-edge research that is being conducted outside its borders. Improved awareness of international developments can significantly enhance the scope and effectiveness of international collaboration and thus benefit all of our international partners in collaborative research and development efforts.

Paul J. Herer
National Science Foundation
Arlington, VA

A. ANNUAL REPORT 1993/94

I. JTEC/WTEC Program at Loyola College

LOYOLA COLLEGE

Loyola College in Maryland, founded in 1852, is part of the proud 450-year old tradition of Jesuit education worldwide. Among the 28 Jesuit colleges and universities in the United States, Loyola was the first to bear the name of St. Ignatius Loyola, the founder of the Society of Jesus. Originally founded to provide a liberal education to Baltimore's Catholic community, Loyola was always open to students of other religious persuasions. Modern-day Loyola continues in this tradition of serving the community by providing a broad liberal education to students from a wide variety of backgrounds. While maintaining an emphasis on undergraduate education, Loyola also offers a wide variety of graduate programs in the College of Arts and Sciences as well as in the Joseph A. Sellinger, S.J. School of Business and Management.

Among these graduate programs are courses in computer science, electrical engineering and engineering science, in keeping with the Jesuit tradition of excellence in science and mathematics. Also in keeping with Jesuit tradition, Loyola College values the benefits of cultural diversity and a global perspective on business. The college maintains international study programs in Belgium and Thailand, actively recruits foreign students for the Baltimore campus, and includes international studies as part of its graduate programs in international business and executive management.

President's Remarks

As part of its mission, Loyola College seeks to provide service to its traditional community and at the same time to be outward looking. In this context we are proud to support and have in residence the Japanese Technology Evaluation Center (JTEC) and the World Technology Evaluation Center (WTEC). These centers are in keeping with a College commitment to excellence in science, and enable us to contribute both to our country and to our home state the best knowledge that exists about world trends in high technologies.

Thomas Scheye
Acting President
Loyola College

INTERNATIONAL TECHNOLOGY RESEARCH INSTITUTE

Loyola's International Technology Research Institute (ITRI) combines the college's strengths in science and technology with its international interests. ITRI is currently housed in the Donnelly Science Building with Loyola's Electrical Engineering and Engineering Science Department. ITRI's co-founders, Drs. Shelton and DeHaemer, also teach and serve as department heads of Loyola's Engineering and Information Systems and Decision Sciences departments, respectively. ITRI's staff boasts professional background in history, science policy, economics, information technology, and political science -- attesting to the interdisciplinary nature of ITRI's endeavors. ITRI is a synergistic umbrella organization that houses three centers for assessment of foreign technology. The Transportation Technology Evaluation Center (TTEC) has the mission of assessing foreign technology in vehicles, transportation, and construction methodology and highway systems. It is supported by the Federal Highway Administration, and is directed by Prof. Shelton. The Japanese Technology Evaluation Center (JTEC) and the World Technology Evaluation Center (WTEC) are directed by Prof. DeHaemer, and are supported by the National Science Foundation under a cooperative agreement.

MISSION

The JTEC program was initiated in 1983 by the U.S. Department of Commerce and the National Science Foundation (NSF) for the purpose of informing policy makers, strategic planners and managers from government and private industry about the status of selected high technologies in Japan in comparison to that in the United States. Subsequently, the WTEC program was established to provide similar studies of countries other than Japan.

NSF assumed leadership of the program in 1984. Consistent with NSF's commitment to open international exchange of scientific and technical information, the JTEC program was one of the first foreign technology monitoring efforts funded by the U.S. Government to operate totally in the public domain. JTEC/WTEC thereby contributes to NSF's goal of promoting international collaboration in science and technology by identifying other countries' strengths in specific research and development areas; these are the areas that can provide opportunities for fruitful international collaboration.

The JTEC/WTEC program has the twin missions of helping the United States better understand the international competition it faces in science and technology as well as helping to identify opportunities for international collaboration in pre-competitive research. It does this by establishing a world-class benchmark for each technology studied and comparing the different approaches being taken in research programs around the world. This international perspective can offer new insights on the direction of U.S. research programs.

METHODOLOGY

The objective of an ITRI study is to produce an up-to-date report on the outcomes of current R&D efforts in a specific field for a specific geographic area. The report is a rendering of the judgements of the leading U.S. experts as to the value --

scientific, technical, and industrial -- of the technologies they have observed abroad. A study answers the following questions:

What is the worldclass benchmark?
What is the competitive environment?
What are the opportunities for cooperative ventures?
Are there different approaches being taken abroad?
Is our research emphasis correct?

A panel for a study nominally has six members, but often seven or more, who travel to a host country for site visits and discussions with researchers to reach conclusions about the state of the observed technology. Panelists are chosen for their own special expertise in and knowledge of the technology under study, both domestically and abroad. Thus they are able to compare this R&D to that in the United States.

Much of the strength of the JTEC/WTEC effort comes from the quality of its panelists. They have included the Under Secretary of Commerce for Technology; a former Associate Administrator of NASA; vice presidents or provosts of UC Berkeley, RPI, and Rice University; and many distinguished engineers and scientists from the academic, government, and industrial communities of the United States.

The results are initially presented in workshops attended by representatives from the public and private sectors who critique the preliminary findings. The panels' written reports are distributed by the National Technical Information Service (NTIS), where they have become best-sellers with leading U.S. and Japanese firms, universities, and the science counselors of the embassies in Washington. Thousands have received gratis copies because of workshop attendance, hosting of panels, etc. The results are also presented in books and articles by the panelists. Studies are usually the subject of national press accounts; a sample of these publications is listed in the Bibliography (Appendix II).

Although ITRI is planning to try out a number of revisions to this methodology in the coming year, this approach has yielded successful results in over thirty studies conducted to-date involving a dozen countries and over 200 panelists and other participants.

II. Review of JTEC/WTEC Activities for 1993 and Early 1994

In calendar year 1993, JTEC/WTEC sent five delegations (totalling 33 panelists and 11 observers) on tours of overseas laboratories, completed five final reports, issued five full draft reports, conducted five workshops and seven smaller meetings, and initiated four new studies. JTEC/WTEC also prepared three summaries of the state-of-the-art of U.S. technology in the course of its ongoing studies, three books of draft site reports distributed for review to hosts and panelists, and three stand-alone executive summaries based on JTEC/WTEC final reports. Including draft reports, workshop viewgraph books, etc., the JTEC/WTEC staff prepared over 4,500 pages of manuscript in 1993 and the first six weeks of 1994, 1,100 of which were in final reports. The staff mailed out or otherwise disseminated a total of over 1.5 million pages in copies of these draft and final reports.

In addition, the JTEC/WTEC program has put renewed emphasis on widening the dissemination of study results, employing large commercial mailing lists, regular press releases, and paid advertising for the first time. JTEC/WTEC mailed over 28,000 workshop invitations in 1993. Participation by U.S. manufacturing companies in JTEC and WTEC workshops in 1993 reached an all time high. JTEC/WTEC enjoyed greater coverage in the technical and general press in 1993 than in the previous nine years combined. All of these developments are discussed in further detail below.

TRIPS

JTEC/WTEC sent two delegations to Japan in 1993 plus three to Europe and the former Soviet Union.

The WTEC Panel on ***Research Submersibles and Undersea Technologies*** visited Finland, France, Russia, Ukraine, and the United Kingdom in May of 1993, stopping to see 39 facilities in those countries. This panel was sponsored by NSF and ARPA, with additional participation from the National Oceanic and Atmospheric Administration. The panel saw many research submersibles that were previously unknown in the West. In Ukraine, the panel saw Mach 1 ocean speed research underway at the Kiev Institute for Hydrodynamics.

The Civil Engineering Research Foundation (CERF) organized a Task Force on ***Constructed Civil Infrastructure Systems R&D*** in early 1993. WTEC commissioned a panel of U.S. civil engineering technology experts to join CERF's Task Force during its June 1993 trip in order to assess the status of European constructed civil infrastructure technologies. Among the Task Force's more interesting observations was a new form of concrete under development in France that can grow its own fiber reinforcement as a result of a delayed chemical reaction.

In September of 1993, JTEC's Panel on ***Micro-electro-mechanical Systems (MEMS)*** visited Japan to look at progress there in the development of millimeter- to micron-scale, batch-fabricated electro-mechanical devices and their applications. This study is sponsored by NSF, ARPA, the Air Force Office of Scientific Research, and the Department of Commerce. The MEMS panel found that the highly publicized MITI national research program in micromachines is focussed primarily on non-lithographic approaches to micro-machine fabrication. However, the MITI program is dwarfed by other Japanese MEMS research, primarily in industry, that closely parallels U.S. efforts in lithography-based approaches. The U.S. probably retains a lead in lithographic approaches, but the panel saw a number of innovative Japanese programs in the non-lithographic area.

The MEMS panel was followed closely by the JTEC Panel on ***Electronic Packaging***, sponsored by NSF, ARPA, NASA, and the Dept. of Commerce, which visited 12 major Japanese electronics manufacturers in early October in a search for improved understanding of Japan's overwhelming success in the global marketplace for ultra-compact and low-cost consumer electronics. That panel found that, though the U.S. is close to or equal to Japan in packaging technology, Japan is far ahead in manufacturing process development and refinement, and in market-pull product and manufacturing technology innovation.

Finally, the WTEC Panel on ***Advanced Display Technologies*** visited Russia, Belarus, and Ukraine in late October to assess opportunities for collaboration between the United States and the countries of the former Soviet Union in advanced display technologies. This effort was sponsored by NSF and ARPA. The panel found many intriguing display technologies under development in these three countries, among which is an electron beam pumped laser projection display (the "quantoscope") that is claimed to have over 3,000 lumen white light brightness at resolutions that easily exceed 2500 lines.

Table 1 shows the JTEC/WTEC foreign trips for 1993. Altogether, 43 JTEC/WTEC panelists and observers visited 188 sites in 11 countries.

TABLE 1
JTEC/WTEC Foreign Trips in 1993

STUDY	DATES OF TRIP	COUNTRIES VISITED	# SITES VISITED
Research Submersibles	May 16 - 30, 1993	Finland, France, Russia, Ukraine, United Kingdom	39
CERF Task Force	June 5 - 14, 1993	France, Germany, Italy, the Netherlands, Sweden, United Kingdom	78
MEMS	Sept 25 - Oct. 2, 1993	Japan	22
Electronic Packaging	Oct. 2 - 9, 1993	Japan	12
Advanced Display Technologies	Oct. 23 - 30, 1993	Belarus, Russia, Ukraine	37

DISSEMINATION HIGHLIGHTS

Workshops

1993 was a banner year for JTEC/WTEC with respect to workshop attendance. Our first workshop of the year, the NASA/NSF Conference on Satellite Communications in Europe, Russia, and Japan, set a JTEC/WTEC record for attendance (over 200). This was due in part to advertisements placed by JTEC/WTEC in five relevant technical journals. Perhaps more significantly, this was also the first major effort by JTEC/WTEC to use large commercially available mailing lists for workshop invitations.

Table 2 shows the number of invitations mailed and attendance at each of the JTEC/WTEC workshops held in 1993 and early 1994.

Thus, JTEC/WTEC has mailed 2,500 or more invitations for each of its workshops since the Satellite Communications Conference, held in February 1993. This adds up to over 28,000 invitations mailed for all workshops in this period, not including invitations distributed via electronic mail and fax. This is in contrast to earlier years, when invitation lists for workshops typically ran in the hundreds. Attendance at JTEC/WTEC workshops in 1993 averaged just over 140, and consistently exceeded 100, compared to an average of 50 to 75 in earlier years.

TABLE 2
Invitations and Attendance at JTEC/WTEC Workshops in 1993/94

WORKSHOP	DATE	INVITED	ATTENDED
Satellite Communications	Feb. 5, '93	2500	240
Polymer Composites	Feb. 18, '93	4500	160
Research Submersibles	July 29, '93	3500	200
CERF	Sept. 1, '93	2500	120
MEMS	Nov. 17, '93	6500	100
Electronic Packaging	Jan. 12, '94	4500	140
Advanced Displays/FSU	Feb. 3, '94	3800	120

Press coverage also increased significantly for the 1993 JTEC/WTEC workshops compared to previous years. Every 1993 workshop received mention in the general or technical press. Participation in our workshops by representatives of U.S. industry was consistently high in 1993, averaging over 50% of total attendance in the most recent two workshops. In two comparable 1991 JTEC workshops, an average of only about 20% of participants hailed from U.S. manufacturing companies.

We have also made efforts to improve workshop presentations and to make the workshop itself more pleasant for the audience. Beginning with the CERF workshop in September of 1993, all JTEC/WTEC workshops have included color presentation graphics. JTEC/WTEC workshops have also had several changes of venue in the past year, as we tried several different facilities in Washington, DC, then moved our workshops to the vicinity of NSF's new offices in Arlington, VA.

Two of the 1993 workshops covered technologies in the newly independent countries of the former Soviet Union (FSU) -- concentrating mostly on the Russian Federation, Ukraine, and Belarus. These took a different approach from previous JTEC and WTEC workshops. Rather than comparing the quality of FSU R&D with that in the West, both the research submersibles and the advanced display technology workshops instead focussed on identifying interesting new technologies and centers of excellence in the FSU. To regular JTEC/WTEC workshop attendees, the most noticeable difference was probably the absence of the traditional "rating chart" summation of the panel's findings. The other notable difference was the active participation of a total of 11 eminent scientists from Russia, Ukraine and Belarus at these workshops (see Table 3). Especially in the case of the advance displays study, the workshop took on a new dimension as a way of fostering cooperation between U.S. companies and researchers and those of the former Soviet Union -- our guests from the FSU participated in more than 40 meetings with representatives of U.S. companies and universities during their week in the U.S.

TABLE 3
FSU Guests Participating in 1993 WTEC Workshops

NAME	AFFILIATION	COUNTRY	WTEC STUDY
Nikolae Dubrovsky	Andreev Institute	Russia	Research Subs.
Vladimir Gevorkian	Ukraine Academy of Sciences	Ukraine	Research Subs.
Victor Grinchenko	Institute of Hydromechanics	Ukraine	Research Subs.
Anatoly Kuteinikov	Malachite	Russia	Research Subs.
Mark Slavinsky	Russian Academy of Sciences	Russia	Research Subs.
V.G. Chigrinov	NIOPIK	Russia	Advanced Displays
Boris Gorfinkel	VOLGA	Russia	Advanced Displays
Andrej Kosarev	IOFFE	Russia	Advanced Displays
Alexander Smirnov	RadioEngineering Institute	Belarus	Advanced Displays
V.M. Sorokin	Institute of Semiconductors	Ukraine	Advanced Displays
Vladimir Ulasjuk	PLATAN	Russia	Advanced Displays

Other Presentations by Panelists

JTEC/WTEC also encourages panelists to make presentations at professional society meetings as a way of further disseminating study results to the research community. An average of two to three such presentations result from each JTEC or WTEC study. Additionally, panelists are often asked to make presentations about their JTEC/WTEC activities inside their own organizations. The JTEC/WTEC staff is aware of a total of 15 presentations made by panel members in calendar year 1993.

In just the first two months of 1994, JTEC and WTEC panelists made a total of 15 individual oral presentations at two major professional society conferences: the annual meeting of the American Association for the Advancement of Science (AAAS) and the Fifteenth International Communications Satellite Systems Conference sponsored by the American Institute of Aeronautics and Astronautics (AIAA).

The AIAA conference's plenary session was based on the findings of our Panel on Satellite Communications Systems and Technologies, and included presentations by three panelists and two of the panel's principal Japanese and European hosts. An additional session at the same conference, chaired by the panel's NASA sponsor, Ramon DePaula, included detailed reviews of Japanese, European, and Russian satellite communications technologies presented by eight other panelists.

The AAAS meeting's session on international technology benchmarking included presentations by George Gamota (Mitre Corporation and Senior Advisor to JTEC/WTEC) and by Mary Good, former member of the National Science Board and now Under Secretary of Commerce for Technology.

JTEC/WTEC also encourages panelists to publish articles in professional journals drawing on study results. The knowledge-based systems study completed by JTEC in 1993 was the subject of an article authored by that panel in the January 1994 issue of *Communications of the ACM.* A more in-depth treatment of the same report has been accepted for publication in the spring 1994 issue of *AI Magazine*. Prof. Karbhari, a member of the JTEC Panel on Advanced Manufacturing Technology for Polymer Composite Structures in Japan, authored an article based on that study for the August 1993 issue of *Advanced Materials and Processes*. Similarly, the co-chairs of the NASA/NSF Panel on Satellite Communications Systems and Technology, Burton Edelson and Joseph Pelton, published a two-article series in the March and April 1993 issues of *Satellite Communications* based on their experiences as JTEC/WTEC panelists. Several members of the JTEC Panel on Bioprocess Engineering in Japan were co-authors of a National Academy of Sciences report issued in 1993 citing the 1992 JTEC study for its conclusions regarding Japan, and calling for a JTEC-style study of bioprocess engineering R&D in Europe. Similar publications arise out of virtually every JTEC and WTEC panel.

Reports

Written final reports are a primary medium for disseminating the results of JTEC and WTEC studies. Table 4 shows final reports published in 1993.

Thus, the JTEC/WTEC program generated over 1,100 pages of final report manuscript in 1993, distributing a total of 5,000 copies of these reports (or a total of almost 1.1 million pages distributed of all reports combined). The comparable figures for 1992 were 745 total pages of final report manuscript and 2,800 total copies

TABLE 4
JTEC/WTEC Final Reports Published in 1993

TITLE	DATE	PAGES/COPY	COPIES PRINTED*	TOTAL PAGES*
Material Handling in Japan	Feb. '93	248	800	198,400
Separation Technology in Japan	Mar. '93	143	800	114,400
Knowledge-Based Systems in Japan	May '93	200	1,000	200,000
Canadian Nuclear Instrumentation & Controls	July '93	35	400	1,400
Satellite Communications, Vol. I	July '93	322	1,500	483,000
Satellite Communications, Vol. II	July '93	186	500	93,000
TOTAL †		**1,134**	**5,000**	**1,090,200**

* With the exception of one or two of the most recent reports, the number disseminated by JTEC/WTEC very nearly equals the number printed (current stocks are negligible). The dissemination figures shown here do not include additional copies that are produced and sold as xerox or microfiche by the National Technical Information Service (NTIS).

† Numbers in this row are the sum of the columns above. Thus, "total pages" in this row is the sum of all "total pages" rows above it, whereas in all other rows, total pages is pages/copy multiplied by copies printed.

distributed (or 530,000 total pages). Even more importantly, the JTEC/WTEC program has shown steady progress since 1990 in increasing the number of final reports and executive summaries disseminated to the public (Figure 1). In addition to reports disseminated directly by JTEC/WTEC, tallied in Figure 1, the National Technical Information Service (NTIS) distributes several hundred more per year.

The increased level of activity at JTEC/WTEC in 1993 is also evident with respect to draft reports, workshop viewgraphs, and other JTEC/WTEC publications not included in the final report category (see Table 5). These draft reports and other interim products play an important role in the program: sponsors get timely access to preliminary findings; hosts are offered the opportunity to correct any errors or misunderstandings before they are published; panelists and staff have a chance to

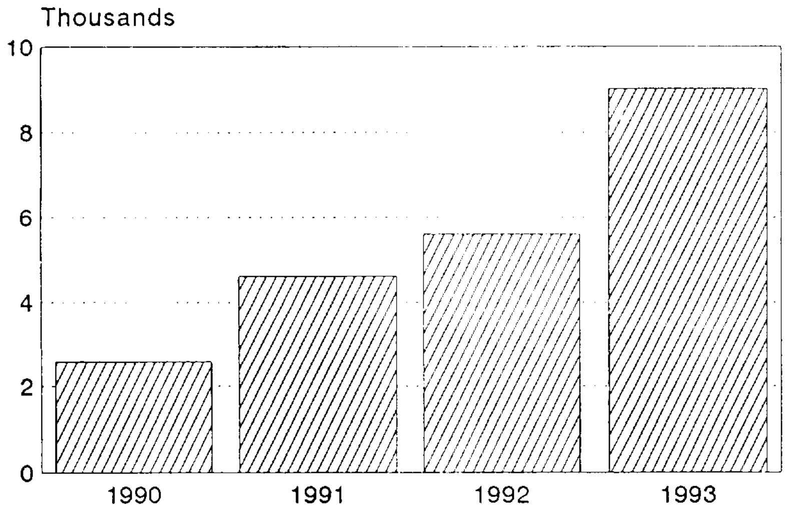

Figure 1. Total Final Reports Printed, Disseminated: 1990-93 (excluding program summaries, including stand-alone executive summaries)

improve the quality and accuracy of the final reports; and the program in general benefits from increased dissemination of study results.

The stand-alone executive summaries listed in Table 5 represent an important thrust in our efforts to widen the awareness of JTEC and WTEC studies in both the R&D and lay communities. JTEC/WTEC printed large numbers of stand-alone executive summaries for three of its 1993 final reports, mailing most of these to professional society mailing lists as a way of promoting interest in and sales of the full reports.

Total manuscript pages in these categories rose from 2,309 in 1992 to 3,480 in 1993 and the first two months of 1994. Total copies distributed of these non-final report manuscripts rose from just over 5,000 copies in 1992 to an estimated 6,855 copies in 1993. Some of these reports have limited distribution (e.g., draft site report books, which are distributed to members of the travelling party and staff while the site reports are under review by hosts). Preparing and distributing these specialized and draft reports accounts for a significant proportion of the total level of effort in the program. In 1993, over three pages of draft manuscripts were generated for each page of final report copy.

Targeted mailing lists have proven to be valuable for workshop invitation and executive summary mailings. Other avenues for expanding dissemination of JTEC and WTEC final reports are also under active consideration. These include commercial publication of final reports and electronic dissemination. For example, in February 1994, JTEC/WTEC signed a Letter of Agreement with MCC providing for all recent JTEC and WTEC reports to be made available to MCC members electronically. As of March 1994, information on the JTEC/WTEC program will be available to all users of Internet's World Wide Web system from a server at Stanford University. Other avenues for electronic distribution of JTEC/WTEC reports through the Internet are also under investigation.

TABLE 5 – Other JTEC/WTEC Publications in 1993/94

TITLE	DATE	PGS./COPY	COPIES	TOTAL PAGES
Material Handling - Stand-Alone Executive Summary	Jan. '93	7	2,000	14,000
Satellite Communications - Preliminary Draft Report	Jan. '93	468	~ 30	14,040
Satellite Communications - Workshop Viewgraphs	Feb. '93	240	350	84,000
Polymer Composites - Workshop Viewgraphs	Feb. '93	251	250	62,750
Satellite Communications - Review Draft Report	Mar. '93	545	120	65,400
Knowledge-Based Systems - Stand-Alone Executive Summary	May '93	10	500	5,000
Submersibles - Summary of U.S. Activities	May '93	30	~ 85	2,550
Submersibles - Workshop Viewgraphs	Jul. '93	208	250	52,000
Satellite Communications - Stand-Alone Executive Summary	Jul. '93	10	2,000	20,000
CERF - Workshop Viewgraphs	Sept. '93	132	200	26,400
Polymer Composites - Preliminary Draft Report	Sept. '93	246	20	4,920
MEMS - Summary of U.S. Activities	Sept. '93	40	~ 100	4,000
FSU Display Technologies - Summary of U.S. Activities	Oct. '93	36	~ 80	2,880
MEMS - Draft Site Report Book	Nov. '93	127	60	7,620
MEMS - Workshop Viewgraphs	Nov. '93	229	200	45,800
Polymer Composites - Review Draft Report	Nov. '93	274	80	21,920
FSU Display Technologies - Draft Site Report Book	Dec. '93	148	70	10,360
Electronic Packaging - Draft Site Report Book	Jan. '94	88	60	5,280
Electronic Packaging - Workshop Viewgraphs	Jan. '94	235	200	47,000
FSU Display Technologies - Workshop Viewgraphs	Feb. '94	156	200	31,200
TOTALS (sum of columns only)		**3,480**	**6,855**	**527,120**

Press Coverage

Table 6 lists reports and articles published in 1993 that cite JTEC and WTEC studies. Thanks in part to the timeliness of the satellite communications study, as well as the reputations of the panelists, in 1993 the JTEC/WTEC program enjoyed more press coverage (27 articles) than in the previous nine years combined. This is depicted graphically in Figure 2.

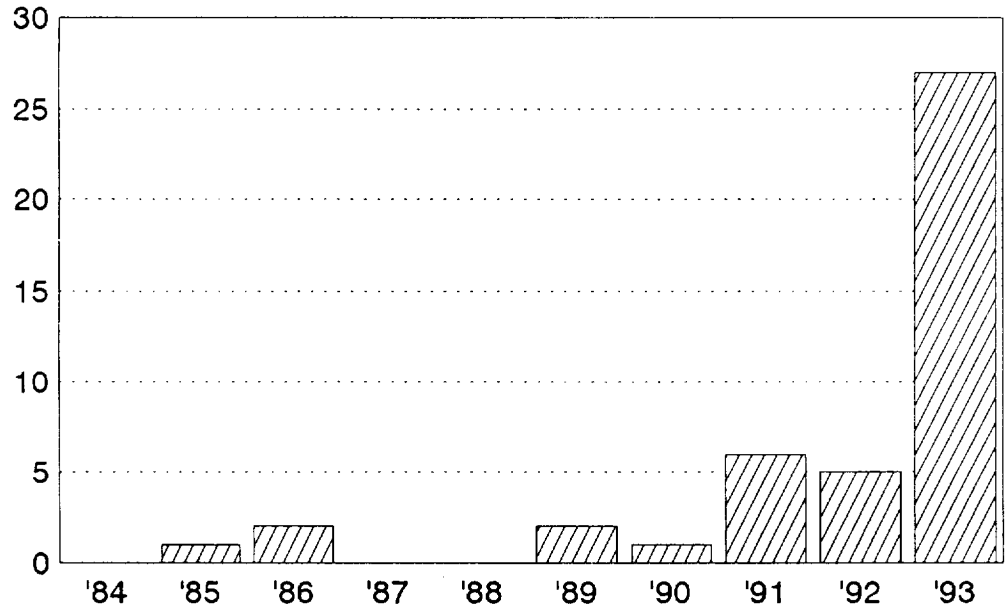

Figure 2. JTEC/WTEC Coverage in the General and Technical Press (excluding articles from Dept. of Commerce and Japan Information Access Project publications)

Of the 27 articles or reports published in 1993 citing JTEC and WTEC studies, 17 were about the satellite communications study. Though this study was of natural interest to the press, we made an effort to attract the press, holding press conferences for several workshops in which there was interest. In 1993, Rosalia Scalia of Loyola's Public Relations Department issued press releases promoting JTEC/WTEC conferences and reports. JTEC/WTEC events have also been listed by the National Science Foundation's Office of Legislative and Public Affairs in its regular press briefings.

The 27 articles listed in Table 6 do not include 18 other references to JTEC and WTEC studies published in special reports (e.g., GAO and OSTP reports) and in the specialized U.S.-Japan technology press (e.g., *Japan Access Alert Bulletin*, *Japanese Technical Literature Bulletin*, *Japan Technical Affairs*, etc.) during 1993. In fact, *Japan Technical Affairs* has published an edited rendition of every JTEC executive summary completed since 1992, and has thus become a highly valued archival publisher of all recent JTEC findings. The Department of Commerce's *Japanese Technical Literature Bulletin* has also faithfully covered JTEC workshops and reports, as has the newsletter of the Japan Information Access Project, *Japan Access Alert*. A full listing of all these citations is included in the Bibliography. Therefore the total number of citations in 1993, including all of the above, was 45.

TABLE 6
1993 JTEC/WTEC Coverage in General and Technical Press

DATE	PUBLICATION NAME	ARTICLE TITLE	RELEVANT STUDY
2/8/93	*New Technology Week*	"Satellites: Another U.S. Industry Faces Decline"	Satellite Communications
2/11/93	*Washington Technology*	"Foreign Sats Lead U.S."	Satellite Communications
2/15/93	*Satellite News*	"Competitors Seek to Narrow U.S. Lead in Mobile Satellites"	Satellite Communications
2/22/93	*New Technology Week*	"Japan Reaches Parity in the Manufacture of Advanced Polymers"	Polymer Composites
3/93	*Satellite Communications*	"The Race Is On"	Satellite Communications
3/93	*Modern Materials Handling*	"Let's Get Going" (Editorial)	Material Handling
3/10/93	*San Francisco Chronicle*	"Elvis: Sun Micro Expected to Team with Russian Firm"	Satellite Communications
4/25/93	*Space News*	"Study: Japan May Catch U.S. Satellite Firms"	Satellite Communications
4/93	*Satellite Communications*	"Japan: Rising Sun or Shooting Star?"	Satellite Communications
5/10/93	*New Technology Week*	"Japan Drawing Bead on U.S. in Membranes?"	Separation Technology
Win/Sp '93	*NASA Alumni League News*	"Satellite Scorecard Mixed as $30 Billion Prize Goes Begging"	Satellite Communications
6/93	*Via Satellite*	"Editor's Note"	Satellite Communications
6/28/93	*Barron's*	"Dangerous Display Flat-Panel Floundering Holds Risks for U.S. Industry"	Display Technology in Japan
7/23/93	*Warfield's*	"Tracking Japan's Growing Strength in Development of High Technology"	JTEC studies in general
7/28/93	*New York Times*	"U.S. is Said to Lag in Space Research"	Satellite Communications
7/29/93	*Space Fax Daily*	"American Sat Makers May Begin Hearing Footsteps of Foreign Rivals"	Satellite Communications

DATE	PUBLICATION NAME	ARTICLE TITLE	RELEVANT STUDY
8/93	*Advanced Materials and Processes*	"Polymer Composites Technology in Japan"	Polymer Composites
8/2/93	*New Technology Week*	"Submersibles in Ex-USSR Eye Openers for Westerners"	Research Submersibles
8/5/93	*Nature*	"Satellite Research 'Needs More Money'"	Satellite Communications
8/16/93	*Electronic Engineering Times*	"U.S. Slipping in Satellites"	Satellite Communications
8/27/93	*The Daily Record*	"U.S. Lags in Construction R&D"	CERF
10/93	*Via Satellite*	"Editor's Note"	Satellite Communications
11/93	*Air Force Magazine*	"The Chart Page -- The Global Race in Satellite Technology"	Satellite Communications
11/93	*IEEE Spectrum*	"The Flat Panel's Future"	Display Technology in Japan
11/24/93	*Space Fax Daily*	"U.S. May Lag in Mobile Satellite Market, Study Warns"	Satellite Communications
11/29/93	*Electronic Engineering Times*	"U.S., Japan Gear Up for Micromachines"	MEMS
12/93	*Signal*	"U.S. Risks Forfeiting Satellite Communications Science"	Satellite Communications

III. Plans for the Coming Year

STUDIES UNDERWAY

As of February 1994, there are two WTEC and three JTEC studies in progress. In addition, the CERF study referred to above, in which JTEC/WTEC has collaborated, is nearing publication of its final report.

- The JTEC Panel on Advanced Manufacturing for Polymer Composite Structures in Japan released its full draft report in November 1993. This has now completed review by the panel's Japanese hosts and the JTEC/WTEC editor. Hosts' comments and editor's changes and markup are now under final consideration by the panel members. The JTEC/WTEC staff will be working with the panel in March and April 1994 to prepare the final report. We have completed review of the panel's executive summary, which therefore is included in this volume.

  It is interesting to note that this panel's conclusions regarding Japanese manufacturing in polymer composite materials closely parallel those of the electronic packaging panel with respect to electronics manufacturing. Both panels concluded that there is usually no "silver bullet" of superior technology that is the secret to Japan's manufacturing successes. Instead, these panels attribute this success to consistent, patient, even painstaking work to make evolutionary refinements in process technology and quality control, sensitivity to customer requirements, and the ability and willingness to make large, long-term, and often risky capital investments to develop and maintain high technology manufacturing infrastructure.

- The WTEC Panel on Research Submersibles and Undersea Technologies released its full draft report in October 1993. Because communications with the panel's hosts in Russia and Ukraine are slow, the hosts' review comments were still arriving at the JTEC/WTEC office as of this writing. The JTEC/WTEC staff and editor will be working with the panel to finalize its report in the spring of 1994. Review of the executive summary from that report has also been completed, and is included in this volume.

- The JTEC Panel on Micro-electro-mechanical Systems (MEMS) in Japan travelled to Japan in late September 1993, and held its workshop in Arlington, VA on November 17, 1993. The panel's draft site reports were reviewed by the Japanese hosts in December of 1993. The full draft report will be available in early April of 1994.

- The JTEC Panel on Electronic Packaging in Japan visited 12 major Japanese electronics manufacturers in October 1993. This panel held its workshop in

Arlington, VA on January 12, 1994. The panel's draft site reports were reviewed by the Japanese hosts in January of 1994, and a full draft report is expected by April.

- The WTEC Panel on Advanced Display Technologies in Russia, Ukraine, and Belarus visited 38 sites in those countries in late October 1993. Draft site reports are now out for review by the hosts. A workshop was held on February 3, 1994 in Arlington, VA. As mentioned above, one of the notable contributions of this workshop was the contacts that it fostered between U.S. companies and researchers and representatives from the former Soviet Union.

- A new JTEC panel on optoelectronics is currently being organized. In addition to visiting Japanese organizations, plans are also being made to visit a number of U.S. companies -- including suppliers, technology companies, and system integrators. This extra effort will provide a better benchmark of U.S. activities against which to compare those in Japan. Plans are also being made to include an economist on this panel. This study has support from NSF, ARPA, Air Force, the Office of Naval Research, and the Departments of Commerce, State, and Energy.

PROSPECTIVE FUTURE STUDIES

As of this writing, probable future JTEC and WTEC studies are, in order of likelihood, software practices in Japan, man-machine interface (including virtual reality and speech recognition) in Japan, environmentally responsible manufacturing (Japan), metal casting technology (Europe and Japan), research submersibles technologies in Japan and Eastern Russia, avionics (Japan), and medical instrumentation.

The studies on software practices, man-machine interface, environmentally responsible manufacturing, and metal casting technology are probable, but scope and funding details have yet to be finalized. The other topics listed above are somewhat preliminary, since funding is still being organized.

HOW TO INITIATE A JTEC OR WTEC STUDY

Up to now, funding for JTEC and WTEC studies has been drawn exclusively from agencies of the Executive Branch of the U.S. Government. Most recent studies have involved funding from three or more agencies working in collaboration with NSF, the lead agency. NSF works with the interested agencies to find common ground for a detailed statement of the study's scope. This work statement becomes the basis for inter-agency agreements, in which contributing agencies transfer funds to NSF in return for NSF undertaking responsibility for the performance of the study. NSF in turn puts these funds into its Cooperative Agreement with Loyola College, under which Loyola carries out the study.

Because of the diversity of interests among contributing agencies (see list of sponsors in Appendix I), a certain amount of negotiation is usually required at the outset of a study in order to arrive at a study scope that satisfies the requirements of all contributors. This is usually accomplished through one or more planning meetings at NSF, in which potential sponsors present their requirements and develop a consensus scope, identify a suitable chair for the panel, and discuss other potential candidates for panelists.

The contact person at NSF for JTEC and WTEC studies is:

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Japanese Technology Evaluation Center
World Technology Evaluation Center
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4501 North Charles Street
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B. PROGRAM SUMMARY

The following is the complete collection of executive summaries from the JTEC and WTEC reports completed to-date under the management of the program by Loyola College. They are preceded by an introduction by George Gamota, originator of the JTEC program concept and the only person who has worked with this program consistently from its inception to the present day. Dr. Gamota, Director of the Mitre Institute, the Mitre Corporation, currently serves as Senior Advisor to JTEC/WTEC. His introduction offers many useful insights into the historical background and rationale for the JTEC/WTEC program, its relevance to the current U.S. science and technology policy context, and the broader lessons that can be drawn from the results of its completed studies. Others may view these results differently from the way Dr. Gamota does. However, his analysis demonstrates that the findings of the JTEC and WTEC technology assessments, with the unique perspectives they offer on the R&D efforts of our friends and allies abroad, can be extremely relevant to the ongoing debate over science and technology policy, and indeed industrial policy, in the United States today.

Introduction: Historical Overview and Comparisons

by George Gamota

HISTORICAL BACKGROUND OF THE JTEC/WTEC PROGRAM

In 1994, the JTEC program is celebrating its tenth year of operation and the completion of its thirtieth study. In addition, the companion World Technology Evaluation Center program has completed three studies, including a landmark global assessment of satellite communications technology, and will be nearing completion of its fourth and fifth by the end of the year. This tenth anniversary affords us an opportunity to take a look back over the history of the program with a view towards gleaning some overall lessons from the program and towards understanding and refining its mission.

Inception of the JTEC Program

Just a decade ago, we had difficulty in even admitting that there was R&D of interest being done outside the United States, in spite of many major surprises coming from abroad. As each new foreign discovery was made public, we went into a series of denials and chest poundings, but very little changed. Basically, we were more interested in our own work than somebody else's. And we always went for the big payoff -- the homerun, the Nobel prize, the revolutionary breakthrough -- and discounted incremental improvements, ideas developed in other countries, and generally efforts requiring teamwork or long-term investments, be they in science, technology, or business.

When the Japanese Technology Evaluation Center (JTEC) program was initiated in 1983, the U.S. high technology trade balance coincidentally was about even (see Figure 3). But, as indicated in the figure, the equality lasted for only a short time. Our trade imbalances grew, and we moved from our status as the biggest creditor nation to being the largest debtor nation.

During the Cold War era, much attention was paid to the smallest bit of information coming from the Soviet Union -- some real threats, some imaginary (e.g., the Alpha class submarines and poly-water, respectively). The Soviets were first in space, and then potentially threatened the West with massive technological prowess to which we had little access. It was easy to convince Washington to fund Soviet technology studies, but there was little interest in learning about other foreign technologies. Meanwhile, the trade imbalances with our *allies* (particularly Japan) began to grow, even in high technology areas the United States had traditionally dominated.

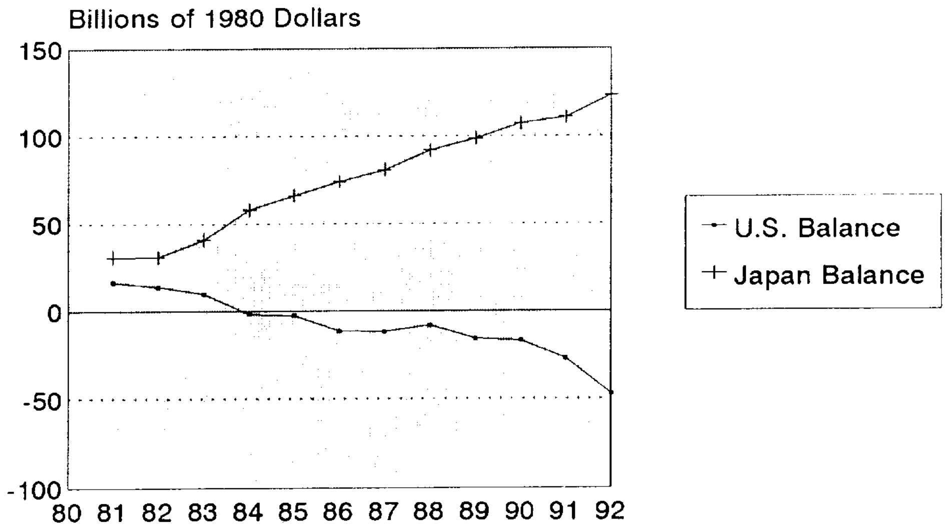

Figure 3. High Technology Trade Balances, 1981-92 (U.S. Government 1993)

The reason for this blind-sided view of other countries was that the United States *was* the leader in many if not most technologies during the early post-World War II era. Therefore we became complacent about our leadership position. We took it for granted that everything important would be developed here. It was in this environment that the JTEC program started back in 1983. Even with the growing U.S. trade deficit with Japan in high technology manufactured products, the JTEC idea proved to be very difficult to sell, until some very senior U.S. government officials finally not only blessed it, but more importantly, marshalled the resources to fund the studies.

JTEC's stated goal was to systematically look at various technologies of strategic value to the U.S. government and industry. Technologies were chosen for study largely by decision-makers in Federal R&D agencies who were willing to supply dollars and were eager for the information. Initially, JTEC was coordinated by the Department of Commerce (DOC), with the National Science Foundation (NSF), the Department of Defense (DOD), and the Department of Energy (DOE) as funding partners. However, due to personnel changes at DOC, in 1984 leadership of the program shifted to the NSF, where it currently resides. Nevertheless, partnerships with key technology agencies have remained a hallmark of the program. Today the JTEC/WTEC program is one of few real cooperative government programs that have survived so many years. Appreciation is due to NSF for its consistent and far-sighted management of the program over the years (see acknowledgments at the end of this introduction). According to one report (Uyehara 1991), the JTEC program has produced over half of all in-depth studies on Japanese technology that are publicly available in the United States.

When JTEC was started, one of the fears was that it would be extremely difficult to get useful information from the Japanese, because they were perceived to be secretive, and the language barrier would give them an easy way not to tell U.S. visitors about the important things that were going on. JTEC panels found the opposite to be true. Like most researchers, the Japanese are eager to share their work. In most cases, they have provided far more information than we would have expected to glean from comparable visits to U.S. companies. To be sure, good advance work has been necessary to ensure that we visited the right places and asked the right questions; but very seldom has a JTEC team been denied access even to assembly plants that it asked to visit. The hardest visits to arrange were those to U.S. subsidiaries in Japan, which operated more like U.S. companies. But in general we have been welcomed, even when, in the case of the 1992 display technology study, we arrived in Japan in the middle of a heated trade dispute. Although language has not really presented a problem, whenever a JTEC team included at least one Japanese-speaking member, more information was exchanged.

The Japanese view JTEC very positively. They believe in the importance of gathering information, and they are very good at it. Their balance of trade with the U.S. in information gathering is roughly 3:1. That is, Japan buys three times more information from the U.S. than the U.S. buys from Japan. In terms of people exchanged, the numbers are even more skewed. For every ten Japanese scientists or engineers who visit the U.S. for an extended time, only one American goes to Japan. The imbalance is so great that the Japanese government even funds Americans to travel to Japan and spend time in Japanese laboratories.

Some technologies -- for example, those in the area of computer science -- have been the subject of several JTEC studies over the history of the program because of the great interest in the subject and rapid changes in the technology. This continuity, combined with the institutional memory of several people who have been involved with the JTEC program since its inception, makes it possible to assemble a picture of the evolution of Japanese technology in comparison with that in the United States. Because of the time that has elapsed since the earlier reports, it is also possible to see which of the predictions came true, which did not, what was missed, and, finally, why some predicted events did not come to pass.

The ICOT Fifth Generation computer project is an example. Many people consider that project a disappointment. My own opinion is that, although it did not achieve all of its goals, it taught the Japanese many things that are critical to the next phase of advanced computing. The 1987 study, *Advanced Computing in Japan*, dealt almost exclusively with the Fifth Generation program, and the 1990 study reflected on the degree to which that project succeeded. The 1993 JTEC report on knowledge-based systems in Japan includes a section on ICOT. One finding from that report is that ICOT has made some impressive achievements, particularly in the development of the "KL1" family of parallel symbolic programming languages. The ICOT program was actually extended for three years beyond its originally scheduled termination date. In the meantime, the Japanese government has undertaken another major project in computer science R&D, the Real World Computing (RWC) Initiative, which is sure to further promote the emergence of Japan as a major world player in the computer and information science fields.

The Global Challenge

In recent years there has been an increasing awareness among the sponsors of the JTEC program that the technological challenge facing the United States comes not only from Japan, but also from Europe and potentially from many other parts of the world. This inspired the formation of the World Technology Evaluation Center. WTEC completed its initial assessment, on European nuclear instrumentation and controls (I&C) technology, in late 1991. This focused on one aspect of nuclear technology that already had been the subject of one chapter of the broader 1990 JTEC study on Japanese nuclear technology. The detailed review of the world's major nuclear I&C technology suppliers was completed in 1993 with the publication of the *WTEC Monograph on Instrumentation, Control, and Safety Systems of Canadian Nuclear Facilities.* Based on these three reports, Jim White of Oak Ridge National Laboratory has now prepared the world-wide summary assessment of nuclear I&C technologies that is published for the first time in this volume. It will also be available separately. Dr. White's assessment, that the United States trails every country but Eastern Europe and the former Soviet Union in nuclear I&C technology and applications, should be of concern even to those who question the wisdom of further investments in nuclear power; instrumentation and controls technology is critical to the safety of our existing plants.

WTEC's second international assessment, completed in 1993, examined satellite telecommunications technology in Europe, Japan, and Russia. This study also resulted in some sobering conclusions: Japan, and to a lesser extent Europe, stand a good chance of wresting a substantial proportion of the satellite communications business away from the United States early in the next century. This is the result of a long period of slackened satellite communications R&D funding at NASA, during which time strong European and Japanese research and applications programs have proven new technologies and given their companies valuable experience and know-how.

With the breakup of the Soviet Union at the end of 1991, the Departments of Energy and Defense requested that I assess the technological potential of Ukraine, the second largest of the newly independent republics of the former Soviet Union (FSU). A five volume report entitled *Science, Technology and Conversion in Ukraine* was published in 1993, and is the most comprehensive look at that country's R&D potential. It reviews the major R&D institutions and activities there, listing key individuals, their addresses, telephone numbers, and, whenever available, their electronic mail addresses.

As of this writing, WTEC is planning to perform its next global assessment in the area of research submersibles and related undersea technologies. A WTEC panel is now completing its report on submersible technologies in Russia, Ukraine, Finland, France, Germany, and the United Kingdom. Within the next few months, we hope to send the same panel to Japan, following which they will visit some sites in eastern Russia (Vladivostok area) that they were not able to visit in their May 1993 trip to European Russia and Ukraine.

WTEC is now filling in another piece of the global picture in advanced display technologies with a panel that visited Russia, Ukraine, and Belarus in October of 1993. As described above in the Annual Report section, WTEC is also collaborating with the Civil Engineering Research Foundation in an assessment of civil engineering technologies in Western Europe. This complements the earlier JTEC study of construction technology in Japan, affording a broader global perspective on the status of the U.S. with respect to another important application of advanced technology. Topics under consideration for future WTEC studies include environmentally benign manufacturing technologies and metals casting technology.

Our experience with Europe and the former Soviet Union is not as long as it is in Japan. Unlike JTEC, which is well recognized in Japan, the WTEC mission is not yet fully understood. This has required more work, particularly in planning and preparation for the site visits. Furthermore, Japan is a single country, with many R&D activities centrally located in Tokyo. Conversely, Europe is a continent with many countries; just the transportation aspect alone makes it harder to coordinate a set of visits in a short time. And most visits have to be completed in a short time; industrial panelists find it particularly difficult to get away from their jobs for more than about a week -- two weeks at the most. By including Russia, Ukraine and possibly other new countries in Eastern Europe, the WTEC trips have stretched these limits.

In spite of these problems, we have been delighted to find out that the JTEC process works well in Europe (East and West). Now after nearly completing four studies in Europe, we find that it is easier to obtain access. Logistics problems have been solved by breaking the team into subgroups and utilizing travel time for other activities -- such as sleeping, eating or site report preparation. A noteworthy addition to our process, when we have visited FSU countries, has been to invite selected hosts from our site visits to our workshop in Washington. This provides them with an opportunity to meet interested U.S. parties and initiate joint ventures or cooperative research. Many of these organizations have been previously closed to the West, and are eager to become known and engage in discussions for cooperation. This is particularly true for Russian organizations situated outside of Moscow and St. Petersburg, and most organizations in Ukraine, Belarus and the other new countries in Eastern Europe.

APPLICABILITY OF JTEC/WTEC TO THE BROADER U.S. TECHNOLOGY POLICY DEBATE

Each JTEC or WTEC study provides a current view of the status of research, development and/or applications of a particular technology in one or more foreign countries. It also provides a snapshot of a particular technology and its relationship to a possible range of products. Finally, most JTEC and WTEC studies include a review of mechanisms for R&D support in the subject country(ies). As such, the large body of JTEC and WTEC studies completed to-date provides a useful benchmark for the ongoing debate in Washington as to the direction that U.S. technology policy should take in the latter part of the 1990s.

First, a number of ideas that are being proposed in Washington today to stimulate the development of civilian and dual-use technologies have been tried in Japan and Europe already, to varying degrees of success. JTEC/WTEC studies can provide valuable information on why these ideas have succeeded or failed abroad, and how they may or may not work in the United States.

Second, foreign governments have identified certain technologies and/or applications as critical to their future, therefore deserving of direct or indirect government support. The debate in the United States over industrial policy must therefore be influenced greatly by the extent to which other governments around the world have already distorted the "free market" forces that would otherwise shape the development and deployment of new technologies and products. The illusion of a free market is further undermined by the behavior of large oligopolistic or monopolistic private corporations and/or consortia overseas. For example, there is no doubt that, due to differing cultural and institution frameworks, Japanese corporations behave very differently from U.S. corporations, especially with respect to long-term investments in R&D. In other words, if governments and large corporations and consortia overseas are practicing technological mercantilism by subsidizing or otherwise fostering the development of civilian high technology industry, the U.S. Government cannot possibly gain from conducting a *laissez faire* free trade policy in isolation. JTEC and WTEC studies can provide key information concerning the mechanisms for corporate and government R&D support abroad to facilitate informed debate on this issue in the United States.

Finally, to the extent that free trade in high technology products and information *does* prevail in this world, U.S. government and industry must have access to reliable information concerning where the best research and technology can be found around the world. The JTEC/WTEC program can contribute in this respect as well.

In order to facilitate such contributions to the broader U.S. technology policy arena, the National Science Foundation has asked us to combine the executive summaries of all the recent JTEC/WTEC reports in a single document and to identify some issues that cut across several of the studies. This program summary presents twenty-two executive summaries from reports completed since the fall of 1989. Summaries of the first ten studies, those completed between 1984 and early 1989, are not included here. Readers are directed to *Gaining Ground -- Japan's Strides in Science and Technology* (Gamota and Frieman 1988), the *JTEC Program Summary* (JTEC 1991) and the *JTEC/WTEC Program Summary* (JTEC/WTEC 1992) for more information on those early studies.

The reports have been arranged according to application areas, so readers can make correlations between similar areas and compare changes reported by similar studies conducted at different times. Whereas in the 1980s it became customary in the Federal Government to organize technology policy discussions along lines of disciplines or categories of "critical" technologies, the current administration appears to be inclined instead to look at the end-result, or applications, of these technologies. This is almost the opposite of the current trend in Japan, where government agencies for the past few years have been putting greater emphasis on improving Japan's basic research capability. However, these recent policy shifts in Japan and the U.S. both represent positive responses to an imbalance that was evident in the 1980s, i.e., that the Japanese did better applied research and product development, while the U.S. excelled at basic research and, at least in the government sector, paid little attention to collaborating with industry in applied R&D and manufacturing technology. Governments in both countries are moving to redress this imbalance: Japan by putting new emphasis on basic research, and the United States by pursuing new initiatives in government-supported applied R&D projects in close cooperation with industry.

Unfortunately, a troubling trend appears to be developing in the United States. To redress the lack of support of applied research and development for commercial applications, basic research funding is now being threatened. There is a need to fill the "gap" in applied R&D funding, in order to ensure that we are prepared to capitalize on basic research discoveries. But this should not be in lieu of support for that basic research. Basic research has proven to be our insurance for the future. If we wish to remain competitive, we need to do so across the full spectrum from basic research to applied R&D.

Table 7 compares the JTEC and WTEC studies with a variety of application areas. The "critical technology" approach is still with us, however. In the U.S., there remain statutory requirements for the maintenance of several lists of critical or sensitive technologies at both the Defense and Commerce departments (U.S. Govt. 1990, 1991a, 1991b). There are several analogous Japanese lists, most notably a 1988 Ministry of International Trade and Industry (MITI) document that ranks the United States and Japan in a wide range of industrial technologies (Govt. of Japan 1988). Similar strategic thinking is evident in the 1990 list of research projects supported by the Commission of the European Communities (EC 1990). These lists have many common themes and, not too surprisingly, include most of the topics that have been studied by the JTEC teams.

TABLE 7
JTEC/WTEC Studies by Application Area

APPLICATIONS	RELEVANT JTEC/WTEC STUDIES (since 1989)
Manufacturing	Electronic Packaging* (JTEC) Polymer Composites* (JTEC) Displays (JTEC and WTEC) Construction (JTEC) CERF Task Force* (WTEC) MEMS* (JTEC)
Communications & Information	Computer Science (JTEC - '84 '87 '90) Satellite Communications (worldwide) Knowledge-Based Systems (JTEC) Electronic Packaging* (JTEC) MEMS* (JTEC) Optoelectronics** (JTEC)
Natural Resources & Environment	Polymer Composites* (JTEC) Separation (JTEC)
Education & Training	All Studies Listed Above Under Communications & Information Technologies
Transportation	Polymer Composites* (JTEC) Advanced Composites (JTEC) Space Propulsion (JTEC)
National Security	All of the Above
Energy Supply & Demand	Nuclear I&C (2 WTEC Studies + Global Summary) Polymer Composites* (JTEC) Nuclear Power (JTEC)
Food & Fiber	Bioprocess Engineering (JTEC) Separation (JTEC)
Health	Bioprocess Engineering (JTEC) Separation (JTEC)

Note: * in progress; ** planned.

As a glance at the titles of all the JTEC studies makes clear, JTEC's sponsoring agencies have emphasized information technologies, although much work has also been done in the areas of materials, manufacturing, and space technology. No studies have directly addressed pharmaceutical, medical, and environmental technologies, though the bioprocess engineering study (completed in 1992) and the separation technologies study (completed in 1993) do cover some relevant material.

LESSONS LEARNED

Perspective is one of several benefits that accrue from compiling the JTEC/WTEC studies. The studies suggest that if current trends continue, Japan and other advanced industrialized countries will present an increasing challenge to the United States in high-technology markets. This is not to say that they will dominate all high technology. But if there is a large market, many if not all of these countries will be participating in it, and will be trying to perform state-of-the-art R&D work to ensure that their products will be competitive. The emerging Eastern European economies also have the potential to present major competitive challenges, as well as cooperative opportunities, for U.S. high-technology industry.

The U.S. can react to these challenges, and in fact has turned a corner in at least one area that was given up by many as a lost cause -- semiconductor manufacturing. Recent advances by U.S. industry giants such as Intel and SEMATECH (a cooperative industry research institute) have made the U.S. competitive again. The Clinton Administration is proposing similar and/or complementary initiatives in automotive technology, information infrastructure, advanced manufacturing technologies, and dual-use technologies in general (Clinton & Gore 1993). The new administration is also advocating a permanent extension of the research and experimentation tax credit as a way of stimulating private R&D investments across the board.

However, one of the most fundamental lessons that we have learned in the JTEC/WTEC program is that one should be very careful in interpreting successes and failures abroad, and trying to compare them to our own experience here in the United States. Too often successes are copied by starting similar efforts only to find out that it takes more than just proclamations and/or money. Unique local conditions (culture, education, etc.) must be taken into account before a successful effort in Japan or Europe can be carried out in the United States. Certainly we can and should learn from the efforts of others, but we must understand them in their full context. Two such cases in point are Japanese consortia and the role of, or apparent lack of, basic (undirected) research in Japan.

In the mid- to late-1980s, it became fashionable in the United States to create industrial consortia. A few succeeded and are still around today, but many did not live up to their expectations. There are many reasons, but one key factor is that the close government-industry relationships typical of Japanese consortia would be viewed as legally or ethically questionable in the United States. The two best known U.S. consortia -- MCC and SEMATECH -- are currently doing well, but they have abandoned many of their original goals, and have succeeded mainly by understanding how Japanese consortia really work, modifying that model to fit the U.S. situation.

Gerald Hane in a recent article in *Issues in Science and Technology* (Hane 1993) has analyzed the workings of Japanese consortia. In simplistic terms, he states that the key to their success is coordination of research, not forced marriages between competitors. Many U.S. consortia tried to force cooperation between natural competitors, and it just did not work. Coordination of research, on the other hand, means that participants can keep their secrets, but know the general direction of their competitors. Taichi Sakaiya, formerly with MITI, expresses this more strikingly. Rather than viewing Japan as a monolithic "Japan, Inc.," a nation with a single purpose precisely executing a complex and cooperative effort, he argues that Japan is more like "a land of a thousand clocks" (Sakaiya 1993). The government makes sure everyone keeps the same time, but there is much less sharing than many in the West believe. He states that in Japan "everyone is first and foremost loyal to his organization." This has been evident in some of the JTEC studies, when we encountered openness to our visiting team, but concern about sharing findings with our hosts' Japanese competitors.

Another key ingredient in Japanese consortia is the role played by the national laboratories. This is a role that U.S. national laboratories -- mostly Department of Energy laboratories -- are now aspiring to play. Unfortunately, the U.S. laboratories have evolved mostly from weapons work or basic research, and do not have any significant experience or background in understanding the commercial world. Thus they are having difficulty in acting as honest brokers between companies, a role Japanese laboratories have played well.

Close relationships between government and industry can benefit R&D, but can also cause other problems. The Japanese construction industry offers a good example. JTEC sent a team to Japan in 1991 to study construction technology. The panel learned that the Japanese construction industry invests a half percent of its revenues in R&D -- nearly five times the percentage in the U.S. This investment has allowed Japan to excel in such areas as tunneling, design and construction of intelligent buildings, robotics, and other related areas. Private R&D funding has also been assisted by the Ministry of Construction, a government agency for which there is no U.S. counterpart. Recently, however, this government-industry relationship in construction has been the subject of public scrutiny, and a number of government and industrial executives have been jailed for illegal activities that stemmed from their cozy relationships. This was, in fact, one of the causes for the recent toppling of the Liberal Democratic Party after 38 years in power.

Another area where Japanese industrial policy is encountering difficulties is in the development of the nuclear breeder reactor, *Monju*. The U.S. abandoned this technology 15 years ago because of potential economic, health, safety, and political problems. In spite of this, Japan continued to pump most of its advanced reactor

R&D investments into this one area. Today, even as *Monju* is being prepared for startup this spring, Japan is reviewing its plans for the plutonium fuel cycle, at least in part in response to worldwide protests on Japan's plutonium fuel shipments from France, as well as the exorbitant cost of the *Monju* project (*Washington Post* 1994).

The debate over industrial policy will be fueled even more by the recent controversy over the Japanese HDTV standard (MUSE). After it became known early this year that the Japanese government was considering abandoning the MUSE system in favor of the new digital standard just adopted by the United States, the Ministry of Posts and Telecommunications was obliged to make a public announcement pledging continued support for MUSE. This apparent turnabout in Japanese government policy was reportedly sparked by a storm of protest from major Japanese electronics companies that have collectively invested billions of their own funds in the MUSE system, and are not inclined to write that investment off as yet. But the future of the MUSE system will be pretty much determined by its lack of acceptance by the U.S. and Europe -- investment or no investment.

However that question is resolved, there is no denying that the MUSE system is an excellent example of a pioneering technology that was developed by Japan completely on its own. The Japanese also have reason to feel pride in the fact that they have the world's only *operational* HDTV system. Japanese manufacturers are in a good position to dominate the world market for digital HDTV equipment *because* they currently dominate the technology and markets for more conventional equipment.

The Japanese thrust to develop HDTV, beginning in the 1970s, has also had an important side-benefit: HDTV requires advanced displays. Thus the Japanese program has included a big effort to develop wall-sized flat panel displays. Though large-scale commercial production of such displays is still in the future, it is no coincidence that Japan now dominates the technology and markets for smaller flat panel displays used in portable computers.

In sum, this is not to say that industrial policy is bad or good, but only that it must be balanced against many considerations; decisions should be reviewed periodically to assure that the original underpinnings and assumptions are still valid. One could also conclude, ironically, that a successful industrial policy requires the taking of risks. Hence, in order to succeed, you must be willing to fail occasionally. If this were not the case, there would be no need for government intervention to mitigate the risks private firms must take in order to invest in new technologies. "Sure fire" new technologies will get all the private investment they need -- only risky (and/or expensive) ones require the sort of nurturing that a government industrial policy can provide. Of course, this argument, when taken to the extreme, could result in government policies that distort the market by promoting *only* losing technologies.

Japanese Strengths and Weaknesses

It is very difficult to make categorical statements about a nation's strengths and weaknesses in a technology without using many caveats. Unfortunately, too many caveats make the argument less persuasive. However, without the caveats, statements can be taken out of context and wrong perceptions created.

Nevertheless, it is necessary to synthesize and present data so that policy makers and the nontechnical community can easily understand the importance and the implications of the findings. Table 8 relies on an overview of the JTEC studies to summarize the Japanese position. This table makes it obvious that the single most important Japanese strength is in product development and manufacturing, not only in the area of electronic components, but also in many other areas. Another interesting observation from the table is that in many cases Japanese R&D is competitive with that in the United States. Japanese technology is weak in many basic research areas; but by launching programs such as ERATO (described below), the Japanese show that they are trying to offset this deficiency.

TABLE 8
Japanese Strengths and Weaknesses

TECHNOLOGY	JAPANESE POSITION		
	Strong	Competitive	Weak
MATERIALS			
carbon-fiber	products & R&D - pitch	R&D - pan	basic research
thermoplastic resin			R&D
processes	co-curing & tooling	hand layup, pultrusion & rtm	thermoforming, filament winding, & tow placement
carbon-carbon composites			R&D, manufacturing
high-strength polymers		R&D, products	basic research
polymer composite structures	civil engineering applications		automotive and industrial applications
electronic (si & gaas)	products	R&D	II-VI materials
biopolymers			all processes (but gaining)

TECHNOLOGY	JAPANESE POSITION		
	Strong	Competitive	Weak
gas separations			R&D and implementation
hydrometallurgical separations	development & implementation	research	
ion exchange membrane processes		R&D	implementation
extraction		solvent, ion exchange, & supercritical fluid	research
superconductors	processing	R&D	theory & space applications
ELECTRONICS AND INFORMATION TECHNOLOGIES			
microelectronics	memory chips	logic chips	microprocessors
lithography	optical & x-ray		
displays	products		
machine translation	products	R&D	European languages
databases		image & multimedia	products
memory storage	optical	magnetic	
computers	laptop components	supercomputers, hardware	workstations, PCs
software	factories	software engineering	R&D, products
expert systems	consumer products, integration, support structure, & national initiatives	tools & applied research	basic research in industry & universities
national initiatives in knowledge-based systems	parallel symbolic computation, very large knowledge bases, & fuzzy logic systems	quality of very large knowledge bases	
sensors	charge-coupled devices	products	research

TECHNOLOGY	JAPANESE POSITION		
	Strong	Competitive	Weak
satellite communications	advanced batteries, solid state amplifiers, & pointing and positioning systems	electric propulsion & intersatellite links	high data rate comm., small satellites, & on-board processing
telecommunications	component & fiber optics	mobile	networks
ENERGY AND PROPULSION			
nuclear power	instrumentation & controls	construction R&D	computer code
nuclear control room design		basic research	advanced design & product implementation
instrumentation & control for nuclear power reactors	architecture R&D	support systems	standards & tools, architecture product implementation
rocket propulsion		liquid rockets	scramjet technology, turbopumps
MANUFACTURING			
flexible manufacturing systems	products		
software			human-machine interface (but gaining)
manipulators	products	R&D	
precision engineering	products	R&D	
robotics	products	systems	
computer-integrated manufacturing	R&D, products		
computer-assisted design		applications	new concepts & tools

Japan has had a definite lead in manufacturing for some time. Some interesting findings have been reported by our current JTEC panel on electronic packaging, chaired by Professor Michael Kelly from Georgia Tech. Although the report is not yet available, the panel released some preliminary findings at a workshop held on January 12th of this year. Gene Meieran of Intel, one of the JTEC panelists, lists U.S. strengths as university research, information technology research, generic company research, and entrepreneurial activity and risk taking. According to Dr. Meieran, the Japanese are best at active involvement in research, manufacturing research, and coherent company and government policies.

Information research is an area in which the U.S. seems to continue to lead. Japan is behind in networks, database systems, electronic mail, and system integration. The U.S. also maintains its lead in software engineering, even though this has been targeted by the Japanese for a number of years. Their effort to "leapfrog" the United States by creating software factories has just not worked. The biggest threat to U.S. software engineers and programmers is an increasing volume of software now being written in India -- often by Ph.D.-educated scientists who cannot find work in their field. They can produce software for a fraction of what it costs in the United States. Similar growth in the software business has been reported in Russia, although the language barrier could prove to be a hurdle there in the immediate future.

The United States still leads in basic (or "undirected") research. This lead is often quite wide, particularly in areas that are not clearly identified as relevant to key industries. This is in part because much "basic" research in Japan is focused, ultimately tied to possible applications. One example of this is superconductivity, a basic research topic the Japanese have singled out for emphasis, and in which they have been competing successfully worldwide. Their focus is on high-temperature superconducting materials, an area with obvious applications.

The Japanese government has started a number of programs to enhance basic research. One of its successes in this respect has been the ERATO program, initiated in 1981 under the sponsorship of the Science & Technology Agency (STA) through its Japan Research and Development Corporation (JRDC). ERATO is unique in its operation. All ERATO projects have a senior director (recruited from industry, national laboratories or universities) and a handful of younger researchers who work together on some specific long-range problem for five years. Considerable freedom is allowed in how funding is allocated within the individual projects. Most projects fall into two major categories -- physics/engineering and biotechnology. The nature of the work has been in almost all cases basic research not explicitly tied to any specific application. The results, however, often are applied to specific problems, instruments, and products that the ERATO office publicizes in its reports. ERATO was designed to bring industry and university scientists together. These factors have helped ERATO attract increasing funding contributions from industry. Funding is modest at about two to three million dollars per year per project. The total ERATO budget is currently about $85 million per year, allocated to 37 projects.

In a departure from previous practices, ERATO recently announced a new project that will be based outside Japan. It will be headed by Yoshihisa Yamamoto from

Stanford University. He will receive $17 million over five years. A spin-off ERATO program has also been announced that will fund a large scale cooperative program between researchers at Tokyo University and the University of California at Santa Barbara.

JTEC studied ERATO in 1988, and a follow-up study has been proposed for this year. The focus of such a study would be not only to examine the quality of ERATO research, but also to look at its impact on career paths followed by young people engaged in the various projects.

As a part of the Japanese move to improve basic research, they have also strengthened their university research and made efforts to more closely couple that research with industry. University research has traditionally played a secondary role in Japan's research enterprise. Early JTEC teams were so disappointed with what they observed that for a long while few teams even wanted to visit universities except to pay social calls. Today that is changing. Recent JTEC teams have noted that university research is improving steadily. Even more significantly, Japanese industry is starting to pay more attention to what is going on at universities. There is a significant new initiative within the Japanese government aimed at improving university infrastructure, including a 29% increase in fiscal year 1993 (ending 4/94) funding for the Ministry of Education. Much of this additional funding is reportedly targetted at buildings and equipment.

Nevertheless, U.S. university research remains unquestionably superior. Despite Japan's efforts to improve university-industry coupling, it is difficult to point to any one area today where Japanese university research plays a significant role in providing results of interest to industry. There is probably more coupling between Japanese industry and *American* university research than there is with their own universities. Part of the problem lies in lack of real incentives for Japanese academic researchers to collaborate with industry.

In some critical areas -- for example, artificial intelligence and software -- the Japanese have decided to fund basic research in the United States. Some of the work is being done at prestigious U.S. universities, and some at Japanese-owned R&D centers at U.S. locations such as Princeton, Palo Alto, and Michigan. The work there is first class, and most of the results are published in U.S. journals. To be sure, the Japanese scrutinize the results for possible applications to their product lines.

With this new emphasis on basic research, particularly in the Japanese government, Japan now faces somewhat of a dilemma. It was much easier in the past for the Japanese to import and absorb foreign technology than it is now for them to forge ahead in areas in which they lead. The reasons may include the following:

First, lack of a critical mass of basic researchers makes it difficult to identify new directions. One contributing factor to this is that Japan has had less success than the United States in attracting foreign scientific and technological talent. There are many foreign students in Japan, but comparatively few of them stay for any extended period beyond their education. Such imported talent has been a key contributor to U.S. successes in basic research, especially since many foreign students have chosen to settle here after their education is complete.

Second, Japanese culture has for the last 120 years (not just recently as some believe) excelled at absorbing and using information from abroad. Even prior to the Meiji Restoration of the 1860s, Japan imported the best of foreign (primarily Chinese) culture and technology, adapting it as appropriate. Japan's Charter Oath, which bears a resemblance to our Declaration of Independence, says in part, "knowledge shall be sought throughout the world, and the foundations of the empire shall be strengthened." During the late 19th and early 20th centuries, foreign experts were recruited, including specialists on railways, mining engineering, communications, and medicine. In 1873 the Imperial College of Engineering in Tokyo (later Tokyo University) became the first university in the world to offer a program in electrical engineering. James Clerk Maxwell said of the work done there by the founding professors, William Ayrton and John Perry, that they had "... moved the center of gravity of electrical engineering greatly eastward." One of Ayrton's Japanese students helped to found one of the companies to form Toshiba, and another became one of the founders of NEC. Countless students were sent abroad at great expense to learn and come back and build upon what they had studied.

Third, basic research requires staying power and very long term investment. Given the current economic situation in Japan and the recent closer view of the bottom line in industry, it is questionable whether the commitment can be sustained. Some reductions in R&D spending have been reported recently at Fujitsu, Hitachi, JVC, NEC, and Toshiba. Industrial funding of research at Japanese universities has also seen reductions.

While the need to send students abroad has greatly diminished due to the excellent schools at home, the Japanese continue to be passionate about learning about the world's good ideas. They have no qualms about honoring foreigners who have achieved greatness. For example, last year Dr. George Heilmeir was honored for his work on liquid crystals while he was a researcher at RCA laboratories. It is a sobering fact that here was a man being honored in Japan for work that could have meant tremendous profits to RCA or other U.S. companies had they exploited this discovery themselves. Unfortunately, we just let it go.

In the West, and particularly in the U.S., being associated with a technological failure is usually detrimental to one's career. In Japan, decisions are made by consensus, and risks are shared by all concerned. If a program fails to meet its technological objective, the people associated with the undertaking share the disappointment; but seldom does such a failure threaten an individual's career, because the group made the decisions. Moreover, the Japanese try to learn from failures, documenting findings just as if the results had been positive. As a result, there appears to be much less "going over the same ground" in Japan than in the United States. The ICOT program, mentioned earlier, is a good case in point. Its almost impossibly ambitious goals were not achieved, but much was learned from the attempt, and the program did raise Japan's level of competence in computer science. Parenthetically, realizing that they have gone as far as anyone in this area, the Japanese invited international participation in their next computer science effort -- the RWC Initiative (also known as the Sixth Generation Project). For policy reasons, the U.S. has declined to participate in the whole program, but has agreed to cooperate in aspects related to optoelectronics.

WTEC Observations

The WTEC studies covering Western Europe are still too few to make many general statements, so I will mention only a few findings, mostly dealing with the FSU.

The first and probably most important conclusion is that we in the United States have taken an overly narrow view of opportunities in the FSU. "Soviet" has meant "Russia" to most of us in the West, and Russia has meant Moscow. The Soviets wanted the window to the Soviet Union to be through Moscow, and we continue to suffer from that tunnel vision. However, it is outside of Moscow in Russia, and in Ukraine, Belarus, and the Baltic countries, that many exciting possibilities exist. To be sure, it will take more time to find them, but the rewards are worth it. The once closed cities are now open; much of the *technology* (applied research and advanced development) is found outside Moscow, which has been the center of basic research. For example, Kharkiv boasts the world's largest aviation complex; Dnipropetrovsk is the site of the most modern former Soviet rocket facility; and Mykolaev has the only nuclear aircraft carrier shipyard.

Another observation is that, while the people in the FSU are very hospitable, they are becoming weary of the large number of delegations that are visiting with no follow up. To a far greater extent than in Japan, there is an expectation in the FSU of a *quid pro quo*. That is one of the reasons we have included invitations to some of our hosts to visit the U.S. and attend our workshops, affording them an opportunity to meet potential research or business partners. Their infrastructure is crumbling, and the window for collaborative work will not remain open much longer. Facilities will deteriorate, or the people will leave. Worse yet, political changes could close these sites to the West, and a new arms race could well begin. This should not come as a surprise; it has happened already twice in this century.

Lastly, focusing now on Western Europe, the WTEC panels are finding a substantial body of excellent basic research in Germany, France, Switzerland and other Western European countries. There is a fair amount of willingness there to invest in research, and even to support intra-European efforts (e.g., CERN). Additionally, one finds a surprising number of U.S.-educated and experienced Europeans who have returned to their native countries after spending 20 years or more in U.S. facilities such as AT&T Bell Laboratories or IBM Watson laboratory.

With the demise of the Superconducting Supercollider Project (SSC), I suspect a fair number of our best high energy physicists will be going to Europe soon. The two most recent major discoveries in high temperature superconductivity were made in Europe -- the first in Switzerland, and the most recent in France. I do not want to argue whether or not the SSC was a good investment at its inception, but I do feel that once the U.S. decided to fund such an important and long term project, terminating it in the middle of construction was unfortunate. Many first rate scientists committed their careers to it, and the U.S. government and the State of Texas had already committed and expended billions.

CONCLUSION

JTEC/WTEC has initiated 36 studies of foreign technology over the past 10 years (six are still in progress, and final reports are expected in 1994). This series of studies gives a fairly comprehensive picture of the status and trends, and the strengths and the weaknesses, of Japanese R&D over a wide spectrum of strategic technology areas. It is inevitable that the 22 executive summaries included in this volume will be vulnerable to misinterpretation when taken out of the context of the full reports. Nevertheless, even a brief perusal of these summaries conveys an overall impression of Japanese R&D that is scarcely subject to misinterpretation: Japan is engaged in a systematic effort to achieve parity with, or superiority over, the United States in virtually every technology that is of current or potential economic significance. The Europeans are evidently following a similar path of strategic investment in high technology. The mechanisms by which Japan and Europe have pursued this strategy, and the extent to which they are succeeding, cannot help but be of great interest to policymakers in the United States and in the rest of the world.

The Japanese make no secret of their objectives or methods in pursuing their strategy; quite the contrary, they offer the rest of the world a possible blueprint for the pursuit of economic prosperity through thoughtful long-range investment in science and technology. The authors of the JTEC and WTEC reports and the other contributors to this summary report hope that readers will find this information to be a useful contribution to the debate over how valid and applicable this Japanese model of technological and economic development is to the rest of the world.

Since 1992 the world has been experiencing a recession, and Japan and Europe are not immune to its effects. Industrial funding for R&D in the U.S. is down, and there is talk that Europe is following suit. Even in Japan there are signs of strain. The JTEC electronic packaging panel heard comments from some of their Japanese hosts last fall that traditional supplier relationships are being disrupted by the recession. However, there is no indication yet that there has been any wholesale cutback in

Japanese R&D funding, either in the private sector or in the government. If the Japanese follow their previous strategy, they will use this time to increase R&D rather than cut it back. Time will tell, and we hope our current and future JTEC reports will provide us with more detailed information. But the recession is certainly not sufficient grounds for the United States to become complacent about the long-term economic and technological challenge posed by Japan and Europe.

Too many people have contributed to the overall JTEC/WTEC effort to list here, though we are grateful for all of their work -- and particularly for the work of the panelists and chairpersons of all the study teams, without whom there would have been no JTEC program. I would also like to thank the numerous hosts in Japan, Europe, Canada, and the former Soviet Union, who have been very gracious in accepting our teams, sharing information, and making our visits very memorable. I will conclude by thanking those whose efforts have most directly led to the success of JTEC/WTEC and to the publication of this document: Paul Herer of the National Science Foundation, who manages the JTEC/WTEC program for NSF; Frank Huband, formerly in charge of JTEC at NSF and now executive director of the American Society for Engineering Education; Duane Shelton, director of the International Technology Research Institute at Loyola College; Michael DeHaemer, principal investigator for the JTEC/WTEC grants at Loyola College. Additionally, I want to give special thanks and credit to Geoff Holdridge of the JTEC/WTEC staff, who edited and produced this summary report.

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KEY

Some of the JTEC and WTEC panels chose to present their basic conclusions in tabular form. Table 9 explains the notations used in the tables throughout this document, except as otherwise noted. Figures use a variety of notations, which are explained under each figure.

TABLE 9
Explanation of the Notation:
Position of Subject Country(ies) Relative to that of the United States

	Absolute Position ("status")		**Rate of Change** ("trend")
++	Far ahead	->>	Pulling away sharply
+	Ahead	->	Pulling away
0	Even	=	Holding position
–	Behind	<-	Falling behind
--	Far behind	<<-	Slipping quickly

I. Information and Communication Technology

SATELLITE COMMUNICATIONS SYSTEMS AND TECHNOLOGY

July 1993

Burton I. Edelson, George Washington University (Panel CoChair)

Joseph N. Pelton, University of Colorado, Boulder (Panel CoChair)

Charles W. Bostian, Virginia Tech

William T. Brandon, Mitre Corporation

Vincent W.S. Chan, MIT Lincoln Laboratory

E. Paul Hager, George Mason University

Neil R. Helm, George Washington University

Raymond D. Jennings, U.S. Department of Commerce/NTIA

Robert K. Kwan, Jet Propulsion Laboratory

Christoph E. Mahle, COMSAT Laboratories

Edward F. Miller, NASA Lewis Research Center

Lance Riley, Jet Propulsion Laboratory

SUMMARY

The National Aeronautics and Space Administration (NASA) and the National Science Foundation (NSF) commissioned a panel of U.S. experts to study the international status of satellite communications systems and technology. The study covers emerging systems concepts, applications, services and the attendant technologies. The panel members travelled to Europe, Japan and Russia to gather information first-hand. They visited 17 sites in Europe, 20 sites in Japan, and four in Russia. These included major manufacturers, government organizations, service providers, and associated R&D facilities. The panel's report was reviewed by the sites visited, by the panel, and by representatives of U.S. industry. The report details the information collected and compares it to U.S. activities.

The panel's principal conclusions are:

1. ***The United States has lost its leading position in many critical satellite communications technologies.*** Table 10 shows that the United States is currently behind or even with its international competitors in most of the key technologies. Furthermore, due to research and development projects now underway abroad, the United States is likely to fall behind Japan, and to a lesser extent Europe, in most of these technologies in the next five to fifteen years.

2. ***The market share of the U.S. satellite communications industry is at risk.*** Currently, the U.S. industry retains a leading position in the marketplace -- a position largely founded on technologies and capabilities developed in the 1960s and 1970s. However, the United States is losing ground with respect to a wide range of technologies and systems that will be key to future communications markets.

These developments have come about largely because Europe and Japan view satellite communications as critical to their future economic growth, and have acted accordingly. European and Japanese government policies are designed to nurture their satellite communications industries both directly and indirectly. The absence of comparable policies in the United States in recent years is one factor contributing to our declining competitive position. Table 11 compares government policies with respect to satellite communications in Europe, Japan, and the United States.

SCOPE

Technology Focus. This is not a market or industrial process study but rather a survey of advanced technology now under development for commercial use in the satellite communications field. All aspects of satellite communications were considered, including fixed, broadcast, mobile, personal communications, navigation, low earth orbit, small satellites, etc.

Advanced vs. Current Satellite Communications Technology. The focus of the study is on experimental and advanced technology being developed in R&D and demonstration programs rather than on today's production capabilities. Although launch vehicles and spacecraft technologies are considered, the primary focus is on technologies and applications unique to the field of satellite communications. Most of the technology reviewed in this study is five or more years away from implementation in operational systems.

TABLE 10
U.S. Scorecard in Advanced Satellite Communications Technologies

U.S. TECHNOLOGY LEAD	
High Data Rate Satellite Communications	
USATs and Personal Communications Transceivers	
Small Satellites	
Space Applications for High Temperature Superconductivity	
On-Board Processing	
U.S. TECHNOLOGY TIE	**WITH**
Traveling Wave Tubes	Europe
Electric Propulsion	Japan & Russia
Spacecraft Antennas	Japan & Europe
Intersatellite Links	Japan
Autonomous Control Systems	Japan & Europe
U.S. TECHNOLOGY LAG	**LEADER**
HEMT Technology	Japan
Free Space Optical Communications	Japan & Europe
Advanced Batteries	Japan
Solar Array Systems	Japan
Solid State Power Amplifiers (FETs)	Japan
Pointing and Positioning Systems	Japan
Large Scale Deployable Antenna Systems	Japan and Russia
Advanced System Design and Long Range Planning Concepts	Japan
New Application Development	Japan

TABLE 11
Comparison of Government Roles

	EUROPE	JAPAN	U.S.
Policy	Strong	Strong	Moderate
Planning	Moderate	Strong	Weak
Advanced Development	Strong	Strong	Moderate
Support of Industry	Strong	Strong	Weak
Support of International Systems	Strong	Strong	Weak

Overseas Focus. The panel has surveyed European, Japanese, and, to a lesser extent, Russian systems and technologies. The panelists' extensive knowledge of U.S. and Canadian industry has been used as a benchmark for that evaluation. But the panel did not formally review U.S. technology, and made no U.S. site visits.

Other Limitations. This report is focused on commercial satellite technology, and does not attempt to review military, defense-related, or other confidential satellite communications capabilities in either the United States or other countries. The report covers both government and industrial research and development programs. The panel has attempted to account for structural differences between the countries studied with respect to the mix of public and commercial efforts.

BACKGROUND

Satellite communications technology is a tremendous force for change and innovation. From the first satellite telephone call, to the moon landing in 1969, to today's global coverage of the Olympics with more than 3 billion viewers, satellites have helped create a world community. From $300 trillion annually in worldwide electronic funds transfers to hundreds of millions of airline reservations, satellites play critical roles in finance, business and international trade. Despite growth in fiber optic cables, some 60% of all overseas communications is satellite based. Today, more than 200 countries and territories rely on about 200 satellites for domestic, regional and/or global linkages, defense communications, direct broadcast services, navigation, data collection, and mobile communications. Satellite communications is the largest and most successful of all commercial space enterprises -- it is currently a $15 billion per year business which could grow to $30 billion per year within the decade.

In the mid 1960s, when satellite communications first became a commercial reality, the United States was not just the leader, but was predominant in every aspect from launch vehicles to satellite technology. The agreements under which the International Telecommunications Satellite Organization (INTELSAT) was established were originally negotiated on an interim basis only, giving the United States a dominant leadership role. Japan and Europe felt they would need a number of years to enter seriously into the field. Today, more than a quarter of a century later, conditions have changed dramatically.

FINDINGS

The global satellite communications industry is now entering a new phase of expansion. While growth in fixed satellite services has slowed, broadcast and mobile communications will experience explosive growth over the next ten years. Services and revenues could triple or even quadruple by early in the next century.

It is thus a matter of great concern that, on the eve of this renaissance in satellite communications, the U.S. technology base in this field is now at risk. Without changes in U.S. R&D policy, the United States will soon fall behind Japan and be locked in a contest with Europe for second place.

Several countries have introduced or are introducing advanced operational satellite communications systems ahead of the United States, particularly broadcast and mobile systems, and have taken the lead in critical areas of technology. The effects are not readily apparent in today's orders for communications satellites, in which the United States still leads. However, the United States lags in many areas of advanced research and technology development from which commercial applications will derive in the next five to fifteen years.

In the course of its work, the panel encountered a rapidly shifting environment with respect to satellite communications around the world: the market is expanding and diversifying; many new applications are under development; and many different types of technologies and system architectures are emerging, including small satellites in low earth orbit, multi-purpose orbiting megastructures, and highly specialized satellite designs. Concepts in satellite manufacturing based on mass production, akin to making VCRs, exist alongside traditional methods for building one-of-a-kind products. European and Japanese satellite communications technologies are emerging rapidly.

The detailed results of this study are presented in-depth in the full report, but some general observations are presented below:

Major Disparities in the Allocation of Resources

The European Space Agency (ESA) and the Japanese National Space Development Agency (NASDA) both devote about 10% of their total budgets to space communications and related activities. NASA, on the other hand, allocates less than 1% to R&D in this area. Figure 4 shows the dramatic differences in resource allocation, particularly over the last five years. Only the funding for the Advanced Communications Technology Satellite (ACTS) program, which manifests itself as a "bump" in the graph of U.S. expenditures, temporarily diminishes this strong disparity in relative funding levels. This disparity is even more significant considering that the total budgets for the Japanese and European space programs are significantly less than that of the United States.

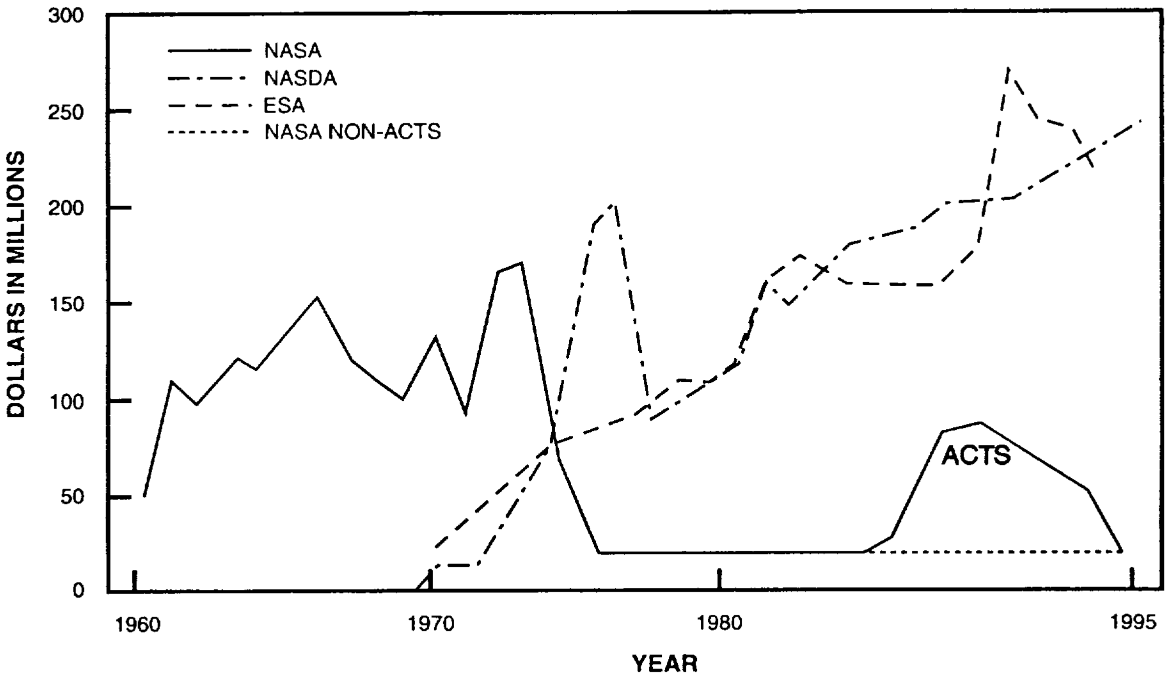

Figure 4. Annual Funding for Satellite Communications Programs

Major Differences in Research and Developmental Programs

The difference in major flight-based experimental communications satellite programs is striking. Figure 5 depicts such programs in the United States, Europe and Japan for the past decade as well as a decade into the future. It shows that the United States has had only one truly major research program, namely ACTS. In contrast, Europe and Japan each have had several flight-based research programs in the past ten years, and will continue in this direction in the next decade.

Service Trends

Of the three general satellite communications service categories -- fixed, mobile and broadcast -- only the fixed satellite service (FSS) may be said to be a mature service, providing global coverage since the late 1960s. FSS traffic growth has now slowed to a rate of about 10% per year. Within the FSS, VSAT systems (very small aperture terminals) are expanding rapidly, but their demand on satellite capacity is light. The

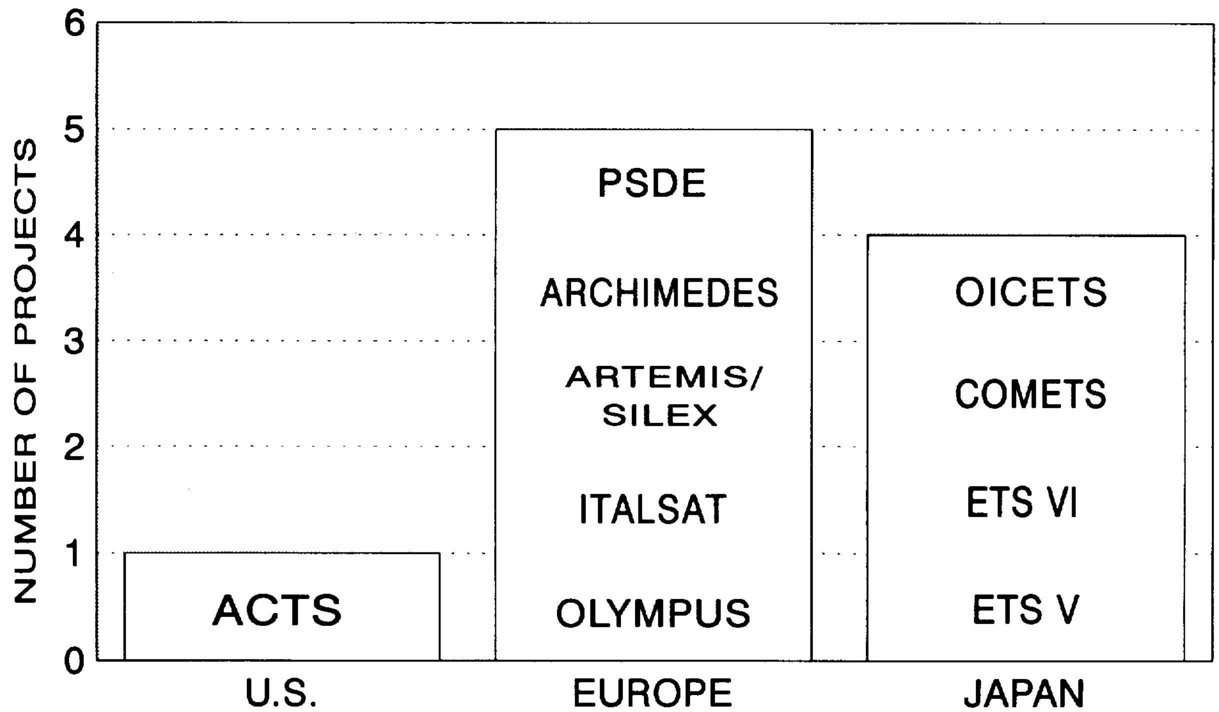

Figure 5. A Comparative View: Experimental Communications Satellite Projects in the United States, Japan, and Europe

greatest potential area for expansion of fixed services is in high data rate (HDR) communications (i.e., 155 Mbits/sec or higher) for data transfer, networking, and HDTV, to complement the growing global network of fiber optic cables. Little interest has been expressed by terrestrial carriers in HDR satellite service, except for cable restoral service. European and Japanese satellite operators are looking to the United States for leadership in HDR communications via ACTS, and would like to cooperate with the United States in developing trans-oceanic HDR links.

Mobile and broadcast satellite services (MSS and BSS) most clearly exploit the advantages of satellite communications over terrestrial means, consume large amounts of satellite capacity, and are growing very rapidly (over 20% per year). Significant R&D and commercial activity in this area is underway in Europe and Japan, far more than in the United States. Satellite broadcast services are extending rapidly to third world countries. The International Maritime Satellite Organization (INMARSAT), which has been providing maritime service for over a decade, has recently extended its service to aircraft and land-mobile vehicles. Perhaps the most exciting, and certainly the fastest moving, field is personal communications services (PCS) via satellite using handheld transceivers similar to those used in cellular radio. U.S. industry is pioneering this area. LEO, MEO and GEO (low earth, medium earth and geostationary earth orbit) systems are all under study and/or development for personal communications.

New Applications and Markets

Markets, applications and technologies are diversifying into GEO, MEO and LEO systems, and both very large scale and small, lower cost satellite designs are emerging. Under these changing conditions, the need for clear targeting of research for the future has become increasingly important. Clear understanding of new applications and markets is strategically even more important. Promotion of new applications and stimulation of markets seem to be more aggressively pursued overseas, especially in Japan, than in the United States. For example, Japan's initiative in direct broadcast satellite (DBS) service began after the United States, but today there are some six million Japanese subscribers in an operational system and ten thousand receivers to test HDTV broadcasting via DBS satellites.

Planning, Systems, and Advanced Technology Studies

A noticeable difference and a serious problem is the lack of planning in the United States. There is no commitment and no mechanism to pursue long-range systems and technology studies in satellite communications, as is being done systematically in Japan and fairly well in Europe. Equally important is the subsequent need to develop and follow detailed technology road maps designed to accomplish or execute the identified system goals. The Japanese COMETS program and possible follow-on programs now under consideration reflect a clear commitment to long term systems goals in the areas of space broadcasting and mobile satellite services. Likewise, the European OLYMPUS, ARTEMIS, and ARCHIMEDES programs reflect strategic commitments to these same areas.

Government / Industry Roles

The panel found considerably more interest and support for satellite communications and a stronger relationship between the governments and industries in Europe, Japan, and Russia than in the United States. As indicated in Table 11, and detailed in the full report, the European Space Agency, individual European countries, and Japan all have industrial policies that support satellite communications. Japan has a comprehensive planning program in which both government agencies and private industry are engaged. The European planning effort, although not as well organized, is still quite ambitious. The United States has no recognized plan for the development of satellite communications, nor even for fitting satellite communications into the national information infrastructure.

Europe and Japan have advanced technology development programs which provide direct support to industry, in most cases aimed at developing specific national capabilities. Perhaps most significant of all is the extent to which European and

Japanese governments and industry work hand-in-hand to promote regional and national interests in international systems -- a good example of which is the heavy support given by ESA and Japanese government agencies to the development of advanced technology for the INMARSAT mobile and personal communications program.

Threats

This panel's year-long review of overseas capabilities in satellite communications has revealed many potential threats to U.S. industry. These threats include a slipping base in advanced satellite communications technologies across a wide range of disciplines, rapidly changing markets and applications, and a lack of effective long term systems planning and related technology road maps to the future. Most of all, there is a dearth of mechanisms for effective long term R&D directed at advanced technologies in which industry, government and universities can play an effective ongoing role.

Opportunities

The United States still holds an industrial lead in today's satellite communications market measured in spacecraft construction and flight hardware sales. This is a result of large investments in many areas of space technology over the last three decades. However, the U.S. space technology base is being depleted rapidly. Also, the position of its launcher industry has eroded considerably in the last five years.

The United States certainly has competitive industrial practices and a reasonably good but aging infrastructure for test and integration. Given these and other factors noted herein, there is good reason to believe that today's threats could be counteracted. If the available opportunities are realized, the United States could maintain its industrial leadership and recover from the effects of its slipping advanced technology base.

In summary, the members of this panel have identified a number of serious and growing risks to the U.S. satellite communications industry, but opportunities exist for future initiatives that could allow the United States to maintain its leadership role.

KNOWLEDGE-BASED SYSTEMS IN JAPAN

May 1993

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SUMMARY

This report summarizes a study of the state-of-the-art in knowledge-based systems technology in Japan, organized by the Japanese Technology Evaluation Center (JTEC) under the sponsorship of the National Science Foundation and the Advanced Research Projects Agency. The panel visited 19 Japanese sites in March 1992. Based on these site visits plus other interactions with Japanese organizations, both before and after the site visits, the panel prepared a draft final report. JTEC sent the draft to the host organizations for their review. The final report was published in May 1993, and is available from the National Technical Information Service as NTIS Report PB93-170124 (see inside back cover for ordering information). A more extensive summary of the panel's findings is being prepared for publication in *AI Magazine*.

RATIONALE, OBJECTIVES AND DESIGN OF THE STUDY

Expert Systems (ES), also called Knowledge-Based Systems (KBS) or simply Knowledge Systems, are computer programs that use expertise to assist people in performing a wide variety of functions, including diagnosis, planning, scheduling and design. These systems have become the most successful commercial applications of Artificial Intelligence (AI) research, first in the United States, and then in Europe and Asia. Thousands of systems are now in routine use world-wide, and span the full spectrum of activities in business, industry and government. Economic gain has been realized along many dimensions: speed-up of professional (and semi-professional) work; cost savings on operations; return on investment; improved quality and consistency of decision making; new products and services; captured organizational know-how; improvements in the way a company does its business; crisis management; and stimulation of innovation.

Because of the potentially large impact that knowledge systems technology can have on the economy, and because Japan has had active and well-funded research and commercialization activities in KBS since 1982, the National Science Foundation and the Advanced Research Projects Agency requested that a study be conducted of the state-of-the-art of knowledge-based systems in Japan.

The primary objectives of this JTEC panel were to investigate Japanese expert systems development from both technological and business perspectives and to compare progress and trends with similar developments in the United States More specifically, there were five dimensions to the study:

1. Business sector applications of expert systems
2. Infrastructure and tools for expert system development
3. Advanced knowledge-based systems in industry
4. Advanced knowledge-based systems research in universities
5. National projects, including:
   ICOT – the laboratory of the Japanese Fifth Generation Computer Project;
   EDR – the electronic dictionary research knowledge-base building effort;
   LIFE – the Laboratory for International Fuzzy Engineering.

The panel conferred with Japanese computer scientists and business executives both before and after the official visits of March 1992. The 19 sites visited included four major computer manufacturers, eight companies that are applying expert systems to their operations, three universities, three national projects, and the editors of *Nikkei AI,* a publication that conducts an annual survey of expert systems applications in Japan.

CONCLUSIONS

The panel reached the following conclusions about the state-of-the-art in knowledge-based systems in Japan.

Business Sector Applications, Infrastructure and Tools

On the basis of our site visits, plus additional data gathered by *Nikkei AI,* we can draw a number of conclusions about the state of the art of expert system applications within the business sector in Japan.

1. The technology of expert systems has now been mastered by the Japanese. Since the early 1980s, when they first entered this field, they have completely caught up with the United States. Their best applications are equal to the best elsewhere in the world. Their use of the technology is widely spread across many business categories.

2. Computer manufacturers play a dominant role in the technology and business of expert systems. The Japanese have mastered and absorbed expert system technology as a core competence. They tend to use systems engineers rather than knowledge engineers to build systems. Consequently, integration with conventional information technology poses no special problem for them, and is handled routinely and smoothly, without friction. These large computer companies also build many application systems for their customers; small firms play only a minor role in applications building, in contrast with the situation in the United States.

3. Within the computer manufacturing companies, there is a close coupling between activities in the research laboratories, the system development groups, and the sales departments. The development and sales groups work closely together to develop custom systems for clients, the results of which are fed back to the research lab to provide the requirements on the next generation of ES tools.

4. Viewed as a technology (rather than as a business), the field of expert systems is doing well in Japan, as it is in the United States. As in the United States, the experimentation phase is over, and the phase of mature applications is in progress. Following a normal learning curve, the number of successful deployments of expert systems has risen sharply, from about 5% in the early years to about 75% in recent years. Japanese appliers of the technology make eclectic use of AI techniques (their attitude seems to be, "Try it, it might work."). Most of these techniques originated in the United States or Europe. As in the United States, expert systems technology is often a component of a bigger system. The Japanese do not attempt to analyze payoff at the component level, but at the system level. Thus they do not measure the return on investment of these embedded expert systems. However, there are many applications in which the expert system is the main technology.

5. Viewed as a business, the expert systems field did not "take off" in any exceptional way versus the United States or Europe. Although the overall level of activity is significant and important, there is no evidence of exponential growth. The components of the business consist of expert system tools, consulting, and packaged knowledge systems. Hitachi's expert system business seems the most viable. Other major players, such as Fujitsu and CSK, have not had business success.

6. With respect to tools for building knowledge-based systems, the Japanese tools are similar in sophistication to those sold and used in the United States. The techniques and methodology developed in the United States have been and continue to be made into products quickly.

7. Japan has more experience than the United States in applications of KBS technology to heavy industry, particularly the steel and construction industries.

8. Aside from a few exceptions, the Japanese and U.S. ES tool markets follow similar trends: vertical, problem-specific tools; a move towards open systems and workstations; and an emphasis on integration of expert systems with other computational techniques.

9. The number of fielded applications in Japan is somewhere between 1000 and 2000, including PC-based applications. The number of U.S. applications is probably several times that of Japan.

10. Fuzzy control systems (not counted in the above tally) have had a big impact in consumer products (e.g., camcorders, automobile transmissions and cruise controls, television, air conditioners, and dozens of others).

11. We saw continued strong efforts by Japanese computer companies and industry-specific companies (e.g., Nippon Steel) to advance their KBS technology and business. This situation contrasts with that in the United States, where we see a declining investment in knowledge-based systems technology: lack of venture capital, downsizing of computer company efforts, few new product announcements. It is a familiar story, and one for concern, as this trend may lead to Japanese superiority in this area relatively soon.

Knowledge-Based Systems Research in Japan

1. A survey of three years of working papers of the Special Interest Group on Knowledge-Based Systems of the Japan Society for AI shows a wide range of research topics, touching most of the subjects of current interest in the United States.

2. The quality of research at a few top-level universities in Japan is in the same range as at top-level U.S. universities and research institutes.

3. In the remainder of the Japanese university system the quality of research is not at the same level as at first or second tier U.S. research centers.

4. The quantity of research (in terms of number of projects and/or number of publications) is considerably smaller (by nearly an order of magnitude) compared to the United States.

5. LIFE is the world leader in applying fuzzy logic concepts to classic AI core problems.

6. The industrial laboratories appear to be doing advanced development that is tightly coupled to application or product development. The computer companies and some high-tech companies are carrying out some knowledge-based systems research, but most non-computer companies do none. We saw, essentially, a thin layer of excellent work at Hitachi, Toshiba, NEC, Fujitsu and NTT, and (on previous visits) also at IBM Japan and Sony. The most basic and deep work is at Hitachi's Advanced Research Laboratory, which is conducting advanced research in model-based reasoning and machine learning.

ICOT

1. Using massive parallelism, ICOT appears about to achieve its stated goal of 100 million logical instructions per second (LIPS) theoretical peak performance.

2. The Fifth Generation Project achieved its goal of training a new generation of computer technologists.

3. ICOT is one of only a few sites in the world that is studying massively parallel *symbolic* computing.

4. ICOT created the funding and motivation to spur significant interest worldwide in AI, KBS and advanced computing paradigms.

5. ICOT's logic programming research is world class, and probably the best in the world.

6. On the negative side, ICOT made little progress in the applications dimension, and has had little impact on knowledge-based systems technology.

7. The choice of Prolog and logic programming, coupled with high-cost research machines, isolated ICOT from industry.

EDR

1. EDR will likely produce a practical scale, machine usable dictionary for Japanese and English.

2. With several hundred thousand entries in their concept dictionary, the scale of EDR accomplishments is very impressive and should be taken as a model for similar research programs elsewhere.

3. A follow-up project, the Knowledge Archives project, may be funded, and should be closely tracked.

4. EDR has not significantly improved the underlying technology for maintaining large knowledge bases, nor significantly added to our theoretical understanding of knowledge base organization.

Comparisons with the United States

A comparison of expert systems activities in Japan and the United States, drawn from the above conclusions, is presented in the following two tables.

TABLE 12
Comparison of Applications of Expert Systems in the United States and Japan
(See Key, p. 44)

	Current State	Trend
Quality of the best	0	=
Quantity relative to GDP	0	->
Support Structure	+	=
Tools	0	->
Consumer Products	+	->
Integration	+	*

* Japan trend is constant or gaining

TABLE 13
Comparison of Knowledge-Based Research in the United States and Japan
(See Key, p. 44)

	QUANTITY		QUALITY	
	Current State	Trend	Current State	Trend
Adv. KBS Research in Industry				
Basic Research	-	=	-	=
Applied R&D	0	->	+	=
Adv. KBS Research in Universities	-	->	-	->
National Initiatives				
Parallel Symbolic Computation	+	<-	+	=
Very Large Knowledge Bases	+	<-	0	=
Fuzzy Logic Systems	+	->	+	=

DISPLAY TECHNOLOGIES IN JAPAN

June 1992

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BACKGROUND

The Japanese have recognized that as we enter the Information Age, both the computer industry and the television industry will need new display technology. The introduction of the laptop computer has created a need for a thin panel display with good readability and low power consumption. Television is entering a new era of high definition television (HDTV). The Japanese have recognized that new display technologies are critical to making their electronic products highly competitive in the world market.

SUMMARY

Japanese-U.S. Comparison

The panel feels that U.S. display technology is competitive in some areas and superior in others. However, without the long-term investment in manufacturing facilities and the resolve to lower manufacturing costs by addressing both the computer and consumer markets, the U.S. will not be able to profit from its investment in display research. Japan is currently expanding its lead in product development, is dominating in investment and manufacturing implementation, and is competitive in basic research (and gaining). The relative status of the U.S. and Japan in flat panel displays is shown in Table 14.

TABLE 14
Comparison of U.S. and Japan in Display Technologies
(See Key, p. 44)

	RESEARCH		DEVELOPMENT		PRODUCTION		MAX. SIZE
	Status	Trend	Status	Trend	Status	Trend	
PASSIVE LCD							
super twist	+	->	+	->	+	->	17" Japan
ferro-LCD	0	->	+	->	+	->*	15" Japan
ECB	+	->	+	->	+	->*	14" Japan
ACTIVE LCD							
metal-insulator-metal	+	->	+	->	+	->	13" Japan
amorphous-Si TFT	0	=	+	->	+	->	15" Japan
poly-Si TFT (low temp)	–	?	–	=	none	none	unknown
poly-Si TFT (hi temp)	–	?	0	->	+	->	10" Japan
polymer dispersed	–	=	0	->	none	none	none
EMITTERS							
electroluminescent	+	=	–	<-	–	<-	18" U.S.
DC plasma display	+	->	+	->	+	->	33" Japan
AC plasma display	0	->	0	->	+	->	31" Japan

* The Japanese announced production for late 1992

Liquid Crystal Displays

By the mid-1980s, it was becoming obvious to displays industry experts that the Japanese displays industry was beginning to make significant breakthroughs in technical developments and in the manufacturing of liquid crystal displays (LCDs). In Japan, the stage is nearly complete for the production of flat panel displays (FPDs) through the end of the 1990s. The LC FPD industry is now orders of magnitude ahead of the other FPD technologies. The research, development, and production activities in Japan are so focused on LCD technology that funding for advancing electroluminescent (EL), plasma, and other FPD technologies is diminishing. In Japan, LCDs are perceived as clearly being the leading edge technology, but the cost and complexity of the new amorphous silicon (a-Si) LCD factory are so extensive that the larger machines of the next generation will not be attempted until the present generation of machines have completely proven themselves and been paid for.

Liquid Crystal Materials

Low-molecular weight nematic liquid crystalline materials for twisted nematic (TN), super-twisted nematic (STN), and ECB displays are well developed, and European nematics materials producers have established joint ventures in Japan to tailor-make mixtures for display manufacturers.

Most improvements in TN and STN displays are expected to come from materials such as retardation films and improved alignment layers. Japanese companies are the only suppliers of retardation films. Other improvements are expected to come from the synthesis and design of new low-molecular weight LC materials for ferroelectric chiral smectic (FLC) displays. Also, several Japanese companies are studying new molecular forms. Gray scale was perceived to be a major problem by most of the Japanese companies.

Most Japanese companies had research programs on polymer-dispersed liquid crystals (PDLC) materials, and there appeared to be interest in these materials for projection applications. Advances are also being made in the development of blue and white EL phosphors. In the plasma display panels (PDPs), new designs and success in discharge cell structure are expected to give new focus to materials research.

University researchers in Japan are more aware of display materials problems and industrial needs than are their counterparts in the United States and Europe. University research is more basic in general, and basic research on liquid crystals is more driven by display technology than in the U.S. and Europe.

Active Matrix Liquid Crystal Technology

Over the past few years, progress in active matrix LC (AMLC) technology has been spectacular. Remaining questions are how low the cost can be, how fast they will penetrate the market, and how good their ultimate performance will be.

Manufacturing issues have become the prime focus of research and development. Research is continuing on low-temperature polysilicon. The market niche that drives polysilicon currently is for view finders and projection light valves.

The main thrust in AMLC technology is directed towards developing cost-effective manufacturing of amorphous-silicon active matrix liquid crystal displays (AMLCDs). In these applications, the ability to integrate the drive electronics onto the AM substrate provides a significant, and at times enabling advantage. Seiko-Epson and Toshiba continue to develop metal-insulator-metal (MIM) technologies, but MIMs are expected to only serve limited applications in which cost is more severely constrained than performance.

There is intense competition for market share, because many major Japanese corporations view this area as a strategic long-term investment.

Passive Matrix Liquid Crystal Displays

Passive matrix LCDs dominate the flat-panel display business today, and will continue to dominate it, at least in unit sales, for the next five years. The passive matrix LCDs covered in this panel's report are twisted nematic, supertwisted nematic, vertically-aligned nematic (VAN), and ferroelectric.

Film-compensated STN (FSTN) LCDs have enabled a new industry (portable and notebook computers), and are also used widely in Japan in word processors. Color FSTN LCDs will continue to improve and will be introduced to the market in significant numbers in 1992-93. FSTN LCDs have not reached their full potential, and improvements are expected in several areas in the next few years.

VAN LCDs have made impressive gains but probably will be limited to niche markets because of their slow response time and low optical efficiency. Ferroelectric LCDs are under active development at a few laboratories, but only Canon has announced production plans. If Canon has solved the manufacturing problems, then these displays will give competition to active matrix LCDs, especially in the larger sizes.

Projection Displays

In Japan, much of the new display development has been motivated by the high-definition television market. At this time the only feasible options seem to be either direct-view large panels -- such as PDPs or AMLCD panels -- or projectors. In the short term, only projectors seem to have the cost and performance characteristics for consumer HDTV displays. For large screen displays, cathode-ray tube (CRT) projectors with good performance have been produced.

Currently, university laboratories in both the U.S. and Japan are doing competitive basic work. In both countries, a large part of the basic research is funded by governmental agencies. Although research in CRT projectors continues, the major effort seems to have shifted to AMLCD light-valve projectors. These projectors provide images with excellent quality and have a number of cost and performance advantages.

Efforts at this time seem to be concentrated on reducing cost and increasing the yield of projectors of the current design in an effort to have consumer-quality projectors available by 1995. The major thrust of the effort seemed to be to concentrate on products using current system designs.

Future Trends

Future display needs will probably be met with a combination of types. For small displays -- from 14- to 16-inch diagonals and eventually up to 20 inches -- it is expected that LCD panels will dominate for the foreseeable future. At present this market consists primarily of passive matrix LCDs, but higher performance AMLCD panels are rapidly expanding their share of the market. It is expected that CRTs will still dominate the market for 20- to 30-inches sizes. For displays larger than this, light-valve projectors using AMLCD panels are thought to be the near-term solution. In the longer term, NHK and several others expect plasma panels to be used for the long-sought-after "hang-on-the-wall" display.

DATABASE USE AND TECHNOLOGY IN JAPAN

April 1992

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BACKGROUND AND GENERAL CONCLUSIONS

This report presents the findings of a group of database experts, sponsored by JTEC, based on an intensive study trip to Japan during March 1991. Academic, industrial, and governmental sites were visited. The primary findings are that Japan is inadequately supporting its academic research establishment, that industry is making progress in key areas, and that both academic and industrial researchers are well aware of current domestic and foreign technology. Information sharing between industry and academia is effectively supported by governmental sponsorship of joint planning and review activities, and enhances technology transfer. In two key areas, multimedia and object-oriented databases, export of Japanese database products, typically integrated into larger systems, is on the horizon.

Database research in industry relies heavily on publications from the U.S. and Europe for conceptual input. The researchers are well-read and often well connected with foreign academic sources; thus they provide an important path for technology transfer.

Role of the Japanese Government

The Japanese government, overall, seems to have less influence on research directions than is perceived by outsiders, although it does appear that the Japanese government has done more than most governments to further database use and technology. Academic researchers have considerable flexibility in choosing the directions for government-sponsored research. The level of government funding for industrial laboratories is relatively low, and does not influence market-driven priorities. However, these projects do require regular meetings of academic, government, and industrial researchers, increasing mutual awareness, understanding, and enhancing technology transfer.

Driving Force: The Japanese Electronics Industry

An important driving mechanism in database development is the Japanese capability in the area of developing electronic products. High-quality image acquisition, transmission, storage, display, and digitized voice data are emphasized. The panel concluded that purchasers of systems with multimedia requirements will, with Japanese image-processing hardware, acquire Japanese database software. This field is likely to grow rapidly. Computer-assisted design (CAD), computer-assisted engineering (CAE), and other application areas that are critically dependent on graphics will be the initial applications of this technology.

Hardware

Japanese hardware for computer systems is roughly equivalent to U.S. systems, except again in the areas of multimedia support and optical mass storage, where the Japanese have a substantial advantage. Parallel architecture and database accelerator schemes are of active interest in Japan.

Hardware support for database systems is provided equally well by Japanese and foreign companies. Sony is an important supplier of workstations, but U.S. companies such as SUN Microsystems are also well represented. Japanese mainframe-based database systems are similar to their U.S. counterparts, but this market shows less growth and is less fluid.

Relevant research on topics such as database accelerators is being pursued. This work can be seen as a specialization of research into parallel computation, which is pursued by computer researchers everywhere with equal intensity. The payoff is likely to come as demands on database computation increase.

The Database Industry in Japan

The JTEC study also surveyed the industry that maintains databases and sells information retrieved from these databases. In this area, Japanese databases provide useful service internally, but are not in a position to export their services. There is substantial use in Japan of Western databases, both via U.S. and European vendors and via Japanese resellers. Some internal developments are oriented towards providing image data as well. Providing such services on an international scale awaits high capacity communication lines and acceptance standards. In this area the relative situation seems stable.

While Japan is not viewed today as a world-level player in the database area, the infrastructure is in place for Japan to make important contributions in areas where there is high growth potential and linkage with consumer hardware.

Qualitative Comparisons Between the U.S. and Japan

The panel has prepared a qualitative comparison of the present status and trends in database systems research in the U.S. and Japan. The subject matter covered by the panel was divided into seven subtopics: mainframes, hardware-PC, workstation-servers, storage, database content, database management systems, and new database technologies. (See Figs. 6-12).

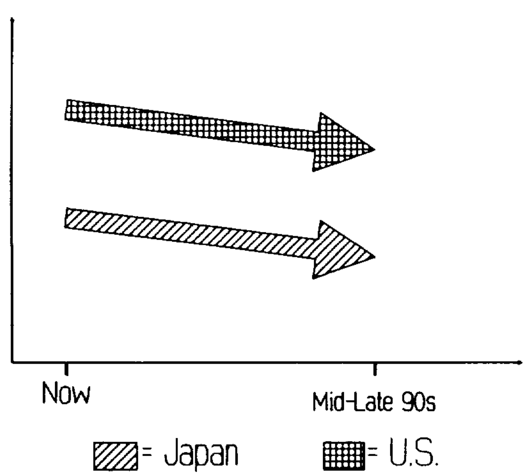

Figure 6. Mainframes

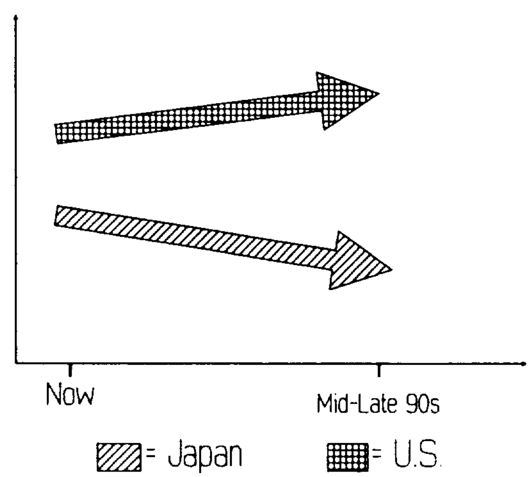

Figure 7. Hardware - PC

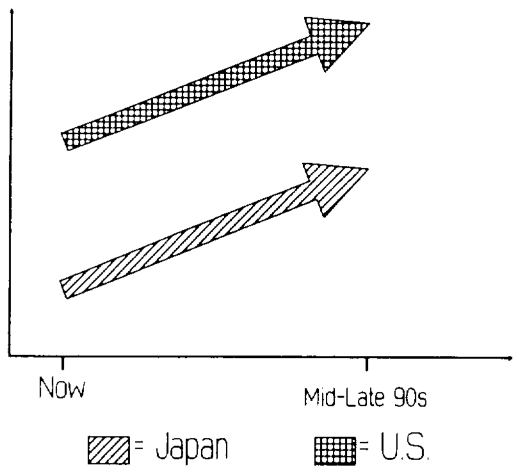

Figure 8. Workstations - Servers

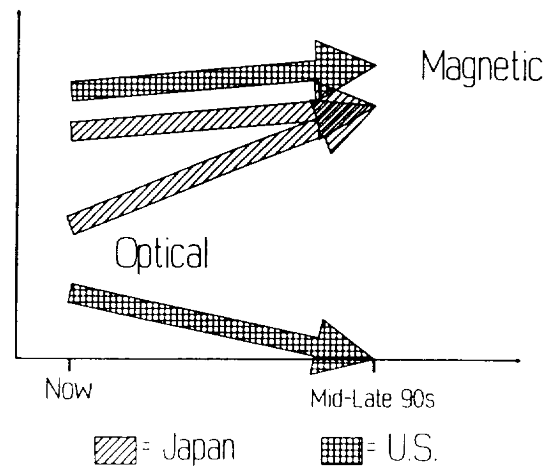

Figure 9. Storage

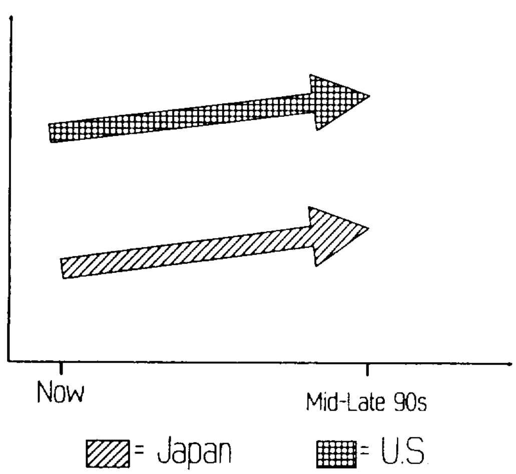

Figure 10. Database Content

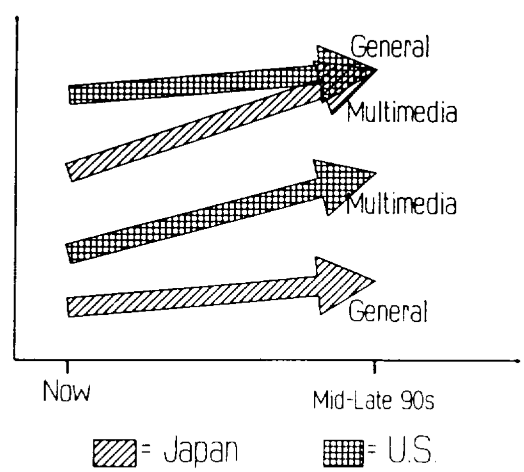

Figure 11. DBMSs

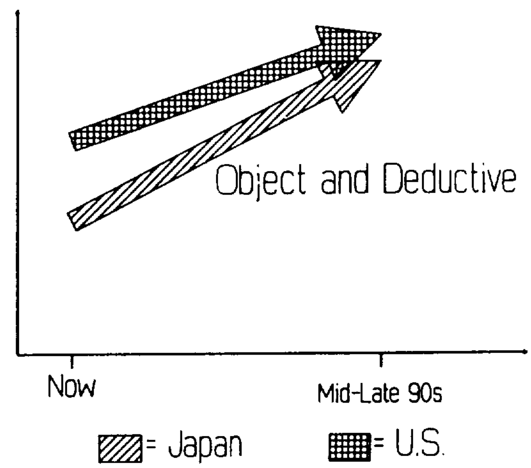

Figure 12. New DB Technologies

MACHINE TRANSLATION IN JAPAN

January 1992

Jaime G. Carbonell, Carnegie Mellon University (Panel Chair)

Elaine Rich, MCC (Panel Cochair)

David Johnson, IBM

Masaru Tomita, Carnegie Mellon University

Muriel Vasconcellos, Pan American Health Organization

Yorick Wilks, New Mexico State University

BACKGROUND

The goal of the JTEC report on machine translation is to provide an overview of the state of the art of machine translation (MT) in Japan, and to compare Japanese and U.S. technology in this area. The term "machine translation" as used here includes both the science and technology required for automating the translation of text from one human language to another.

SUMMARY

In Japan, machine translation is viewed as an important strategic technology that is expected to play a key role in Japan's increasing participation in the world economy. As a result, several of Japan's largest industrial companies are developing MT systems, and many are already marketing their systems commercially. There is also an active MT and natural language processing (NLP) research community at some of the major universities and government/industrial consortia.

The principal use for MT today is in translating technical documentation for products to be sold abroad. The volume is still relatively small but appears to be growing steadily. There is also an increasing use of MT embedded in other applications, such as database retrieval systems, electronic mail, and (in the prototype stage) speech-to-speech translation systems.

Users have reported varying degrees of success with MT. While a few users have actually experienced lower productivity using MT compared to conventional approaches, productivity gains of 30 percent appear average. Higher numbers are

typical for restricted domains and lower numbers for broader domains. Most uses of MT require some human pre- or post-editing to produce acceptable quality translations.

SPECIFIC R&D COMPARISONS

In both the U.S. and Japan, total funding for MT appears to be on a gradual but steady rise. Japanese commitment to MT is greater than that of the U.S., though the U.S. commitment is by no means insignificant.

In both Japanese and U.S. markets, MT is gaining gradual acceptance (Fig. 13), with Japan having and maintaining a lead. The same situation and trends are present for the integration of MT systems into other text processing software (Fig. 14).

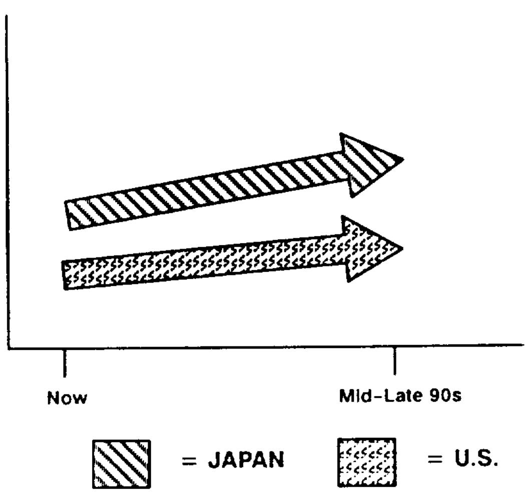

Figure 13. Acceptance of MT

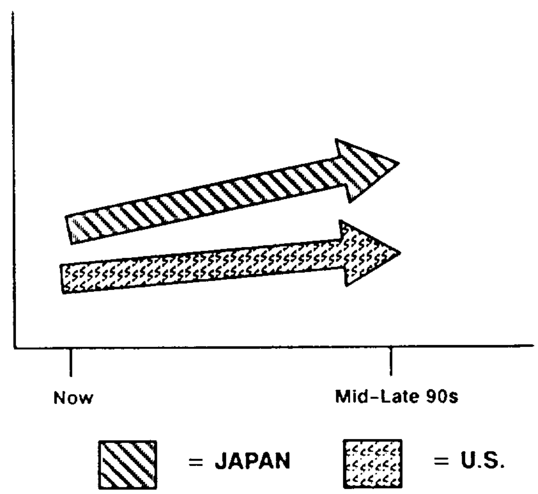

Figure 14. Integration of MT

Improved accuracy appears to be the single most important factor in determining how widely MT will be accepted. Japanese and U.S. efforts are expected to show steady improvement in accuracy between now and the mid- to late-1990s (Fig. 15).

MT requires multiple knowledge sources, which are large and expensive to build and maintain. Consequently, they are valued resources in MT research and are even more important in successful MT system deployment. Japan is currently leading the U.S. in private knowledge sources, and this lead may be widening (Fig. 16).

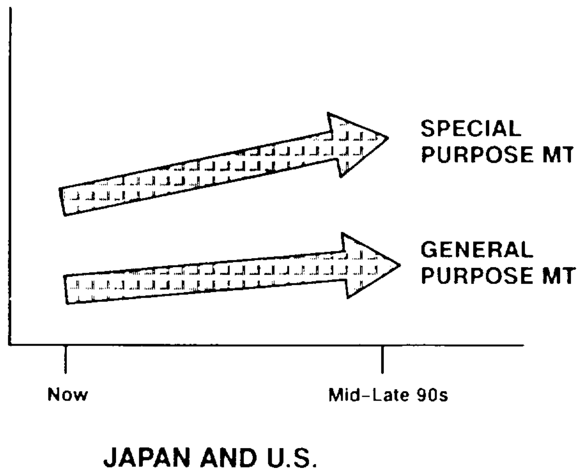

Figure 15. Accuracy of MT

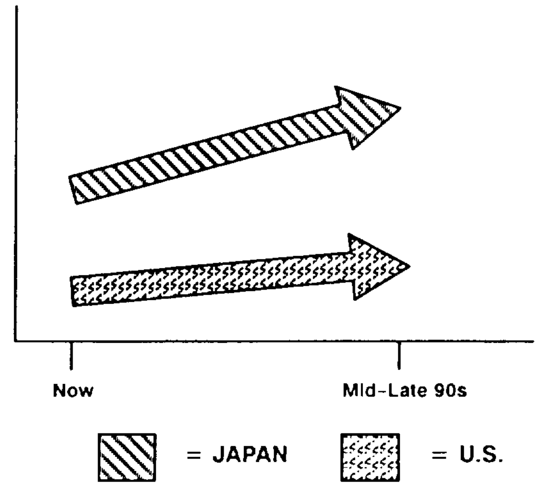

Figure 16. Private Knowledge Sources

Although Japan also leads in shared knowledge bases (Fig. 17), the gap may narrow assuming continued funding from the Defense Advanced Research Projects Agency (DARPA) and other U.S. government agencies that are targeting some funds specifically at building shareable knowledge sources.

The basic science and technology underlying MT is natural language processing (or computational linguistics), which is the study of computer processing of language. Traditionally the U.S. has been a bastion of scientific research in this area, but research funds in the U.S. have been decreasing. Funding in Japan and Europe has been increasing and will surpass the U.S. level, if it has not already done so. Thus, the U.S. risks being surpassed (Fig. 18) in the one area where it has traditionally led: computational linguistics, both the basic theory and computational methods.

The U.S. is ahead of Japan in some areas. For example, the U.S. currently leads Japan in technological diversity, that is, the variety of approaches to MT (Fig. 19) and linguistic diversity, that is, the number of languages being developed (Fig. 20). Present trends indicate that although the U.S. will maintain its lead in technical diversity, the gap will narrow in linguistic diversity.

The U.S. also maintains a lead in other related research areas. For example, the U.S. leads in speech recognition technology (Fig. 21), but both the U.S. and Japan are working on the early integration of speech technology into speech-to-speech MT. The U.S. also has a narrow lead in natural language processing technologies (Fig. 22) such as automatic extraction of knowledge from text, NLP-based human-computer interfaces, routing and classification of texts for assimilation, etc.

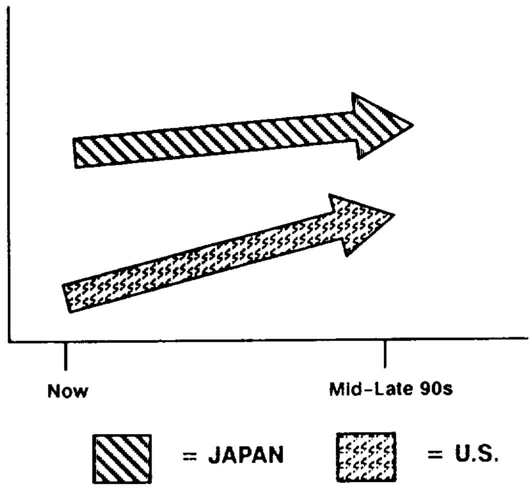

Figure 17. Shared Knowledge Sources

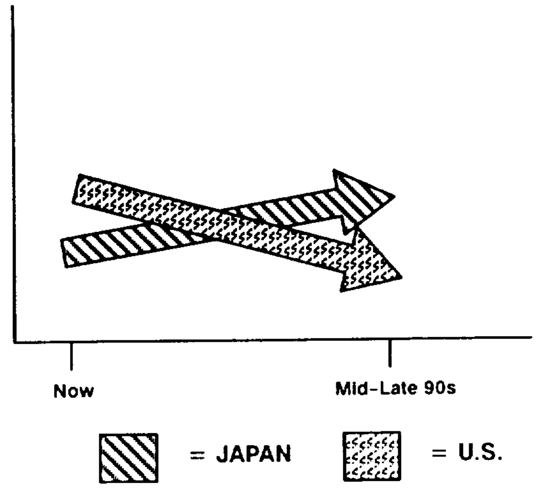

Figure 18. Funding for Basic Research in Natural Language Processing

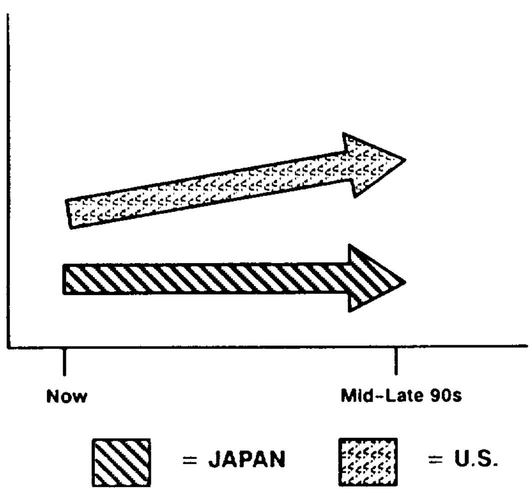

Figure 19. Technological Diversity

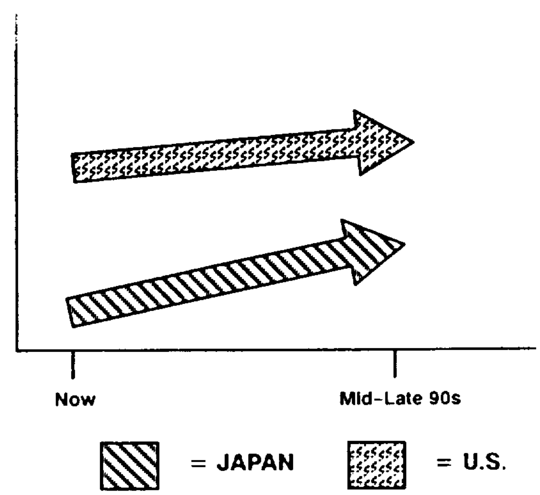

Figure 20. Linguistic Diversity

THE FUTURE

A substantial amount of research is being conducted in Japan. Figure 23 shows that funding for MT R&D in Japan is substantially higher than in the U.S., although U.S. funding is expected to increase. New Japanese corporate funding is more focused on productivity and commercialization. Figure 24 indicates the expected increase in commercial MT in Japan in response to this trend.

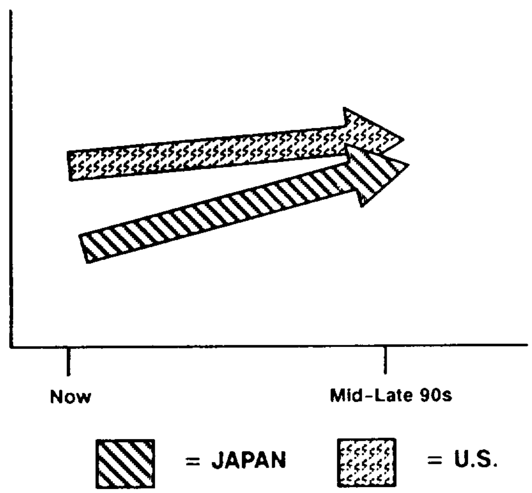

Figure 21. R&D in Speech Recognition and Speech-to-Speech MT

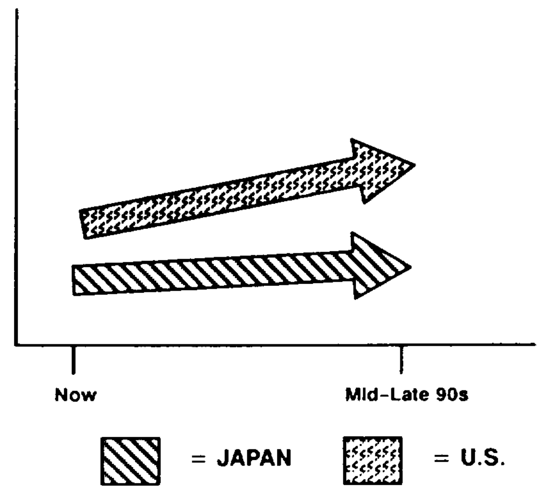

Figure 22. R&D in Other Natural Language Processing Technologies

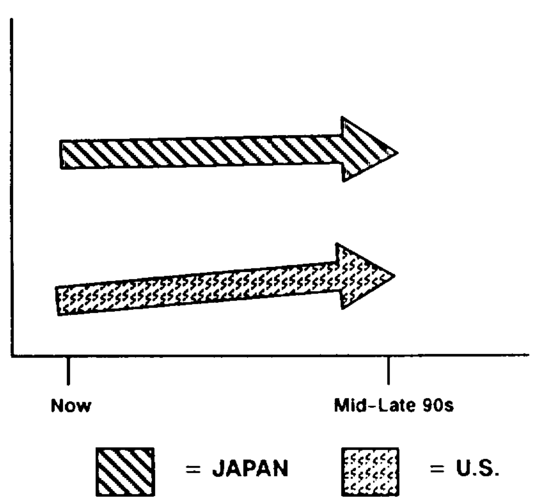

Figure 23. Funding for R&D in MT Technology

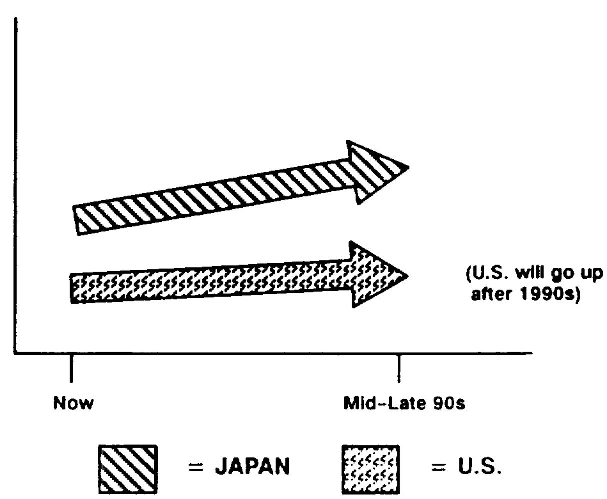

Figure 24. Commercial Use of MT

While there are unlikely to be any major technology breakthroughs in MT during the next five years, steady progress is expected, especially in the quality of machine translations. As knowledge bases grow in quantity, quality, and comprehensiveness, the sharing of these intellectual properties will become more common. User interfaces are also improving, partially as a result of the positive feedback from the growing community of MT system users. As a result, the Japanese fully expect to see a return on the substantial investment that they have made and are continuing to make in MT.

X-RAY LITHOGRAPHY IN JAPAN

October 1991

James T. Clemens, AT&T (Panel Chair)

Robert W. Hill, Hill Associates (Panel Cochair)

Franco Cerrina, University of Wisconsin

Gene E. Fuller, Texas Instruments

R. Fabian Pease, Stanford University

Henry I. Smith, MIT

BACKGROUND

The goal of the JTEC report on X-ray lithography, fully funded by the Office of Naval Research, is to provide a detailed appraisal of the technology, personnel commitments, and strategies for implementation in manufacturing of X-ray lithography in Japan.

Integrated circuits (semiconductors) are the key components of modern computers, communication systems, consumer electronics, and the new generations of smart machines and instruments. Microlithography is one of the most critical elements of the semiconductor manufacturing process because it determines the minimum feature size and the functional capabilities of the semiconductor. The quality of the microlithography process is critical in determining the yield and cost of semiconductors and hence the competitiveness of the electronics industry.

At present, all volume semiconductor manufacturing is done with optical UV (ultraviolet) projection lithography. X-ray lithography, however, holds the promise of providing higher yields in manufacturing semiconductors by virtue of enhanced process latitude, process robustness, and resolution.

SUMMARY

The major Japanese microelectronics firms have a broad, well-developed strategy for research and development of microlithography technology that includes UV, deep UV, X-ray proximity and projection, and electron-beam lithographies. They are investing in all of these alternatives. All of the manufacturers visited either had in-house X-ray programs, were members of the SORTEC X-ray consortium, or both.

Their commitment to X-ray lithography was firm and appeared to be well balanced. In the U.S. there is limited interest from semiconductor manufacturers in X-ray technology, with the exception of AT&T, IBM, and Motorola.

Research Funding

Most funding for X-ray lithography efforts in Japan comes from individual industrial organizations. The Japanese government directly and indirectly has provided seed money to major research and development efforts. The government has funded roughly $70 million of the SORTEC development through MITI, and industry has funded $30 million. Japanese companies are making the major part of the X-ray investment in their own companies.

In the U.S., there has been a significant X-ray lithography program for over ten years at IBM. Motorola has recently joined the effort. Congress has provided money to DARPA for applied research and development on X-ray lithography in all sectors of the technical and industrial community. However, the U.S. industrial community has not been independently preparing itself for insertion of X-ray lithography into manufacturing.

Optical Lithography

The consensus among Japanese semiconductor manufacturers was that optical lithography would continue to evolve for advanced semiconductor manufacturing until the late 1990s, and that the potential switch to X-ray lithography would probably occur when the minimum critical dimension reached 0.25 micron or less. While their first choice for 256 megabit dynamic random access memory (DRAM) was optical, they were prepared to use X-ray technology for manufacturing. Although they recognized potential of higher yield and lower manufacturing costs with X-ray, manufacturers will not change technology until absolutely necessary. This same viewpoint prevails in the United States and in Europe.

Synchrotrons

There were many large efforts in Japan to develop synchrotron-based lithography systems because they are bright, collimated sources. Smaller laser and gas plasma sources, while more desirable from a granularity standpoint, were not visible or discussed in detail. X-ray projection projects exist; they were mentioned at several companies but not extensively discussed.

The size, cost, and configurational aspects of synchrotron-based X-ray lithography did not appear to be serious issues in Japan with the DRAM manufacturers. Their view was that if X-ray lithography were used, it would be for large-volume manufacturing, which would require multiple synchrotron facilities. Cost has been a major issue with the U.S. and European manufacturers since their volume semiconductor production has not been DRAM-based, their companies are smaller, and many are not using the leading edge of microlithography technology. The initial investment is beyond the means of most of these manufacturers; only IBM, AT&T, and Motorola have major active internal X-ray programs. Also, in the U.S. several synchrotrons originally developed for other purposes are being used in part for X-ray lithography R&D.

DARPA is administering a program sponsored and financed by Congress that attempts to overcome some of these difficulties by helping to build the infrastructure necessary for X-ray lithography. DARPA is expanding that program to support other lithographic alternatives.

Other Research

Development of X-ray mask technology, exposure systems, and resists has been pursued vigorously in Japan, as has integration of the total system.

There appeared to be a consensus that materials for X-ray masks were adequate. The Japanese were using silicon nitride membranes with tantalum absorber mask technology licensed from NTT. They were researching silicon carbide membrane and tungsten absorber materials, and planned to research diamond membranes.

The major mask concern was 1X electron-beam mask patterning, specifically errors in feature placement and dimension control. There was no work on mask inspection and repair underway; the Japanese believe these tools will be available from domestic or overseas sources when required.

Several independent efforts were being pursued on exposure system aligners, with critical elements under development. Heterodyne interferometric alignment techniques were favored for alignment; these were more advanced in concept than current U.S. or European projects.

With respect to fundamental understanding of the science of X-ray lithography, the Japanese and the U.S. technical communities were on a par. The trend, however, was for the Japanese to pull ahead of the U.S. due to a higher level of funding and staffing, particularly at the company level.

If X-ray lithography becomes necessary for producing the next generation of semiconductors, Japanese industry will be in an excellent position to maintain or increase its market share in semiconductors and the advanced systems dependent on them.

HIGH DEFINITION SYSTEMS IN JAPAN

February 1991

Richard J. Elkus, Jr., Prometrix Corporation (Panel Chair)

Robert B. Cohen, Consultant

Birney D. Dayton, NVISION

David G. Messerschmitt, University of California

William F. Schreiber, Massachusetts Institute of Technology

Lawrence E. Tannas, Jr., Consultant

SUMMARY

"High definition" describes new products or systems whose value resides in their ability to process greatly increased amounts of audio and video information. Processing of information is fundamental to the infrastructure of electronics, telecommunication, and media markets. The panel's goal was to study technological developments in Japan pertaining to high definition systems. A brochure from Japan's Ministry of Posts and Telecommunications described high definition television as "the cornerstone of the information age," which indicated a dedication to the concept of HDTV in Japan. The purpose of this dedication seemed to be to focus the Japanese electronics industry on a problem that, when solved, might have advanced the state of the electronics manufacturing art in Japan a generation beyond that of the rest of the world.

The Japanese manufacturers the panel visited indicated that near-term applications of HDTV technology that would justify their investment were in information systems and industrial applications. Public relations literature made clear the long-term focus of Japanese electronic companies on the increasing use of speech, image, and video in all phases of information systems and illustrated a combined vision of and commitment to a new age of information technology.

The panel report does not address the new digital approaches to HDTV, which were publicized after the panel had completed its work.

HDTV and Its Signal Processing

High definition systems require a lot of bandwidth to store and transmit video. The two major technological components of high definition systems (HDS) are digital signal processing (DSP) for compression and quality enhancement, and high-resolution displays. An example is the Japanese MUSE system, which is analog transmitted by satellite but uses large doses of DSP in the transmitter and receiver to compress the bandwidth. In 1989, six Japanese manufacturers were cooperating with the public broadcasting organization NHK on a reduced-cost MUSE receiver that required development of thirty separate application-specific integrated circuits. The panel saw several projects engaged in compression of digitally-encoded HDTV.

The importance of these DSP developments transcend their near-term application to HDTV. For example, the U.S. was strong in DSP, which was a technology driver because it required high arithmetic processing rates that often exceeded even those of supercomputers. DSP was also a key component of many military and commercial systems. HDS requires some of the highest processing rates of any DSP applications and, hence, drove Japanese manufacturers toward very advanced electronics technologies and advanced architectures such as multiprocessor DSP. The Japanese expect HDS to be an element of many future commercial applications, such as multimedia applications in computing and new products in medicine, manufacturing, publishing, filmmaking, education, and telecommunications. Japanese manufacturers would be well positioned in these markets, given their DSP and display capabilities.

A twenty-year research effort coordinated and facilitated by NHK led Japanese manufacturers to world leadership in HDTV technology. Participating Japanese manufacturers could justify their investment knowing that, with NHK coordinating, their components would fit into the larger system. NHK's coordination was much more important than any public-sector monetary support it offered. This illustrated one way to pursue a research effort for a system so complex that it transcends the capabilities of any single manufacturer.

Evolution of Displays in Japan

High-quality, high-resolution displays are critical to the success of HDTV. At the time of the panel report, one technical limitation of HDTV lay in the display. The five problems were to: (a) generate the resolution in one continuous image plane; (b) make the image plane large to create realism; (c) change images to show real-time dynamics; (d) create the image in color; and (e) combine all these features at a consumer market cost with acceptable weight, power, and volume characteristics. Many display panels could meet some of these requirements. For example, ac plasma panels could be made with high resolution, but not simultaneously in color or at acceptable cost. Japanese industry was attempting to develop a large ac plasma panel and active matrix liquid crystal flat-panel, direct-view HDTV display prototype by 1995. U.S. industry was reportedly no longer attempting to develop an NTSC TV flat-panel display to hang on the wall. HDTV displays available in Japan had come about from improvements in cathode ray tube (CRT) and projection technologies. The second contender for consumer HDTV displays that the panel identified was the LCD light valve using three active-matrix liquid crystal cells. It was not yet clear whether this technology could compete with CRT projectors.

High Definition Standards and Equipment Development in Japan

JTEC panelists were often told that the Japanese could build to any standard within one or two years of learning about it. The process of developing standards in Japan was similar in some respects to that in the U.S., but the panel also found differences. Japanese companies had been participating in the U.S. process. This participation had been made possible because many Japanese could speak English, the diverse nature of U.S. culture made it very easy to find proxies, and Japanese companies had a strong export orientation. By contrast, U.S. companies were usually distant from the standards process in Japan.

Numerous standards for different HDTV (1125/60) equipment had been developed or were under development in Japan. Work had been done on a variety of television standards of intermediate resolution (greater than NTSC but less than true HDTV) under the rubric "EDTV," or enhanced definition TV. Significant progress had also been made in standards setting for components, such as HDTV semiconductors and displays, and for end-use products, such as studio HDTV equipment, industrial products, and consumer products.

A rapid cycle of standardization, manufacture, improvement, adaptation, and restandardization characterized Japan's standards process. Japanese companies were willing to adopt standards from elsewhere, adapting them to suit their changing needs. By contrast, the standards generation process in the U.S. was seen as slow.

Japanese High Definition Television Systems

That HDTV existed as a standards issue in the U.S. was largely due to the development of a system and equipment in Japan, and to Japanese efforts to have their system adopted worldwide. NHK began HDTV development in 1970. The plan was to implement HDTV in Japan as an entirely new service, delivered to viewers by direct-broadcast satellites (DBS) to supplement the over-the-air (terrestrial) system that would continue to use NTSC, the color standard used in both the U.S. and Japan. Scanning standards were chosen with the intention of making the picture quality comparable to that of 35-mm motion pictures. Since standard satellite transponder channels were inadequate for this studio system, the MUSE transmission system was developed to allow a compressed version of the signal to be transmitted in a normal satellite channel. System and equipment developments were paralleled by efforts to have the studio system adopted as an international standard for program production and international exchange. However, the system was not optimum for cable or terrestrial broadcasting. U.S. industry may learn from the Japanese experience in HDTV development and devise a system suitable to U.S. needs.

Japan's Public Policy Initiatives in Support of High Definition Systems

Japan's leading electronics corporations and the Japanese government have invested substantially in R&D to commercialize HDS and HDTV. Many Japanese leaders seemed to view HDTV as the center of a move to a vastly different Japanese economy that would offer huge benefits in growth and consumption. They also appeared to believe that government financing for the early stages of HDS development was important to reduce corporate risk and ensure that private funds would be forthcoming for the first stages of commercialization. Government funds also supported the development of key HDTV component technologies.

Sales to industrial customers were expected to support the growth of the new HDS market initially. Corporations would develop controls for design, engineering, and production or service-delivery processes, advances that would create new market opportunities for these firms. Development of HDTV was likely to enhance the interdependency of some of the most dynamic parts of Japanese industry and promote further vertical integration of the largest Japanese electronics firms.

The strong base that Japan's major corporations had in the consumer electronics industry facilitated their move into HDS. By playing a major role in the consumer electronics and semiconductor industries, these firms had a greater ability to benefit from economies of scale in developing new display, semiconductor, and processor products. The Japanese recognized the need for government-promoted R&D in high-risk areas such as large flat-panel displays. Therefore, they created new business-government entities, including the Key Technology Center and an HDTV leasing corporation. The Japanese also expected a significant boost in demand for semiconductors from HDS development.

High Definition Products and Systems: The Strategy of Leverage

To Japanese businessmen, strategy is everything. Every person, business, and industry must have a goal and a strategy by which to achieve it. Because resources are usually scarce, the successful Japanese plan includes the concept of leverage. Some markets are considered more strategic than others. By targeting strategic markets, an infrastructure can be built that ensures a solid basis for economic expansion. However, the leverage is not based simply on the importance of one market over another, but rather on the assumption that, as they develop, strategic markets will become interrelated and interdependent, with the whole becoming substantially larger than the sum of its parts. Therefore, coordination of strategy and direction is essential -- a point that is fundamental to the strategy of product and market development in Japan. It is based on the concept that if the development of a product or market is pushed to its logical extreme, it becomes related to other products and markets. Thus, Japanese business strategy does not reject a product or market on the basis of profit potential, but rather assumes that every product becomes the basis for another, and every technology becomes the stepping-stone for the next. The resulting efficiencies of scale are enormous.

The market for high definition products and systems can help push the markets for electronics products, telecommunication services, and software (including mass media) to their logical extreme. The Japanese expressed the view that, perhaps by the year 2000, the requirements and possibilities created by improving the technology to rapidly process large amounts of audiovisual information would force a confluence of these three end-use markets into a single information systems market. They expected that the information systems market would grow to represent 33 percent of all capital investment, 44 percent of all new jobs, and 22 percent of all economic growth.

The Japanese felt that in the future information age, any nation without a proprietary position in or reliable strategic access to each of the market segments within electronics, the media (including software and mass media), and telecommunication services would be at a significant competitive disadvantage. This concept was in part the basis for the accelerated development in Japan of high definition products and systems, and underscored the significance of high definition technology and its effect on all parts of the industrial structure of Japan.

ADVANCED COMPUTING IN JAPAN

October 1990

Michael A. Harrison, University of California, Berkeley (Panel Chair)

Edward F. Hayes, Rice University

James D. Meindl, Rensselaer Polytechnic Institute

James H. Morris, Carnegie Mellon University

Daniel P. Siewiorek, Carnegie Mellon University

Robert M. White, Department of Commerce

SUMMARY

To assess Japanese technology in advanced computing, the panel divided the subject into electronic components, data storage, computer architecture, software, computer/human interface and multimedia, and supercomputers. The panel obtained a baseline of U.S. accomplishments in these areas by reviewing literature, attending conferences, visiting laboratories, and discussing the subject with specialists. The panel then spent a week in Japan visiting five university sites, sixteen industrial sites, one consulting company, and nine government laboratories.

The Technical Bottom Line

Table 15 summarizes the positions of the U.S. and Japan in advanced computing.

Japan has made a significant long-term commitment to information technology, from research through commercialization. Policymakers, aware that Japan would have difficulty being self-sufficient in food and in energy, decided as early as 1955 to meet international competition and make international contributions by cultivating information as a resource. Japan would draw on a highly educated and motivated labor force to promote information-related, knowledge-intensive industries. Japan has implemented this goal through national programs. Industrial strategies have been coordinated, and MITI introduced a series of multi-year plans devoted to achieving excellence in information technology.

Japan's success in information technology is due in large part to its support of industries in the allied technologies -- advanced semiconductors, chip-making technology, data storage devices, and so forth.

C-2

TABLE 18
Japan's Position vs. U.S.: Advanced Computing
(See Key, p. 44)

Area	Position	Rate of Change
Electronic components	+	->>
Data storage	0	->>
Computer architecture	–	->
Software	–	=
Scientific calculations and supercomputers	0	->
Computer/human interface	–	<-
Multimedia	+	->

Japan's success in the computer industries has led to significant market share; the profits have been reinvested in R&D, and Japanese capital expenditures have remained high. Thus the panel expected that the Japanese competitive position would remain strong for at least the next five years. Whether the U.S. could maintain its competitive position would depend on whether the U.S. was willing to match Japan's rate of investment.

The panel found Japan relatively weak in software but effective in software engineering. There was a serious shortage of talented software people who could be hired to work in the large, high-technology Japanese companies, partly because many young people chose to work for higher salaries in the financial community. Japan had nothing yet to compare with the strong community of creative and talented software people in the United States.

Japanese universities remained substantially weaker than their U.S. counterparts because they have had no large projects of the type supported by DARPA in the U.S. Japanese students graduated from universities with a good conceptual education. The companies then provided continuing education to train them in design, production, and so forth. Employer-sponsored continuing education in the U.S. was much less intensive and effective because of employee mobility.

A key theme in Japan was internationalization. Japanese companies were using the profits from their success in consumer electronics and other information industries to establish themselves in the U.S. and elsewhere. Individual companies were establishing R&D laboratories, product development laboratories, manufacturing facilities, and sales and distribution centers in the U.S.

Electronic Components

Table 16 shows Japan's position in electronics components by indicating the number of years Japan is ahead of (behind) the U.S. in various areas.

TABLE 16
Japan's Position vs. U.S.: Electronic Components

Device	Gap
SRAMS	= +2 years (high density)
DRAMS	= +3 years
NVRAMS	= 0 years
Gate arrays	= +1, 2 years (high density)
Microprocessors	= -2 years or more
Gallium arsenide	= +2 years
Packaging	No U.S. presence
Infrastructure	Eroding

The panel qualified the findings in Table 16 by noting that the interval between an R&D announcement and commercial production was typically smaller for U.S. companies than for their Japanese counterparts. This tended to exaggerate the gap between the countries' positions.

Data Storage

Table 17 compares the two countries in data storage. Most Japanese industrial research focused on near- to medium-term issues. The panel found an enormous amount of exploratory work being done on alloys for thin film media, tribology, magnetoresistive sensors, and so forth. By comparison, efforts in the U.S. appeared more fragmented but more adventurous -- for example, the holographic storage at MCC and attempts to exploit high-resolution scanning microscopy.

Computer Architecture

The Japanese were experimenting with a vast number of computer architectures. Although their projects were based on American architectures, the gap between the American roots and the first Japanese project had narrowed from over a decade (i.e.,

TABLE 17
Japan's Position vs. U.S.: Data Storage
(See Key, p. 44)

Area	Position	Rate of Change
Magnetic recording		
Heads	–	–>
Media	–	–>
Head-to-disk interface	0	=
System	–	–>
Optical Recording		
Optical media	+	–>
Lasers	+	–>

from the American Illiac IV in the mid-1960s to the Japanese PAX in 1977) to less than a year (i.e., hardware simulation engines). Furthermore, although the number of advanced architectural projects was roughly equivalent in the U.S. and Japan, the sheer volume of Japanese projects initiated since 1980 was very impressive.

The U.S. was ahead of the Japanese in computer architecture. However, the Japanese were strong and growing stronger in hardware, prototyping, vector processing and pipeline design, dedicated hardware simulation architectures, multimedia workstations, and technology transfer between research and products.

Software

Except in software engineering, Japan has traditionally been weak in software, as is shown in Table 18. Although Japan has improved significantly in graphics, logic programming, and artificial intelligence applications, so has the rest of the international community. Ironically, the panel found that Japan had the lead in software engineering. U.S. researchers were conducting better software engineering research, but the Japanese were applying U.S. methods in a more disciplined fashion and achieving impressive results.

Multimedia and Computer/Human Interfaces

The panel found the U.S. to be significantly ahead in computer/human interfaces, although the Japanese were beginning to concentrate in that area. In multimedia systems, the Japanese were ahead in hardware technology because of their significant consumer electronics industry; the U.S. was far ahead in software applications. Table 19 shows the panel's rankings in multimedia systems.

TABLE 18
Japan's Position vs. U.S.: Software
(See Key, p. 44)

Area	Position
Programming languages	–
Operating systems	–
Artificial intelligence	–
Databases	–
Software engineering	+

TABLE 19
Japan's Position vs. U.S.: Multimedia and Computer/Human Interfaces
(See Key, p. 44)

Area	Position	Rate of Change
Computer-supported collaborative work	–	<<–
Hypertext	–	<<–
Electronic books	–	<–
Multimedia		
Components	+	–>
Workstations	0	–>
MM Mail	–	<–
User interfaces	–	<–

Supercomputers

Table 20 records the panel's impressions of Japanese research in supercomputers. In most areas of computational science and engineering, the number of researchers in Japan was smaller than that in the U.S. by a considerable margin. However, the numbers were growing in each of the fields surveyed.

The panel predicted that for the next five years the U.S. would continue to have more researchers working in supercomputers and scientific calculations. If U.S. researchers continued to have access to enough state-of-the-art supercomputers, the U.S. would continue to provide leadership in developing new approaches, algorithms, and software.

TABLE 20
Japan's Position vs. U.S.: Supercomputers
(See Key, p. 44)

Area	Position	Rate of Change
Hardware	0	->
Architecture	–	->
Systems software	–	->
Monitoring tools	+	=
Vectorization	0	?

Technical Summary

In the field of advanced computing in general, the panel found Japan to be ahead of the U.S. in basic building blocks such as chips and components. The U.S. predominated in software. However, revenues for software development could not be compared to those for the manufacture of electronics, and so forth. Therefore, the panel predicted that Japan would continue to have both market share and profits, which would fund R&D.

The panel judged the United States' investment in advanced computing R&D unimpressive. Because future government funding was uncertain, industry has been left with an increasing responsibility for funding computer-related R&D. IBM has taken a leadership position in forming cooperative ventures, although some collaborative ventures had not lived up to expectations. Therefore Japan's position in advanced computing hardware could become dominant unless new initiatives are undertaken.

II. Materials

ADVANCED MANUFACTURING TECHNOLOGY FOR POLYMER COMPOSITE STRUCTURES IN JAPAN

March 1994

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Moto Ashizawa, Ashizawa Associates Composites Engineering

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Dee R. Gill, McDonnell Douglas

Vistasp M. Karbhari, University of Delaware

Joseph S. McDermott, Consultant

INTRODUCTION

The United States has invested a great deal of effort in developing polymer composite structures. Now, the government seeks expanded applications. Experts perceive that the barrier to expanded applications is the high cost of manufacturing. This is not only an American issue, but an international one. Consequently, the government asked this panel to evaluate the status and outlook for manufacturing, or fabrication, technology in the U.S. and Japan, with an eye toward finding or developing mechanisms of cooperation.

The title for this study is "Advanced Manufacturing Technology for Polymer Composite Structures." The title reflects the panel's emphasis on polymer composites, and the focus on manufacturing technology as the key to wider use of composites by lowering the cost of using them.

For the purpose of this study, we define a composite as a combination of two or more materials that enhances their properties. Composites are being used because of their superior capabilities in the following categories:

Stiffness/weight
Ability to tailor structural performance
Ability to tailor thermal expansion
Strength/weight

Corrosion resistance
Fatigue resistance

Familiar applications include boats, surf boards, fishing rods, racquets, skis, and tool handles. Many advanced applications of composites have been made in the aircraft industry:

Commercial aircraft flaps, slats, elevators, tails
Helicopter blades and bodies
F-16 tail surfaces
F-18 wings and tails
AV-8B Harrier fuselage, wings, tails
F-117
B-2

The manufacturing methods of major interest for this study are shown in Table 21.

TABLE 21
Manufacturing Methods of Major Interest

Lamination	Hand or machine layup of dry of pre-impregnated layers; Vacuum bag, press, or autoclave molding
Pultrusion	Continuous pulling of fiber preform through resin bath and heated die
Filament Winding	Dry or wet winding around mandrels
Compression Molding	Press molding of structural molding compound (SMC)
Thermoforming	Stamping of pre-impregnated fibers and resin
Liquid Molding (RTM, SRIM, etc.)	Injection of resin into mold containing fiber preform

APPROACH

The panel's approach was to develop a draft report summarizing the status and outlook for advanced manufacturing technology of polymer composite structures in the U.S. This report was given to the hosts in the approximately 20 Japanese organizations that the ten-person JTEC team visited over a ten-day period in December 1992.

Sponsors for this study were:

NSF: Paul Herer
Army Research Office: Dr. Andrew Crowson
Air Force Office of Scientific Research: Dr. Charles Lee
Department of Energy: Dr. Paul Maupin, Dr. George Jordy

The study was carried out under the auspices of the Japanese Technology Evaluation Center (JTEC) at Loyola College, funded by the above agencies through NSF's grant to JTEC. JTEC studies are carried out by the International Technology Research Institute (ITRI) at Loyola College; ITRI is directed by Dr. R.D. Shelton. Within ITRI, the JTEC Principal Investigator and Director is Dr. Michael J. DeHamer and the JTEC/WTEC Staff Director and Series Editor is Geoff Holdridge.

As detailed in Appendix B of the full report, the panel had unique qualifications for this study:

Dick Wilkins (Chair), University of Delaware
17 years at General Dynamics, Fort Worth in composites development (Coordinator of F-16 Tail Certification)
5 years as Director of UD Center for Composite Materials (2 years as President of American Society for Composites)
2 years as Director of Institute for Applied Composites Technology

Moto Ashizawa, Ashizawa and Associates Composites Engineering
15 years in composites design, analysis & development at Douglas
10 years in composites program management, certification, & manufacturing at Douglas
1 year in composites consulting in both the U.S. and Japan

Jon DeVault, Advanced Research Projects Agency (ARPA)
25 years experience in advanced materials industry with Hercules
Former President of Hercules Advanced Materials & Structures Company
Now starting a new position organizing composites initiatives at ARPA

Dee R. Gill, McDonnell Douglas
25 years in manufacturing methods development at Hercules
4 years as Director of Production Operations and Director of Manufacturing in the New Aircraft Division of McDonnell Douglas

Vistasp Karbhari, Center for Composite Materials
Associate Scientist, Center for Composite Materials, U. of Delaware
Research Assistant Professor in Civil Engineering, U. of Delaware

Joe McDermott, Composites Services Corp

11 years as Director, Composites Institute of SPI

12 years in composites consulting in both the U.S. and Japan

During the visit to Japan, the panel was assisted by a number of highly qualified sponsor representatives:

Dr. Iqbal Ahmad, ARO

Excellent background in materials science

Army Representative in Japan

Dr. Alan Engel, ISTA

Several years in polymer & composites research at DuPont

JTEC Advance Arrangements Contractor

Dana Granville, ARL

Army Materials Directorate Coordinator for Composites

Dr. Bruce Kramer, NSF

Program Director for Manufacturing & Materials Processing

Xavier Spiegel, JTEC

Teaches materials at Loyola College

The mission of the study was to summarize the current status and future outlook of polymer composite structures in Japan and in the United States. It was motivated by the desire of the U.S. to move from invention to commercialization, which dictates advancements for low cost, repeatable manufacturing. The hope was expressed to the Japanese hosts that the U.S. and Japan could cooperate so as to expand the market for composites.

Available literature was used to summarize the U.S. status in a document for the Japanese hosts to see the scope being sought. Available literature and key Japan site visits were also used to summarize the Japanese status. Summary findings were presented at a Workshop in Washington, D.C. on February 18, 1993. This report was then developed.

OVERALL FINDINGS

It is overwhelmingly clear that individual organizations in both Japan and the United States practice the same basic manufacturing technologies. But Japanese companies practice them with a much greater respect for detail. This respect for detail leads directly to the high quality evident in their operations and parts.

The Japanese hosts expressed great confidence in the training and skills of their work force. At the same time, factory workers help develop the fabrication methods to achieve the best chance of success.

Many of the processes observed were relentlessly developed to remove chances for errors and reduce cost. This persistence was striking.

The panel observed impressive efforts to reduce composite detail part count. One derivative is the high level of excellence achieved in co-curing. Another is the observed emphasis on dry-fiber preforming.

There were a number of interesting areas showing strong potential for success. These included:

Co-cured Omega stringer panels
3-D and 2.5-D weaving
Curved pultrusion
Super composite bolt
Continuous forming of thin-walled pipes

DETAILED FINDINGS

The JTEC panel's qualitative comparisons between the United States and Japan in advanced manufacturing technology for polymer composite structures are shown in Table 22. The full report addresses each of the topics listed in the table in some detail. Conclusions in each of these topics are also summarized below.

Aerospace

The aerospace sector is focused on commercial applications of aerospace technology. Japanese technology was introduced through alliances with U.S. and European companies, from whom the Japanese companies have transferred both good and bad habits.

Automotive and Industrial

While the U.S. seems to still have opportunities in automotive applications, Japan appears to be stymied by recycling concerns.

Japan is quite aggressive in this industrial field. Many cost-driven applications are being tried.

TABLE 22
Japan Compared to U.S. in Advanced Manufacturing Technology for Polymer Composite Structures
(See Key, p. 44)

	R & D		PRODUCTION	
	Status	**Trend**	**Status**	**Trend**
AEROSPACE	–	=	–	–>
Advanced Materials				
Carbon Fiber (Pan)	0	=	0	=
Carbon Fiber (Pitch)	+	–>	+	–>
Thermoset Resin	0	=	0	–>
Thermoplastic Resin	–	–>		
Processes				
Hand Layup	0	=	0	–>
Auto. Tape Layup	0	=	0	–>
Ply Cutting & Stacking	–	–>	–	–>
Filament Winding	–	=	–	=
Tow Placement	–	<–	–	<–
Pultrusion	0	–>	0	–>
RTM	0	–>	0	=
Thermoforming	–	<–		
Co-Curing	+	–>	+	–>
Tooling	+	–>	+	–>
SPORTING GOODS	0	=	0	=
AUTOMOTIVE	–	<–	–	<–
INDUSTRIAL	–	<–	–	<–
CIVIL ENGINEERING	+	–>	+	–>

Civil Engineering

In contrast to the U.S., where the construction industry is fragmented, the Japanese opportunities in civil engineering applications are many and varied.

Materials

There is still a large effort to introduce pitch carbon fiber into applications. The economics are still mysterious, however.

Emphasis on thermoplastics was evident, in spite of the reduction in emphasis in the U.S. Similarly, high temperature resins are getting much attention.

Manufacturing Processing

In contrast to the U.S. approach of developing computational models to understand processes better, Japanese manufacturing science appears to reside in experienced workers who develop understanding of the processes over long periods of time.

Product and Process Development

Japanese product and process development use concurrent engineering by definition. Japanese teams have developed the human factors issues far beyond those in the West.

POLICY CONSIDERATIONS

Advantages in Japan

- The Japanese appear to be able to accomplish more with less.
- They drive to low cost from a life cycle viewpoint.
- Manufacturing people have high status.
- While the U.S. is better at university-industry links and university education, Japan is better at *keiretsu*, consortia, and industry-government links. A good example is the 3-D Composites Research Corporation that was formed by a number of Japanese organizations for a fixed number of years to advance the technology of preforming.
- The Japanese will derive a cost advantage from government projects in standards and data bases.
- The Japanese appear to be better at a number of aspects of composites manufacturing. They focus more on long-range strategy, and invest more up front to ensure success. These up front investments are frequently justified by careful cost trade-offs. The other critical investment is in the training of the entire work force to achieve a unified approach throughout the company.

The high-quality people assigned to production management maintain a high priority on manufacturing. They enforce high standards and goals in development and execution of fabrication processes. The above-mentioned attention to detail is a direct result.

IMPRESSIONS

Japan and the U.S. have much to gain from each other. Each country has different strengths to bring to composites manufacturing. Many of our hosts expressed the belief that they must develop ways to cooperate with the U.S. In perspective, producers in both countries can reduce costs by obtaining a deeper understanding of basic processes. Companies in both countries must also develop a unified basis for understanding what it takes to make repeatable composite structures so that new markets may be opened with more confidence and reliability. It is also clear that the process advancements made by the Japanese can be transferred to the U.S. only by also transferring the spirit of cooperation that exists within Japanese companies.

ADVANCED COMPOSITES IN JAPAN

March 1991

R. Judd Diefendorf, Clemson University (Panel Chair)

William Hillig, General Electric Research and Development

Salvatore J. Grisaffe, NASA Lewis Research Center

R. Byron Pipes, University of Delaware

John H. Perepezko, University of Wisconsin

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SUMMARY

The JTEC Panel on Advanced Composites surveyed the status and future directions of Japanese high-performance ceramic and carbon fibers and their composites in metal, intermetallic, ceramic, and carbon matrices.

Japan's ambitious space program includes development of a hypersonic civilian aircraft, to be completed by 2005. A major factor in the program is new materials, one of three areas selected by MITI for national development investment. The Japanese believe that technological superiority in space structures and launch systems could help them become dominant in the aerospace market.

Japanese industry and government are willing to forgo short-term gains to build for the future. The new MITI materials thrust initiated in 1989 (*High Performance Materials for Severe Environments*) was scheduled to continue for almost ten years, longer than would be possible in the U.S. The Japanese support parallel approaches to materials research and technology that often involve overlapping activities among several groups, sharing information at the precompetitive stage. By contrast, the U.S. seems to select one best approach initially, frequently finding later that other options are needed.

By attempting to find an immediate application for less-than-optimum materials, the Japanese gain the manufacturing experience to produce a lower-cost, more reliable product. For this reason, they tend to place less emphasis on basic science and more on manufacturing and large-scale pilot plants. Compared with the U.S., there seems to be more learning by doing and fewer analytical studies.

Some previous MITI materials programs have led to new consumer markets and substantial returns on government investment. The Japanese formed technical teams within and across industries that remained intact for the long periods required to develop and exploit markets. The 1989 MITI initiative was different: although materials would be an enabling technology for a hypersonic transport vehicle, they might only be produced in small quantities. MITI also set very ambitious performance for its new program in 1989. The panel felt that these goals would be revised downward to achievable levels.

Because of a strong carbon and fiber industry, Japan is the leader in carbon fiber technology. Japan has initiated an oxidation-resistant carbon/carbon composite program. With its outstanding technical base in carbon technology, Japan should be able to match present technology in the U.S. and introduce lower-cost manufacturing methods. However, the panel did not see any innovative approaches to oxidation protection.

Ceramic and especially intermetallic matrix composites were not yet receiving much attention at the time of the panel's visit. There was a high level of monolithic ceramic R&D activity. High-temperature monolithic intermetallic research was just starting, but notable products in titanium aluminides had already appeared. Matrixless ceramic composites was one novel approach noted. Technologies for high-temperature composites fabrication existed, but large numbers of panels or parts had not been produced.

The Japanese have selected aerospace as an important future industry. Because materials are an enabling technology for a strong aerospace industry, Japan initiated an ambitious long-term program to develop high-temperature composites. Although the program was just starting, its progress should be closely monitored in the U.S.

Reinforcements

High-temperature/high-performance composites for aerospace applications depend on the availability of strong, lightweight fibers. Japan's commitment to several advanced aerospace efforts -- for example, Mach 4-6 hypersonic technology -- make its fiber accomplishments of particular interest. Japan has done well in developing a number of useful fibers, primarily through the polymer precursor approach. The Japanese are learning how to produce quality fibers in reasonable quantities and fabricate lower temperature composites with the fibers. They are developing insights into advanced composite fabrication and higher temperature composite durability, which would help them exploit improved fibers as they become available.

Ceramic Matrix Composites

Japanese researchers have focused on enhancing the toughness of the best already-available monolithic structural ceramics. Japan has been a prime supplier of continuous high-performance, high-temperature fibers that have been used in the development of ceramic composites in the U.S.. The Japanese themselves have focused on the use of SiC and Si_3N_4 whiskers and particulates.

The Japanese are also devoting significant effort to processing hybrid ceramic/metal composite systems. They are developing sophisticated techniques for making functionally gradient materials (FGMs) whose properties change gradually from ceramic to metal. FGMs are designed to overcome the severe problems of thermal expansion mismatch in joining metal to ceramic parts in high-temperature engines. A separate processing effort is directed at making the high-temperature, high-performance composite materials into shapes needed for such engines. This effort involves combining self-propagating high-temperature synthesis with hot isostatic pressing to produce high-quality material in the desired complex shapes.

Metal and Intermetallic Matrix Composites

Japan entered the field of metal matrix composites about a decade later than the U.S. did. However, the Japanese have more than made up for lost time. At the time of the panel's visit, the Japanese had not developed widespread commercial applications for metal matrix composites; rather, the focus of activity was development of lower-cost production methods. The Japanese R&D programs also emphasize self-sufficiency in components. Some early successes have been achieved with intermetallic alloys that perform well in high-temperature turbines.

Carbon-Carbon Composites

The technology for fabrication of fiber-carbon matrix (C-C) composites has been funded by the U.S. government for almost twenty years. A mature domestic industry is manufacturing large, complex C-C shapes. In contrast, Japan has only recently begun to emphasize C-C components manufacturing. Although several Japanese companies possess the facilities and basic understanding to produce C-C components, the lack of applications and design experience has put Japan at a disadvantage.

C-C manufacturing innovation in Japan is driven in part by a concern with production costs and associated efforts to identify commercial nonaerospace applications for C-C composites. Japanese efforts to develop new low-cost fabrication methods have no parallel in the U.S. Clearly, even if new and significant industrial uses are not realized, the Japanese aerospace industry would very likely benefit from such improvements in C-C manufacturing methods.

HIGH-TEMPERATURE SUPERCONDUCTIVITY IN JAPAN

November 1989

Mildred S. Dresselhaus, Massachusetts Institute of Technology (Panel Chair)

Robert C. Dynes, AT&T Bell Laboratories

William J. Gallagher, IBM

Paul M. Horn, IBM

John K. Hulm, Westinghouse Corporation (retired)

M. Brian Maple, University of California, San Diego

Rod K. Quinn, Los Alamos National Laboratory

Richard W. Ralston, Los Alamos National Laboratory

SUMMARY

To study and assess the state of the art of Japanese R&D in superconductivity, the panel first prepared a preliminary assessment of the state of the art in the United States. In ten days, the panel visited three university, eleven industrial, and seven government laboratories. Panel members interacted with Japanese leaders in superconductivity R&D and with many younger, active researchers. The panel then prepared appraisals of Japan's basic superconductivity program, materials research, large-scale applications, materials processing, and electronics applications, including thin-film R&D.

The panel found that Japan has a deep, long-term commitment to superconductivity R&D in industry, academia, and national laboratories. This commitment could be seen in several factors -- such as the number of people involved in superconductivity R&D, which was about the same as in the United States, although the Japanese population was less than half that of the United States at the time of the panel's visit in 1989. Several five- to ten-year superconductivity projects were in place, sponsored by MITI, the Science and Technology Agency (STA), the Ministry of Education (Monbusho), and Japanese Railway.

Because of its perceived scientific and technological importance, superconductivity had been selected as a flagship to show the world that the Japanese could be successful in fundamental scientific research. Although the Japanese had been

extremely successful in advanced technology and commercialization, they were criticized for their lesser contributions to basic research. To answer this challenge, the Japanese were taking bold steps to enhance their basic research effort in superconductivity. This included increasing support to leading academic groups, establishing MITI's International Superconductivity Technology Center (ISTEC), strengthening their infrastructure for basic research, and promoting personnel exchanges with foreign countries. The panel judged Japan and the U.S. to be comparable in basic experimental studies and materials research, but the Japanese were improving rapidly and competing strongly.

The Japanese identified superior materials as the key to success in high temperature (high-T_c) superconductivity research and technology. They were translating this philosophy into a sustained, systematic approach to materials synthesis and processing, including new materials research. Most of the outstanding achievements of the Japanese in the field of superconductivity stemmed from this systematic approach, which was reinforced by a top-down management structure and an appreciation of the people who did materials synthesis, processing, and scale-up. The Japanese were leading the United States in their ability to mount sustained, systematic materials R&D programs, and they had a better trained work force to implement such programs. However, although Japan's top-down management system may be excellent for reinforcing sustained, systematic research, it could be less conducive to creativity.

In basic science, interaction between groups in different Japanese organizations in industry, university, and government laboratories was not as strong as in the United States, although teamwork within an organization tended to be stronger. With government leadership, the Japanese were taking steps to break down the interorganizational barriers by funding large interuniversity programs, establishing R&D consortia such as ISTEC, and encouraging strong project-related interorganizational collaborations (which, however, tended to be in applied areas). Examples of interorganizational efforts in applied areas were the Josephson Scientific Computing System project and the Multi-Core Project in Superconductivity. The latter was aimed at developing high-T_c superconductors to the point of commercialization. The government had successfully encouraged technology transfer from government laboratories to industry in the areas of large-scale superconducting magnet projects and low-T_c Josephson junction electronics.

Japanese universities' facilities and infrastructure for superconductivity research had steadily improved, so that the best Japanese universities were equipped nearly as well as their U.S. counterparts. The equipment and facilities for superconductivity R&D in Japanese industry and national laboratories were equal or superior to those in the United States and were steadily improving. Research opportunities in Japan had begun to attract foreign talent, despite the large social and language barriers.

The Japanese had developed a strong industrial base for the large-scale application of low-T_c superconductivity. While U.S. consortia were being organized to enhance technology transfer, the Japanese already had a ten-year history of successful technology transfer in large-scale superconductivity applications. R&D personnel at the national laboratories had worked collaboratively through the R&D cycle with electrical industries and with wire and cable companies. These collaborations had produced an array of large magnet systems for magnetic fusion, high-energy physics, magnetic levitation, power generation, and magnetic resonance imaging applications. Japanese capabilities in superconducting wire for the next generation of magnets (above 15 tesla) significantly exceeded U.S. capabilities, and the gap was widening.

Low-T_c Josephson digital capabilities at four Japanese laboratories far exceeded those at any laboratory in the United States. One overwhelming achievement of the MITI superconducting electronics project was low-T_c digital chip technology, which provided a model of technology development and transfer through a national laboratory-industry collaboration. By 1989, Japan dominated digital Josephson technology, and Japanese companies were well positioned for possible future commercialization.

However, because the United States had greater analog superconducting device expertise, U.S. efforts in these devices were well advanced over those in Japan. Because early high-T_c electronics applications would very likely be in analog devices, the United States was considered to be well positioned to lead in these areas. U.S. leadership would be threatened, however, if superior low-T_c technology remained the norm in Japan, and if the analog device expertise in Japan grew in conjunction with expanded superconducting thin-film and electronics developments. The Japanese were maintaining strong low-T_c electronics programs as a critical component of their superconducting technology development effort.

Japan and the United States were both strong in superconductivity R&D. Thus they would have many opportunities to work together and learn from each other. Because the Japanese placed greater emphasis on sustained, systematic materials research, they were offering the United States strong competition in research and were developing the potential to pull ahead in commercial applications.

III. Manufacturing and Construction

SEPARATION TECHNOLOGY IN JAPAN

March 1993

C. Judson King, UC Berkeley (Panel Chair)

Edward L. Cussler, University of Minnesota

William Eykamp, Consultant

George E. Keller II, Union Carbide Corporation

H.S. Muralidhara, Cargill Research

Milton E. Wadsworth, University of Utah

BACKGROUND

The objective of this study was to survey technological activity in separations in Japan, and to compare this activity with that in the United States. For this purpose, the six-person panel and accompanying support personnel spent a week in Japan, visiting one or more sites at seven corporations, five government laboratories, and six universities.

The panel's full report describing our findings is organized as follows:

1. this Executive Summary;

2. an introduction and analysis of major issues (Chapter 1);

3. individual chapters delving into particular areas of separations -- separation and purification of gases, water purification, separations of several other sorts involving liquids, hydrometallurgical separations, ion-exchange membrane technology, dewatering and crystallization (Chapters 2-7); and

4. descriptions of the panel's various site visits (Appendices B-F).

A succinct presentation of the JTEC panel's conclusions regarding the relative status and trends of Japanese and U.S. technology and support structure is given in

Table 23. Japan is strong and highly competitive in several areas of separations. For the most part, this position has not been achieved by invention or creative new departures. Instead, it comes from careful selection of the most effective technology available on the world market, followed by diligent implementation, evolutionary advances, strong emphasis on management and control of quality, and effective use of corporate experience. This thrust has been greatly aided by the fact that Japan until recently, in contrast with the United States, has had a steadily expanding economy and growing production, which have provided the opportunity for installation of new capacity with the latest technology.

RELATIVE STATUS AND VECTORS

Table 23 is the JTEC panel's effort to categorize the relative strengths of separations technology in Japan and the United States. The table is divided into various methods of separation, and also by categories of research, development and implementation for each method. Following the entries for various methods of separation, the panel addresses certain cross-cutting aspects of research, development and implementation (Table 24).

DISTINCTIVE CHARACTERISTICS OF JAPANESE SITUATION

The panel observed a number of distinctive characteristics of the Japanese situation (Chapter 1 of the full report). Since it has essentially no indigenous energy resources, Japan seeks avenues toward energy independence. Energy costs are high, and there is a strong drive for energy conservation. Energy costs and restricted land area both promote reuse and recycling. In many other areas Japan seeks self-sufficiency; production of salt (NaCl) is an example. Cultural viewpoints and the peculiar nature of the Japanese labor market sometimes bring about specialized approaches. Thrusts in separations technology often support areas of Japanese industrial strength, notably in the electronics industry. Conversely, approaches to meeting separations needs often utilize Japanese strengths, such as instrumentation and photovoltaic technology.

The drive for energy conservation has been particularly apparent in the Japanese paper industry, as is presented and analyzed in more detail in Chapter 7 of the full report. Environmental concerns are ascendant in Japan, and much is happening in the area of pollution abatement. However, the issue appears to be addressed much less through formal legal regulation, and more through government coordination and influence upon industry, than is the case in the United States.

TABLE 23
Japan Compared to U.S. by Types of Separation
(See Key, p. 44)

TOPIC	RESEARCH		DEVELOPMENT		IMPLEMENTATION	
	status	trend	status	trend	status	trend
Gas Separations	–	<–	–	<–	–	<–
Hydrometallurgical Separations	0	=	+	–>	+	–>
Adsorption	–	<–	–	=	–	<–
Ultrapure Water	+	–>	+	–>	0	–>
Reverse Osmosis & Ultrafiltration	–	–>	0	=	0	=
Ion Exchange Membrane Processes	0	=	0	–>	–	=
Membrane Separations of Organics	–	=	0	=	–	<–
Extraction						
Solvent	–	=	0	<–	0	<–
Ion Exchanging	0	=	0	<–	0	<–
Supercritical Fluid	–	=	0	–>	0	=
Crystallization	–	=	0	–>	0	=

Universities

Japanese universities utilize the "*koza*" system, where for a particular area a professor is assisted by junior faculty members. This structure enables organized and efficient usage of resources, but would seemingly suppress the development of junior faculty as independent investigators. Research in Japanese universities focuses on derivative advances and supporting information, more than upon creativity and progress toward new scientific understanding. Research facilities in Japanese universities tend to be in very poor condition and crowded. There are major problems of safety and housekeeping, in comparison with the norm in U.S. universities. Research instrumentation is abundant and strong.

TABLE 24
General Aspects
(See Key, p. 44)

	status	trend
Creative Approaches	–	<–
Development of Existing Approaches	+	=
Quality Control	+	–>
Support of Academic Research	–	=
Support of Industrial R&D[1]		–>
Instrumentation Support	+	=
Relevance of University Research	–	<–
University/Industry Synergy	–	<–
University/Government Synergy	–	=
Government/Industry Synergy	+	=

Corporations

Corporate activity seems to be relatively more diversified in Japan than in the United States. An example is Kobe Steel, Ltd., which has followed a thread of high-pressure technology that has led the company into a number of very different areas of application.

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[1] Note: The panel did not gather sufficient information to rate the current status of support for industrial R&D in Japan compared to that in the United States.

NATIONAL THRUSTS

Membrane Separations

Japan has national technological thrusts, involving government, industry, government laboratories, and universities. The thrusts most closely connected with separations have been the Aqua Renaissance Project, which deals with water purification, and Project Sunshine and Project Moonlight, which deal with energy independence and related issues. Membrane technologies have been emphasized in these thrusts.

Many of the membrane-based separations activities in Japan have come about through these national initiatives. Membrane separation is an area of Japanese strength, where Japan has about 25 percent of the world market. Membranes are far more prominent among the mix of separation technologies in Japan than in the rest of the world. Here again the Japanese position is not attained through entirely new approaches, but through perceptive selection of available technology, evolutionary improvements, and emphasis upon quality.

The emphasis upon membrane separation technologies in Japan seems to result in large measure from definition of priorities at the government level. The panel can only surmise about the reasons for choosing this emphasis. Synthetic membranes are an area where Japan is already successful and derives considerable economic benefit. Membrane separation may also be regarded as an area where the most opportunities are available for advances. In that sense, the Japanese may regard membrane separations as a less mature technology than do the United States and the rest of the world. Membrane technologies do serve the needs of the strong Japanese electronics industry. For example, membranes are useful in ultrapurification of water (Chapter 3 of the full report); however, this is an area where U.S. companies (e.g., Millipore) have most of the market. Membrane separations may be regarded in Japan as an effective path for energy conservation and/or technological independence. Developments in membrane technology can lead to advances in technology for batteries, analytical instrumentations and medical applications, notably diagnostics.

Global Environment

Another interesting national thrust pertains to global environmental issues, notably global warming and depletion of the stratospheric ozone layer. Japan has proposed an international plan called "The New Earth 21 (Action Plan for the 21st Century)." The large, main research facility for the Research Institute of Innovative Technology for the Earth (RITE) will be completed in the Kansai Science City in the summer of 1993. One of the areas being given the most emphasis in this initiative is fixation and utilization technology for carbon dioxide (CO_2). As typically described, this involves use of membrane separations to remove and recover CO_2 from the flue gases of fossil-fuel power plants, with conversion of the recovered carbon dioxide to large-scale chemical products such as methanol. This endeavor raises several very fundamental issues concerning feasibility: (1) the very large volume of CO_2 that would have to be recovered to make a difference in the global environment; (2) whether a CO_2-benign source of hydrogen for conversion to chemicals can be achieved; and, (3) whether the uses of recovered CO_2 would themselves return CO_2 to the atmosphere. Therefore the true economic basis for the New Earth 21 initiative is questionable.

SPECIFIC R&D COMPARISONS

The following more detailed comparisons are drawn from the individual chapters of the full report.

Separation and Purification of Gases

Japanese development of technology in gas separations has in general trailed that in other parts of the world, but the commercialized technology in a number of cases may be roughly equivalent to that found elsewhere (Chapter 2). Membrane technology for large-scale, selective recovery of carbon dioxide is receiving attention in connection with the RITE global-warming initiative. However, there is surprisingly little research on membrane technology for other gas separations, especially when the overall Japanese emphasis on membrane separations technology is taken into account. Several small-scale, specialized applications are being developed in connection with the needs of the electronics industry.

Water Purification

Membrane technology for water purification in Japan is largely conventional, but two applications are pushing the limits of current technology -- water for the nuclear industry and water for the production of microelectronic chips (Chapter 3). Approximately 1,000 liters of ultrapurified water are used per wafer in the chip manufacturing industry. The purity required is related to the minuscule dimensions of features on the chips. Contaminants of concern include bacteria, particles, organic matter and dissolved oxygen. Highly sequential purification trains are utilized, with extensive and repeated use of membrane separations and ion exchange. Interestingly, the needs of the Japanese electronics industry are met by vendors of pre-packaged water-purification assemblies, while in the U.S. the tendency is for individual chip manufacturers to assemble their own water-purification plants. The two approaches seem to achieve roughly equivalent results. The water-purification needs for next- and future-generation chips require substantial advances beyond current technology.

Also related to water purification, but on a larger and coarser scale, the panel found that there has apparently been a decision in Japan to replace chlorine with ozone for municipal water treatment. The use of ozone is generally considered to be more expensive and less proven for general use, but it does avoid the formation of trace levels of chlorinated organics.

Separations with Liquids

Much of the research and development activity in Japan for other separations involving liquids focuses on membranes (Chapter 4). Pervaporation, a method of vaporizing a liquid mixture selectively through a membrane, is receiving attention for ethanol-water separation, as it is elsewhere in the world. There is also attention to use of this technique for separation of isopropanol and water (an electronics industry need) and for separations of trace organics from water. There is also work on absorption of nitrogen and sulfur oxides (NO_x and SO_x) from power-plant flue gases and on supercritical fluid extraction, largely for oils and other substances that serve specific Japanese food and flavor needs. Finally, there are several efforts directed toward "chiral" separations, that is, separations of mixtures of optically active isomers.

Hydrometallurgical Separations

There are numerous instances of metals refining and separations in Japan, with substantial and diverse accompanying research (Chapter 5). Emphasis is on smelting and refining, rather than recovery from the ore, since Japan imports most of its metals as concentrates. As in other areas, processes are based upon conventional technology, but a high degree of improvement has been achieved. Equipment is more modern than in the U.S. because Japanese industry has been able to add substantial capacity in recent years. Over the past four decades there has been a major decline in U.S. zinc production. Meanwhile, Japan has become the world's third largest producer of zinc.

There has been a significant amount of research on the fundamentals of leaching, solvent extraction, ion exchange, and chemical and electrochemical reduction. University research in this field is generally of high quality but mainly theoretical.

Ion-Exchange Membrane Technology

Japan has over forty years of experience in the development and manufacture of ion-exchange membranes; much of the development has evolved in the context of producing salt from seawater by means of electrodialysis (Chapter 6). Japan is a world leader in this area, with a broad spectrum of membranes for sale and internal use, with a main theme of environmental applications. Advances are being made in spacer materials and adhesives for membrane modules. Other innovations are in implementation of ion-exchange membranes in tubular geometries (ED CORE, Tokuyama Soda -- see Chapter 6), replacing the conventional flat-sheet geometry, and in bipolar, "water-splitting" membrane technology.

Dewatering (Pulp and Paper Industry)

Japan ranks second and third in world production of paper and pulp, respectively, behind the U.S. in both cases. Over the past two decades Japan has achieved very large reductions in the amount of purchased energy needed for the paper industry -- about a factor of two for the industry as a whole (Chapter 7). For the most part, these savings have not resulted from innovative technology, although the addition of new capacity utilizing newer and more efficient technology has been one factor. Other factors include extensive use of recycle, obtaining a higher concentration of black liquid (separations) within the plants, use of high-pressure and therefore high-temperature boilers, and conversion to continuous digesters.

Crystallization

The most striking technological innovation that the panel found was Kobe Steel's pressure-driven crystallizer, used for separations of organics (Chapter 7). This advance follows from Kobe's practice over the years of using its high-pressure expertise to branch into different areas of application. Increasing pressure, an instantly transmitted thermodynamic parameter, to a great enough extent can bring about solidification in a controlled way, and subsequent reduction and/or cycling of pressure brings about controlled melting that can cause formation of more perfect, and therefore purer and easily separable crystals.

MATERIAL HANDLING TECHNOLOGIES IN JAPAN

December 1992

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Richard E. Ward, Material Handling Industry (Panel Cochair)

James M. Apple, Jr., Coopers & Lybrand

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SUMMARY

Material handling plays a vital role in all sectors of business and commerce, but nowhere is it as important to an efficient operation as it is in manufacturing, warehousing and distribution. Those who study this field and understand how material handling methods, equipment and systems can be used to increase productivity look on the material handling process and the technologies available as strategic competitive factors. Cost reduction (capital and operating), increased throughput, improved response times, work place safety, and total quality are measures of performance that have strategic implications for a business. These factors are all directly affected by how well an organization performs its material handling functions.

These factors alone are enough to cause business leaders to want to study this field and to research best practices and available technology worldwide. The strategic advantages that many say Japan has in a wide variety of industries (e.g., automobiles and consumer electronics) present a particular impetus for studying developments in and applications of material handling in Japan. Japan's competitive position in high technology manufacturing helped motivate the National Science Foundation and the Department of Defense to commission an expert panel to conduct a study of material handling in Japan that would include visits to Japanese suppliers and users of material handling technologies.

This report synthesizes the findings from approximately sixty site visits, attendance at major Japanese trade exhibitions, a review of current literature, and discussions

with numerous Japanese experts in the field. Although much of the research was conducted during the first five months of 1992, visits dating back to 1990 provided additional valuable information. A summary of the conclusions drawn from this study follows:

1. *Prior to 1960 Japan trailed the United States in industrial productivity and in the application of modern production methods, especially in the use of state-of-the-art material handling technology. All that has changed.*

In the late 1950s the Japanese Productivity Center sent a team to the U.S. to study what was being done in material handling and to recommend measures for implementation in Japan. The result was the licensing of U.S. material handling technology for production and use in Japan. Today, we see spin-offs and derivations of that early technology, which has improved vastly in several areas. Japan is not only using its own material handling technology and equipment domestically, but Japanese suppliers are selling them on a worldwide basis, including in the United States. Japan is now a leader in several equipment/technology categories.

2. *Productivity improvement--and the strategic advantages that accompany such improvement--have provided the rationale for Japan's quest for the best production methods and technologies over the last thirty years. However, that rationale today is being amplified manyfold by changing demographic, social, and business conditions in Japan. The result has been an acceleration in the application of automated material handling systems that dwarfs what we see occurring in the United States.*

The evidence is fairly clear that factors such as declining population, aging work force, changes in work preferences, and the ever-present congestion and lack of space are fueling the use of automation. The corollary in this case is that demand (application and use of automated material handling technologies) fuels supply, which translates into a rationale for ongoing research and product development. In many cases, economies of scale in the production of material handling equipment can also be associated with high demand levels.

3. *Automated material handling equipment and systems in Japan are not deployed exclusively in large, complex integrated systems. The result is many examples of simple, stand-alone installations.*

This factor partially explains the extremely high Japanese material handling equipment installation statistics in comparison to those in the United States. In the United States such installations are often called "islands of automation," and are generally viewed as less than desirable. In Japan, however, stand-alone installations mean greater control and cost savings. Two business factors have contributed to greater use of simple, stand-alone installations in Japan. One is the general Japanese attitude that simple is best. The other is the availability of Japanese users willing to make use of such systems without demanding often costly modifications and "bells and whistles." A benefit of this phenomenon is that it has allowed Japanese suppliers to concentrate on research and development that focuses more on issues such as product reliability and maintainability.

4. *The Japanese government has taken an active policy role in stimulating the application of automated material handling systems.*

The 1958 study team is perhaps the earliest, albeit an indirect, example of Japan's active government policy. A more direct example has been the Japanese government's policy of making funds available at attractive lending rates for capital projects that address demographic changes in the Japanese work force. The strategic significance of investments, coupled with a long-term view of their benefits (versus short-term payback), has long been recognized as something that differentiates Japanese attitudes about capital investments in business infrastructure from attitudes in the United States. The added motivation of having access to capital at attractive rates for the specific purposes stated above only compounds the advantages enjoyed by Japanese manufacturers.

5. *Research and development in the field of material handling, though very active, is apparently performed exclusively within the confines of private industry.*

This is no different from what takes place in the United States or elsewhere. In the United States, however, there is evidence of greater academic interest in the field of material handling. This has led to the direct incorporation of material handling into U.S. college curricula, and to more independent research associated with the operational design and control of material handling systems. This is not to be confused with electro-mechanical design or testing. There is little to no work of this type underway at U.S. or Japanese universities. Nevertheless, there is greater evidence of industry sponsorship of college and university material handling education and research in the U.S. than in Japan. There is somewhat of a dichotomy here because the rate of investment in material handling automation in Japan far exceeds that in the United States, regardless of what is done in or by universities.

6. *Industrial productivity in Japan still lags behind the productivity of U.S. industry, but the two have been converging rapidly.*

Japan's material handling practices have contributed significantly to its gains in productivity. The gains have been made possible by the enlightened attitude of Japanese business managers, the types of products and systems that Japan's material handling industry delivers to the market place, and the way that Japanese suppliers and users work together to accomplish an objective.

7. *An assessment of whether Japan is ahead or behind in its material handling technology depends on the technology being examined.*

A broad spectrum of equipment categories is analyzed in Table 25.

TABLE 28
Japan Compared to U.S. in Material Handling Technologies
(See Key, p. 44)

	DEVELOPMENT		APPLICATION	
	Status	Trend	Status	Trend
AS/RS - unit load	0	->	+	->
- mini load	+	->	+	->
AGV - unit	0	=	+	->
- small	0	=	+	->
AEM - unit	0	->	+	->
- small	+	->	+	->
CONVEYOR - transport	0	->	0	=
- sortation	–	<–	–	=
SORTING TRANSFER VEHICLE	+	->	+	->
DEPALLETIZING (for case pick)			0	=
CAROUSEL	–	<–	–	<–
ROTARY RACK	+	->	0	=
INTELLIGENT PICK CART	+	->	+	->
LIGHT-AIDED PICKING	+	->	+	->
CLEAN ROOM SYSTEMS	+	->	–	=
CONTROLS				
radio frequency - machine cntrl.			–	=
- operator cntrl.			+	->
dock management	+	->	+	->
warehouse management systems			–	=
auto ID			–	<–
EDI			–	<–
IMPLEMENT. TIME & SMOOTH STARTUP	+	=	+	=

CONSTRUCTION TECHNOLOGIES IN JAPAN

June 1991

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SUMMARY

To evaluate the innovation and effectiveness of R&D in Japanese construction technologies, the JTEC panelists focused on processes, materials, and systems. They examined R&D; materials; field operations; and automated equipment, building systems, and structural systems. They also examined management systems, safety, environmental technologies, and public/private interactions.

The Japanese Ministry of Construction (MOC) assists industry; its efforts are complemented by MITI, the Building Research Institute (BRI) and the Public Works Research Institute (PWRI). MITI's construction focus is on housing-related matters. The role of the MOC is to establish criteria for qualifying contractors to bid public works projects, promote R&D through the BRI and PWRI, and maintain the national building code. The U.S. has no such common code; many codes exist throughout the nation.

In Japan, a private contract is usually negotiated and a government contract awarded to the low bidder from a technologically prequalified group. Design-build contracting is common in private work, but design-then-build dominates public-sector projects. Japanese construction companies are led by engineers and architects who are familiar with the specific technology used on their projects. Like their U.S. counterparts, they are concerned about productivity and safety. To attack these problems, the large Japanese contractors conduct substantial R&D.

Research and Development

Of Japan's annual construction volume, 0.51 percent is spent on construction R&D, compared with under 0.1 percent in the U.S. for comparable sectors. As a matter of national policy, the Japanese see continued and increased R&D investments as important to upgrading housing, renewing and expanding the public infrastructure, and keeping their industrial capital base efficient and up to date. Industry, government, and universities generally work independently, yet there is cooperation in setting goals and working on certain priority areas.

Japanese construction companies have well-established in-house R&D programs, generously funded mainly from their own internal sources; the programs have well-equipped laboratories on a level almost totally absent in U.S. construction companies. Partly through application of their research findings, Japanese construction companies have moved ahead of their U.S. counterparts in many areas, including soft-ground tunneling, design and construction of intelligent buildings, deep foundation construction, construction robotics, and long-span bridge construction. They are likely to expand their lead rapidly in the future.

Government laboratories in both countries have good and approximately equal capabilities for construction R&D. The U.S. appears to have an advantage only in universities. In construction, Japanese universities seem isolated from industry and government R&D; they have few if any counterparts to NSF-funded engineering research centers and industry-supported centers at leading universities in the U.S.

Materials

Japan's government, manufacturing industry, and engineering-construction industry laboratories have given extensive, sustained, collaborative attention to the improvement of construction materials. R&D elsewhere in the world is monitored carefully and useful results licensed in Japan. Government research activities are more extensive than those in U.S. government laboratories. The Japanese manufacturing industry has increased R&D, but U.S. building materials manufacturers have been abandoning product development research to cut expenditures. Japanese engineering-construction firms have large-scale construction materials research efforts that are generally unmatched by U.S. counterpart companies. University professors and researchers collaborate in these efforts, but on a smaller scale than their U.S. counterparts.

Thus Japan matches or leads the U.S. in implementation of state-of-the-art construction materials technology and has growing leadership in research. Strong research and implementation activities have given the Japanese steel industry clear leadership in weldable and fire-resistant, high-strength structural steels. A major cooperative government, industry, and university program for high-performance concrete research is likely to give Japan leadership in this internationally significant area of construction technology.

Automated Equipment

Japanese companies have also invested heavily in developing automated equipment, although they have produced very few practical pieces. Much of their motivation to automate seems to stem from their desire to improve the image of the construction industry among workers, make construction safer, and help sell both existing customers and new prospects. Despite their push to automate construction equipment Japanese companies do not use computers for schedule or cost control as widely as U.S. companies do, relying instead on manual methods. However, Japanese companies are actively exploring ways to transfer information from computer-assisted design models to field equipment, and then manipulate that data from the surrounding environment using artificial intelligence.

Infrastructure

Improving Japan's infrastructure has depended on efficient development and use of space. The Japanese have sought new space by building up, building out, and building down. They attack the construction of office and apartment buildings from a new perspective: the building is a system and needs systems solutions. The concept of the intelligent building is key to this strategy. One of the MOC's key objectives for the 1990s is to achieve "good-quality housing and infrastructure that suit the needs of the nation." The boom in office building and home construction markets offers an excellent opportunity to apply high-technology concepts to building construction to improve the working and living environment.

The quality of buildings and support systems in Japan equal that of new buildings constructed in the U.S. Most of the systems are adaptations of existing technology, which may lead to a fusion of technology. Emphasis on automation, robotics, and new structural and construction systems to support super-high-rise buildings could lead to new breakthrough technologies in building systems by 2000. A wide range of structural systems are being systematically developed that focus on factory automation and use of robots and intelligent tools. Extensive use is being made of CAD/CAM systems for design, manufacture, and construction of structural systems. Although the U.S. is ahead in R&D efforts in these areas, implementation is at least equal, or even ahead, in Japan.

Structural Systems

Development and availability of thermomechanical process control (TMPC) steels in Japan place the Japanese well ahead of the U.S. in applying these special steels to structural systems. The Japanese experience indicates that these materials make steel structural systems more competitive for building and bridge applications.

Concrete structural systems in Japan seem on a par with those in the U.S. for precast structural elements. In high-strength concrete for structures and high-rise construction, Japan appears to be lagging behind the U.S. The panel found that R&D efforts and trial implementation of active control damping systems for earthquake and wind resistance far exceed U.S. efforts. Passive control damping systems, such as base-isolated structures and special dampers, are being actively studied, and trial implementations are under way.

Conclusions

The Japanese have one of the most advanced construction industries in the world. Japan has long acknowledged the U.S. contribution to its technological and managerial practices. The Japanese have blended these practices into their culture, resulting in a robust construction industry that contributes significantly to the welfare of Japanese society. The U.S. construction industry could use some of the lessons learned by Japanese companies.

IV. Aeronautics, Space, and Ocean Technology

RESEARCH SUBMERSIBLES AND UNDERSEA TECHNOLOGIES IN FINLAND, FRANCE, RUSSIA, UKRAINE, AND THE UNITED KINGDOM

March 1994

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BACKGROUND

The World Technology Evaluation Center (WTEC) panel on Research Submersibles and Undersea Technologies was formed to review the state of the art in this broad field within the former Soviet Union (FSU) and in selected Western European countries. The panel visited leading companies, academic research programs, and government laboratories in Finland, France, Russia and the Ukraine, and the United Kingdom. Because of the large geographic area and the breadth and technical complexity of the subject, the study could not be comprehensive. However, by carefully selecting the sites to be visited -- based upon the substantial prior knowledge of many committee members -- it was possible to acquire a meaningful evaluation. The end of the Cold War and the resulting efforts to commercialize some of the military technology, plus the increased utilization of sophisticated equipment in the exploration for and production of oil and gas in the North Sea, had led the sponsors of this study to the belief that a review of subsea technology in this geographical area would be productive. This was verified by the panel's findings.

Because much less was known a priori about the technologies in Russia and the Ukraine, there were more new findings in those countries than in those Western

European nations visited. Some general conclusions will be drawn based upon the panel's overall experiences, and these will be followed by more specific conclusions in each of the study's subject areas.

There is a pronounced emphasis in the United Kingdom on the development of advanced sensors and affordable autonomous and remotely operated vehicles. These vehicles are being developed for use in both the research community and the offshore industry.

Research and development is being conducted in the United Kingdom and in France on developing very great endurance (hundreds of kilometers to full ocean width) for autonomous vehicles.

The European community is making substantial progress in cooperative and coordinated research in subsea technology, including the development of standards. No such cooperative research and development is underway in the United States, which may have a significant impact on future competitiveness.

The economic stimulus for subsea technology development in Western Europe appears to be largely to support fisheries management and offshore oil and gas production.

All of the countries visited and all of the agencies interviewed see shrinking horizons for research and development and for economic opportunities in this field.

Russia and the Ukraine have developed a highly educated and experienced manpower pool, skilled in almost all phases of subsea technology, that is substantially underutilized at this time. Russia and the Ukraine possess impressive, and in some cases unique, facilities for physical testing. These assets are also under-utilized and offer opportunities at very low cost for Western nations.

Researchers in Russia and the Ukraine have extremely limited computing facilities compared to Western engineers in this field. As a result, Russian and Ukrainian researchers take a strong theoretical or analytical approach to most problems, which appears to be very valuable. It has also resulted in an ability to write extremely efficient computer code to facilitate numerical analyses and signal processing on limited computer platforms. Given the ready availability of large platforms in the West and the greater difficulties in maintaining tightly-coded programs, it is not clear that this capability represents a technological asset to the rest of the world.

Russia and the Ukraine possess extensive fleets of seagoing research vessels capable of long voyages and possessing state-of-the-art facilities for conducting oceanographic investigations. With the exception of those vessels under contract to Western nations, these vessels are largely inactive at this time.

Russia and the Ukraine have adopted a philosophy of including human presence in nearly all subsea geophysical and oceanographic investigations. They have produced an impressive variety of manned research submersibles, again largely unused at this time. The beginning of research on autonomous vehicles in Russia means that country has, in effect, largely skipped the development of conventional cable-controlled remotely operated vehicles.

The panel principally visited government entities in Russia. In a few cases, it was possible to visit newly-formed commercial companies associated with such centers. It became apparent that large numbers of companies with shared personnel and objectives have been established surrounding many of the important "mother" research and development facilities, and that these companies form sources of technology and commercial capability that were not adequately assessed by the panel.

Many of the panel's observations can be assumed to represent only the general state of the art in the research and development laboratories in that country. That is, there are almost certainly more advanced technical investigations and facilities that the panel was not able to visit.

SPECIFIC CONCLUSIONS

Sensors and Instrumentation

Deep ocean submersibles, such as the *Mirs* and *Nautile*, continue to be effective platforms for undersea work and research because of their extensive sensor, instrumentation, and manipulative capability. The *Mir* submersibles are considered to be the best equipped and most capable research tools for deep sea (6,000 m) research by some scientists.

Although the FSU has developed limited remote sensing capability for ocean studies using Lidar and acoustic Doppler current profilers, these designs are not unique and are within the current international state of practice.

The FSU is marketing oceanographic instruments (such as conductivity, temperature, and depth, or CTDs, and current meters). Their data quality is unknown, and intercalibrations should be conducted to determine measurement capabilities. Other factors, such as reliability, maintainability, and service must also be addressed. Prices are currently quite low, but this may be a short-term situation that will eventually change to correlate more closely to Western prices.

Several European countries outside of the FSU are actively developing research-type remotely operated vehicles (ROVs) and autonomous underwater vehicles (AUVs). The European Economic Community is supporting as major programs unmanned platforms for undersea and oceanographic research using enhanced sensors and samplers. This is in marked contrast to the United States, where there is no major focused thrust for developing scientific AUVs.

Energy, Hydrodynamics, and Propulsion

Energy. The WTEC teams did not see any particularly new concepts in energy systems at any of the sites visited. However, at the same time, panelists were impressed with the variety of sources being used, or designed for use, in underwater vehicles. The spectrum ranged from small, simplified nuclear reactors (e.g., the Russian *Ocean Shuttle* concept) to conventional lead-acid batteries (used in the numerous Russian and Ukrainian manned submersibles). In Europe, the panel found fuel cells, semi-fuel cells, Rankine Cycle engines, Sterling Cycle engines, and hydrazine gas generators all presently at sea on board various vehicle platforms.

In Russia, the most impressive directions were nuclear power systems (first developed for military submarines) and fuel cells (first developed for the space program). While the fuel cells were of conventional design, several had been built and many hours had been logged in spaceflight conditions.

In Europe there was a clear developmental trend towards high energy density energy sources such as the Rankine, Sterling, and Hydrazine-powered engines. The semi-fuel cells, such as Alupower's aluminum oxygen battery, offer long-duration power supplies that can make AUVs true underwater satellites. As in Russia, there was very little research and development work evident in storage battery technologies. Most designers were using advanced concept batteries from the automotive and aerospace sectors.

Hydrodynamics. Design of both relatively slow-speed manned submersibles and remotely operated vehicles is less dependent on hydrodynamic considerations than are high speed vehicles. For military submarines and torpedoes, speed is a military virtue. For long-duration autonomous unmanned vehicles, on-board energy conservation is critical to permit prolonged mission times.

As might be expected, the former Soviet Union has an extensive family of organizations and institutions concerned with hydrodynamics. Having the largest and most diverse submarine force in the world required a major technical support base. While this was evident to the WTEC teams, unfortunately, not much of this work has direct relevance to deep submergence technologies, the primary subject under investigation.

Propulsion. Efficient conversion of energy to propulsive force/thrust is critically important to manned submersibles, remotely operated vehicles, and autonomous unmanned vehicles. Here energy conservation and the resulting tradeoffs are key concerns of the designer. However, with the exception of the work being done with the AUTOSUB project in England, the panelists did not see much research and development work in this area. At several of the sites in Russia, there was some mention made of work they were doing in propulsion for high speed submarines, but no documentation was provided.

On a much larger application scale, the Russians are doing work in magneto-hydrodynamic propulsion (MHD), and in the Ukraine there is ongoing work on mechanical emulation of fish swimming motions. But in both cases it is difficult to see how these mega-technologies can be applied to deep submersible vehicles.

Manned Submersibles

There is great interest among ocean engineers and ocean researchers in the former Soviet Union in manned submersibles and tourist submarines. Previous interest in manned submersibles in the United Kingdom has been replaced by remotely operated vehicles and a growing effort in autonomous underwater vehicles. IFREMER, in France, continues to support the notion of placing man in situ using *Nautile*.

The WTEC group was surprised by the variety and number of manned submersibles built in the FSU, in operation now, and planned for the future. Several visited activities, mostly those that have been either involved in manned submersibles or military submarines in the past, now have tourist submarine plans on their drawing boards. (Computer-Aided Design is essentially unavailable.)

The existing manned submersibles are fundamental, low cost, uncomplicated, reliable, tested, and available. Ocean researchers are enthusiastic users who are quite satisfied with the capabilities of these tools. The ability to use and fabricate titanium in undersea vehicles in the FSU is advanced. The acceptability of Russian Registry Certification by Western insurance companies needs to be examined carefully before contracting for use of manned submersibles built in the FSU.

Academically, industrially and operationally, the existing manned submersible base in the FSU is truly impressive and has great potential.

Unmanned Submersibles

Great Britain and France. Slingsby Engineering Ltd. (SEL), located north of London, is the major large ROV supplier in Great Britain. The company's only competition is Perry Tri-Tech, a Florida-based company owned by a French company (Coflexip) and International Submarine Engineering (ISE) of Port Coquitlan, B.C., Canada. SEL identifies the customer needs and designs the hardware accordingly, as is the case with its *MRV* ROV. Where needed, SEL continues to improve the components. SEL will remain a small organization because the customer market is small and because more user/service companies are fabricating their own special purpose ROVs.

The Mobil-FSSL project is a typical example of a major oil company starting with a large working ROV (the SEL MRV) and adding specialty tools to undertake major underwater tasks. This trend will continue.

Great Britain has a respectable position in scientific unmanned systems. The Deacon Laboratory AUTOSUB is very ambitious but must wait at least five more years to see final results. The Marconi *ODAS* vehicle, based on torpedo technology, could have a major impact on the scientific community because of its low cost.

The observed trend is for universities to undertake a more narrow view of technology development because of funding constraints. Also there is a cooperative nature for technology development, not just within Great Britain, but within the European Community. A prime example of this is the European Community Marine Science and Technology (MAST) research programs. A new MAST program aimed at furthering autonomous underwater vehicles is the Advanced Research for Unmanned Autonomous Underwater Vehicles. The contributors to this program are Deacon Laboratory and DRA from Great Britain, IFREMER, ECA, and INRIA from France, the National Technical University of Athens, Greece, and Institute Hidrografico from Portugal. There may be something to learn from this type of cooperative technology development, especially in a tight money environment.

Former Soviet Union. Russia's present position relative to the Western world is difficult to establish. The country's low-cost ROVs are dated technology. However, the operating techniques of Russia's 6,000 m ROV systems have much to offer. There is nothing technologically exciting about their unmanned systems, primarily because the nation's efforts have been concentrated on manned systems.

The observed trend is for members of universities and governmental agencies to form private ventures in an effort to generate needed funds. There are many ventures formed to develop tourist submarines. This is disappointing because the world market for tourist submarines is already nearly saturated. Another trend is for foreign firms to form teaming agreements with individuals and facilities to conduct business on a world-wide basis. Intershelf demonstrates this trend. Russia must overcome the credibility and logistic support gap before it can compete in the world markets for underwater unmanned systems.

Acoustic Applications

In Western Europe the technology developments are very similar to those efforts in the United States. Some of Western Europe's sonar imaging systems are more interesting than similar units manufactured in the United States due to price and performance issues. In the FSU the situation is different. The following observations relate mostly to what was seen in the FSU.

Understanding of Basic Theory. The researchers participating in the discussions were very clearly aware of the basic principles of the technology with which they were involved. Possibly the limitation of computer capability and the need for efficient problem solving has forced this need for in-depth basic understanding. This is clearly different in the United States, where computer capability and the cost of people can force development to proceed along lines where an engineering solution is more important than reaching a total understanding of all aspects of a problem to be considered.

Application Ideas. There were several interesting discussions about new applications under consideration by researchers in the FSU. Some of these ideas were considered to be novel and had not been considered in the United States, at least in circles represented by members of the WTEC team. It may well be that the new freedom to consider research directions has allowed researchers to consider novel applications of technology. It may also be that having to compete in a world marketplace demands new and novel products and ideas.

Implementation Software and Hardware. As has been alluded to in other chapters, there is a general agreement that the FSU research has been undertaken in an environment with limited computer hardware capability. On the other hand this limitation has most probably been the reason for the direction of software development. The emphasis has been on efficient algorithms and highly capable microprogramming in the Russian computer systems.

Maturity of Applications. There have been many applications of technology that are both interesting and novel. It must be understood, however, that the actual maturity of those applications is not clear. Many of the technological concepts discussed were in their conceptual stages only. With limited financial resources, it is unclear just how many of those applications will come to fruition.

Infrastructure. The changes in the FSU have had a strong impact on the technology infrastructure. Communications among various groups is unclear. Also, the method for moving from concept to final prototype was controlled very completely in the past, and the resources needed to accomplish a development effort were planned and in place. It seems that this is no longer the case and it will be a while before such an infrastructure evolves in this new environment.

Several factors affecting technology development in the FSU were apparent during the visits and discussions. Although they are not necessarily related to technology development, the following factors are among those that are important to the process used to develop technology:

Publishing in professional journals
Acquiring better computer hardware
Establishing better communication channels

Better understanding of how to do business with the West
Better understanding of technology outside of the FSU

There were applications of acoustic technology that were both exciting to consider and important to advancing the state of the art in this field. Due to limited time, it was not possible to truly understand the technical accomplishments of the technologists, yet their ideas were intriguing and their concepts novel. More should be done to fully understand many of these efforts.

As mentioned previously, one of the factors that constantly surfaced was how far specific applications had been taken. It was not clear, at times, whether a discussion was of a concept not yet moved to hardware; a concept for which a prototype had been developed; a concept that had been evaluated in a real world setting; or a concept that had already advanced to a product.

It was also unclear, at times, what the future held for specific applications that were discussed. With limited resources and a very dynamic environment, the future of an idea is uncertain. Many of the applications discussed could well be moved into viable products readily sought after in the world marketplace. Whether they will reach that goal is not clear.

It was recognized by many members of the WTEC team that solutions to technological problems had been implemented on computer hardware of limited capability. Emphasis was placed on efficient algorithms and clearly understanding the principles of the problem. Many can remember how their first efforts at applying microcomputers to instrumentation forced the use of machine languages and complex interface programming. This is not unlike what seems to be the norm in the FSU. The benefit of this has been to develop unique solutions to complex programming problems.

There is a genuine desire for cooperation and collaboration. On one hand this is obvious since funding and equipment are lacking. More importantly, however, is the perception that technologists in the FSU truly believe that cooperation and collaboration will bring new insights and further advance their technological interests. The individuals involved in the visits were very talented technical people. Much would be gained by the synergism resulting from true cooperation.

An interesting factor recognized during many discussions was that the current environment in the FSU is allowing technologists the freedom to choose their own research directions. In addition, many technologists are starting small businesses to privatize their talents and products. This has not been possible in the past since funding and resources were directed at specific projects planned outside of the various institutions. It is clear that this new freedom will allow researchers to consider directions that were not available in the past.

The WTEC team agreed unanimously that the time available for the visits did not allow for in-depth discussions. This was probably inevitable for this first series of visits, but should be corrected during future visits. There is much to learn in the FSU regarding acoustic applications. Learning is always a slow process that follows a less than straight path. Future visits should allow time for technical discussions with the actual professionals involved in moving applications from concept to reality.

System Engineering

Europe. Underwater vehicles and marine technologies are very important to the European countries visited. This is evidenced by government-funded programs, such as the Marine Technology Directorate (MTD) program, sponsored by the United Kingdom's Science and Engineering Research Council (SERC) and France's IFREMER program. Also, a European-wide focus is offered by the Marine Science and Technology program. European marine technology and underwater vehicle (UV) activities are well planned and focused, and funding, though never enough, is adequate. The bottom line is that the Europeans are making good progress in developing AUVs, and are moving toward some very useful national and regional objectives in ocean research. Good work is also in progress toward development of ROVs for the offshore oil industry.

The organizations involved in UV development and marine research are well equipped for research, engineering, and overall system integration. The computer equipment and test facilities are modern and as capable as any in the United States.

Former Soviet Union. Labor and materials are still cheap in the FSU, and the availability of micro-electronics is limited. This has led in the past to an emphasis on manned UVs rather than unmanned units. Manned UVs are easier to integrate and maintain, and use low-cost labor to good effect. This trend will probably continue into the near future, until the CIS industrial sector begins to mature and costs drive it toward unmanned systems. In the West, the high cost of labor and the risk of litigation and insurance penalties have driven scientists toward unmanned solutions. However, the same cost of labor has made sophistication and high technology expensive. The United States has improved performance and minimized man-dependency, but in some cases has violated the basic rules of - "keep it simple" and "sufficient is good enough." The United States is too often enamored of the whiz-bang solution rather than the simplest one.

Fundamental science in the FSU is impressive and based on sound theory. Due to lack of computational capabilities, there has been a focus on empirical validation rather than in-depth analysis. This will continue during the process of economic, political, and defense conversion.

FSU scientists and engineers have been very creative in applied research, and have many accomplishments that equal or exceed those of the West. Some examples include manned submersibles, acoustic tomography, nonacoustic ASW, high-speed underwater projectiles, and materials development for the marine environment.

The FSU's engineering is generally behind that of the West in sophistication but not necessarily in results. Some of the FSU's engineering and integration achievements include:

- Numerous and very good research test facilities.
- Short development spans based on a theory of build it, field it, and then improve it.
- Avoidance of the analysis paralysis that slows progress in the West.
- Lack of preoccupation with aesthetics. They build systems stout to last and simple for easy maintenance.

Navigation, Communication, Automation, and Control

There is limited technology in the former Soviet Union in the areas of automation in underwater vehicle technology. The control technology is based primarily on manual operation. Navigation and communication systems in the former Soviet Union use technologies that are currently available worldwide. There are a large number of well-trained engineers and scientists in the FSU who are underutilized because of the current funding situation. There are several very nice designs, test, and fabrication facilities in the former Soviet Union. The FSU would like to make these facilities available in some form to be used in the world market. The engineers said that access to computers, computer-aided design and simulation software, and more reliable electronics, would make them more effective.

France is the leader in the field of underwater vehicle technology. French programs in the integration of local sensor data for navigation and control have the potential of opening up new capabilities for underwater vehicles.

The United Kingdom is leading a European Community effort in developing long-range underwater vehicles. This program is pushing the limits in underwater vehicle technology in automation, navigation, and control.

SPACE ROBOTICS IN JAPAN

January 1991

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James W. Lowrie, Martin Marietta Astronautics Group

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SUMMARY

Infrastructure and Program

Japan has been one of the most successful countries in the world in the realm of terrestrial robot applications. The panel found that Japan has in place a broad base of robotics R&D, ranging from components to working systems for manufacturing, construction, and human service industries. From this base, Japan looks to the use of robotics in space applications, and has funded work in space robotics since the mid-1980s. The Japanese are focusing on a clear image of what they hope to achieve through three objectives for the 1990s: developing long-reach manipulation for tending experiments on Space Station Freedom, capturing satellites using a free-flying manipulator, and surveying part of the moon with a mobile robot. This focus and a sound robotics infrastructure is enabling the young Japanese space program to develop relevant systems for extraterrestrial robotics applications.

Space robotics in Japan has involved government agencies, national research laboratories, universities, and companies. The government agencies responsible for space activities are the National Space Development Agency and the Institute of Space and Aeronautical Science, and, to a lesser extent, MITI.

Japanese industry recognizes the future potential of space, and the larger Japanese mechatronics companies engage in space robotics research. The panel found most industry research to be strongly applications-oriented. Government contracts have been let to companies with aerospace and industrial robotics experience; multiple contractors may take part in a major project. In the U.S., by contrast, one corporation usually acts as the prime integrating contractor. Japanese universities are also involved in space robotics research. Universities provide a stream of basic research contributions, but have played only minor roles in large robotics projects.

Funding for Japanese space robotics research and projects has come from the government, with cost sharing by corporations. Japanese procurement practices appear to have engendered cooperation among Japanese corporations, and companies have rotated contracts. Government contracts tend to be smaller and to make up a smaller proportion of a company's business in Japan than in the U.S. Less funding is apparently available in Japan than in the U.S., but major Japanese space robotics programs and a diversity of smaller projects are supported.

Japanese Experimental Module

The Japanese Experimental Module (JEM) is Japan's contribution to the international Space Station Freedom project. JEM is a space laboratory for experiments in areas such as biology and crystal growth. When deployed, JEM will have a pressurized module for researchers, an exposed facility for experiments, and a remote manipulator system (RMS) to service experiments and maintain the exposed facility. JEM's exposed facility portion is designed to be robot-friendly, eliminating the need for astronauts to perform routine maintenance and repair functions. The JEM/RMS has a large arm and small fine arm (SFA). The large arm is designed to conduct overall assembly tasks and to transport the SFA; the SFA provides dexterity. JEM's pressurized module includes an interior workstation for teleoperating the JEM manipulators using a single joystick.

JEM's large arm is mounted on the pressurized module just above the airlock and had 7 degrees of freedom (DOF). The manipulator is 9.7 m long and has a mass of 370 kg. It will maneuver a payload massing up to 7000 kg. Two cameras mounted on the arm permit the operator at the workstation to view large arm actions. A standard grappling mechanism is mounted on the end of the large arm to dock with tools, payloads, or the SFA.

The SFA relies on the large arm for transport, positioning, and stabilization. The SFA includes an interface with the large arm, an electronics module, camera assembly, manipulator, and end effector. This arm is 1.6 m long, has 6 DOF, and features a 3-DOF wrist. The SFA can move up to 10 cm/sec with a payload of up to 300 kg. A stereo camera mounted at the base of the manipulator displays images on a video monitor at the workstation.

In addition to the RMS, the Japanese have conceived the active compliance effector (ACE), which is designed to be mounted on the end of the JEM/RMS arm. ACE provides small motions that could be useful in compensating for inaccuracies of the large arm. ACE was particularly interesting to the panel because the U.S. was planning nothing like it for its long-reach space manipulation.

Orbital Operations

Japan has identified orbiting space structures as a means to conduct space activities in the future. In addition to the Space Station Freedom, the Japanese envision their own robotic space laboratory, the Cosmo-Lab, and one corporation hopes one day to operate an orbiting space hotel. To realize these scenarios, the Japanese foresee free-flying robots that grab, dock, and manipulate while in orbit. Fixed-base systems, such as those appended to shuttles or stations, have many limitations.

The Japanese are developing a free-flying manipulator with satellite capture capabilities. Named the Autonomous Satellite Retrieval EXperiment (ASREX), it is a scientifically motivated, special-purpose experimental robot for retrieving satellites. A key technology required for the ASREX is coupled control of the free-flying vehicle and manipulator. Movement of the manipulator will cause a reactive movement of the satellite, which must be compensated for by position and attitude control. The Japanese plan to accomplish satellite capture autonomously using feedback from laser radar, which is being developed specifically for this project. In addition to the ASREX, the Japanese are planning the ETS-7, an ASREX-like device that would be controlled by a combination of autonomy and teleoperation and would be capable of rendezvous and docking operations.

Japan's Space Flyer Unit (SFU) is a reusable satellite bus with onboard infrastructure, such as power, telemetry, and control, which could host free-floating experiments. Scheduled to fly in the early 1990s, it was justified independent of its relevance to space robotics, though it would enable scientific robotic experiments.

Japanese assembly and service robot concepts were still in the early planning stages at the time of the panel's visit. The Orbital Service Vehicle (OSV) is envisioned as a free-flying extra-vehicular activity (EVA) robot for inspecting, assessing, and repairing satellites or space structures. It will include thrusters, a manipulator, visual sensors, laser radar, a high-gain antenna, and a docking mechanism. *Hope* is envisioned as an unmanned shuttle-type vehicle. Its long-reach manipulator will transfer cargo, capture satellites, and aid in space assembly. As of 1990, the first launch was planned for the mid-1990s.

Surface Exploration and Construction

The Japanese are envisioning missions to the moon and to Mars, and speculate on the use of robots for surface exploration. Extreme conditions on other planets, including heat and cold, radiation, and rough terrain, require robots that are mobile; have competent motion in hard or soft terrain; remain upright or are self-righting; and that are physically self-contained, durable, and autonomous. In May 1990, the

Japanese announced a three-part lunar survey mission projected for launch in 2000. The unmanned Lunar Mobile Explorer (LME) is planned to investigate soil characteristics, collect samples, and confirm the presence or absence of water under the moon's permanent shadow.

The Japanese are also conducting research and development in mobile robots for nonspace applications. They have developed several wheeled, tracked, and hybrid mobile robots. They have also conducted research on legged robots that were candidates for space applications. Although the Japanese have had no experience in developing and testing mobile robots on planetary surfaces, they have a wealth of experience in terrestrial analogs, particularly in nuclear and construction applications. This will be a clear advantage for future surface operations.

Supporting Technologies

The Japanese are performing basic research for future generations of robots. The panel encountered a spectrum of supporting technology, including task control, motion control, master-slave systems, novel mechanisms, actuators and devices, and special-purpose robot integrations. Task control technologies were advancing Japanese manipulation from teleoperation toward autonomy. The panel observed outstanding Japanese motion control technologies: position and force control, hybrid control, use of digital signal processors to successfully increase the response and stability of control systems, and miniaturized actuators and components.

One notable system uses a series of head-mounted video displays to drive a slave video camera. This system includes a master-manipulator, slave-manipulator, and real-time graphic simulator. Human movements, including head and eyeball movements, are measured in real time. The movements of the robot sensors are controlled to follow the human operator, and images taken by the robot sensors are displayed to the human operator's eyes. Other notable Japanese master-slave systems include a 6-DOF bilateral teleoperator with a kinematically dissimilar master and slave, a master-slave manipulation system with visual and force feedback, and teleoperators enabling dynamic manipulation.

Japanese robotics researchers have developed a number of novel mechanisms, actuators, and devices, including manipulators, serpentine mechanisms, and high-performance miniature actuators and controllers. One interesting flexible finger system is controlled by pneumatic servos. Each finger is a hollow rubber cylinder divided into three chambers that are pressurized independently. The fingers are moved by varying the pressure in the chambers. Each finger is capable of fine, controlled movement, e.g., threading a bolt into a plate.

Serpentine mechanisms have a great deal of potential for space applications because gravity loads do not apply. Such systems, morphologically and functionally analogous to snakes, tentacles, or elephant trunks, are characterized by long reach, narrow profile, and the ability to conform to complex shapes.

The panel noted that the Japanese have excelled in developing focused, special-purpose systems, some of which could find applications in space: a ladder-climbing robot; a teleoperated live-line maintenance robot; an inspection robot for containment vessels; vacuum-compatible actuators and robots; bipedal walkers; a plant tissue culture robot that can select, grasp, cut, and transport seedlings; and a piano-playing robot that can read and play music.

Perspectives

Vision and planning, coupled with a strong robotics research infrastructure, are enabling the young Japanese space program to develop relevant systems for space. Many successful Japanese development programs involve a stair-step approach, or rapid prototyping of technology generations, rather than a continuous evolution or one-time technological leap. The typical Japanese approach to robotics system challenges has been, and will probably continue to be, to first develop and deploy a baseline capability. System improvements can then take the form of distinct incremental upgrades.

At the same time, the Japanese often display a minimalist approach to space robotics technology. In some of their robots, they use technology adequate to getting the job done, thus avoiding the major costs associated with concerns about future evolution. To a marked degree, the Japanese tend to incorporate special-purpose electronics and devices (digital signal processors, application-specific integrated circuits, very large-scale integration, and special-purpose actuators) into their robotics. Overall, Japanese robotics hardware is more notable than its associated software.

The panel concluded that the Japanese were significant participants in space robotics with everything necessary to succeed: the technology, experience, and commitment to reach their objective of competent space robots.

SPACE AND TRANSATMOSPHERIC PROPULSION TECHNOLOGY

August 1990

Charles Merkle, Penn State University (Panel Chair)

Maynard L. (Joe) Stangeland, Rockwell International

James R. Brown, Pratt & Whitney

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SUMMARY

This report focuses primarily on Japan's programs in liquid rocket propulsion and propulsion for spaceplane and related transatmospheric areas. It refers briefly to Japan's solid rocket programs and to new supersonic air-breathing propulsion efforts.

Japan's long-term plans for space activity and its generic paths for achieving these plans were originally outlined in 1978 in the *Fundamental Policy of Japan's Space Development*. This document was revised in 1984 and 1989, and was expected to be updated periodically to keep Japan's policy consistent with advances in technology and changing socioeconomic factors. It shows Japan's space program to be a very aggressive and forward-looking one. This program emphasizes development of internal resources for various domestic and international space activities. Japan's domestic space interests encompass activities to exploit the unique environmental conditions of space, prepare for civil space development, and promote manned space activities. Plans for international collaborations include cooperating with programs established by other countries, initiating collaborative programs, and assisting developing countries.

Japan's space program is founded on two basic tenets: development of assured access to space and use of space activities solely for peaceful purposes. Work conducted by NASA with the U.S. Air Force might conflict with Japan's guideline concerning peaceful uses of space. However, there should be ample room for cooperative Japan-U.S. space endeavors. Japan's goals for the 1990s include plans for continuing its already strong thrust in scientific space research, bringing its

satellite and launch technologies up to international standards, creating the infrastructure for space station activities, and developing the basic technologies required for manned space activities.

Space transportation systems are of primary importance in Japan's near-term space plans. Near-term goals in space transportation are aimed at the development of an expendable launch system for transporting materials to geostationary orbit, technology for unmanned space-to-ground transportation, and fundamental R&D for long-term manned space transportation capabilities. Current transportation plans for expendable launch vehicles focus on developing and enhancing the H- and M-series of liquid and solid rocket systems.

GENERAL FINDINGS

Japan has several distinct space transportation efforts, including three expendable rocket launch vehicle programs and three air-breathing hypersonic vehicle concepts. The rocket launch vehicles include operational and developmental systems -- the N-series, the H-series, and the M-series. Air-breathing hypersonic vehicles were in the concept definition phase at the time of the panel's visit. The N-series of launch vehicles is based on U.S. technology developed under license. H-I vehicles include technology based in part on Japanese design and development and in part on licensed U.S. technology. The H-II vehicle, scheduled for first use in 1993, is completely Japanese in design, and positions Japan as a full-fledged member of the world launch community. The M-series rockets, solid boosters of Japanese design, are highly advanced and have proven capabilities for launching scientific satellites.

Japan's Tanegashima launch facilities are at nearly the same latitude as the U.S. facilities at Kennedy Space Center. The size of the launch site at Tanegashima is much smaller than that at Kennedy, and transportation facilities in the immediate area are somewhat limited. But these facilities appear to be adequate for the H-II. An agreement with local residents limits launch windows to a few weeks per year.

At the time of the panel's visit, engine development for Japan's space transportation efforts was divided into eight programs in stages ranging from concept development to operational: four cryogenic hydrogen-oxygen rocket engines and four advanced air-breathing systems. In conjunction with the H-series expendable launch vehicle program, the LE-5 cryogenic propulsion engine was operational, and propulsion development was under way for the LE-5a and the LE-7 cryogenic engines. Also under development were the HIPEX expander cycle engine, an additional new liquid hydrogen-oxygen engine; the liquid air cycle engine (LACE), a generic propulsion system oriented towards advanced air-breathing systems such as strap-on boosters for upgraded versions of the H-II; and the ATREX engine, an air turboramjet system. The remaining two propulsion systems were a scramjet engine concept intended for eventual hypersonic applications and a newly announced Mach 5 turbojet/turboramjet engine being developed for high-speed commercial transportation.

The panel found the systems and performance of Japan's cryogenic liquid rocket engines to be comparable to those of engines developed in the United States. The Japanese made extensive use of U.S. data, procedures, and technology in their designs; their engines also have similar specific impulse and vacuum thrust-to-weight ratios. However, the new engines are decidedly Japanese designs, showing a number of subtle but significant philosophical differences from U.S. systems. Japanese engine development programs were composed of carefully planned steps involving low-risk, well-characterized options. Japan's slightly more conservative design approach may facilitate reliability and be particularly beneficial if the engines or their derivatives are man-rated.

In the area of turbomachinery, Japanese turbopumps and turbines demonstrate performance levels similar to those of U.S. products. The Japanese are behind the United States in some areas of turbomachinery but ahead in others. In one instance they chose a two-stage over a three-stage pump to avoid a technology development program. Their cooperative efforts minimize duplication and maximize the rate of advancement.

By 1989, the Japanese were beginning a study of spaceplane concepts that emphasized such diverse topics as aerodynamics, structures, slush hydrogen fuel, Computational Fluid Dynamics (CFD), advanced propulsion, and system development scenarios. The propulsive cycles under study included the turbojet, the ramjet, the turboramjet, and the supersonic combustion ramjet (scramjet). The propulsion systems of primary interest appeared to be those for the Mach 3 to Mach 6 range for the low-Mach-number portion of hypersonic cruise or SSTO vehicles, strap-on booster augmentation engines for launch systems, or air-breathing engines for a civilian SST. Efforts in higher Mach number propulsion systems were directed more toward accumulating a database.

In engine development, the panel found two classes of engine in the prototype phase: the LACE engine at Mitsubishi Heavy Industries and the ATREX air turboramjet at Ishikawajima-Harima Heavy Industries. The LACE demonstrator engine used the LH2 pump and combustor from the LE-5 engine, along with new components for the air liquefier and the liquid air pump. The ATREX engine relied on existing turbojet-turbofan production and design experience and on the expander cycle technology developed in the HIPEX engine.

The Japanese program in scramjet applications was only in the concept definition phase when the JTEC panel visited. Scramjet technology programs included experimental studies of supersonic combustion, including ignition and diffusion flame studies, and shock tube studies of elementary reaction kinetics of hydrogen. High-speed inlet tests on a scale model were under way, as were university efforts in hypersonic reacting flows and component technology for advanced propulsion systems.

In advanced fuels development and on-plant construction for hydrogen production, Japan had two high-density hydrocarbon fuels for rocket applications, and was stepping up its hydrogen production capabilities to serve the H-II and advanced air-breathing propulsion systems. It was building a plant that made hydrogen as the by-product of ethylene production and a pilot facility to produce hydrogen from coal.

Japan was using the latest U.S. and European advanced diagnostics systems, but was leading in the development and manufacture of many of the basic lasers, optics, and electro-optic components for these systems. Tunable diode lasers and a surface-emitting diode laser with reduced beam divergence were developments in advanced diagnostics implementations that offered possibilities for improved spatial resolution.

CFD, important in all propulsion development, was seen to be an area of strength in Japan. Japanese supercomputers were acknowledged to be among the best in the world, and their availability had resulted in rapid progress in computational areas. The Japanese routinely included real gas effects and complex reaction kinetics in flow field analyses, and their codes were based on the latest algorithms. Their visualization and postprocessing capabilities were also at the leading edge. The Japanese had appropriate CFD capabilities to move rapidly in this aspect of propulsion development.

CONCLUSIONS

The panel observed that the Japanese had a carefully thought-out plan, a broad-based program, and an ambitious but achievable schedule for propulsion activity. Japan's overall propulsion program was behind that of the United States at the time of this study, but the Japanese were gaining rapidly. The Japanese are at the forefront in such key areas as advanced materials, enjoying a high level of project continuity and funding. Japan's space program has been evolutionary in nature, while the U.S. program has emphasized revolutionary advances. Projects have typically been smaller in Japan than in the United States, focusing on incremental advances in technology, with an excellent record of applying proven technology to new projects. This evolutionary approach, coupled with an ability to take technology off the shelf from other countries, has resulted in relatively low development costs, rapid progress, and enhanced reliability. Clearly Japan is positioned to be a world leader in space and transatmospheric propulsion technology by the year 2000.

V. ENERGY

COMPARATIVE ASSESSMENTS OF NUCLEAR INSTRUMENTATION AND CONTROLS IN THE UNITED STATES, CANADA, JAPAN WESTERN EUROPE AND THE FORMER SOVIET UNION

February 1994

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BACKGROUND

The subject of instrumentation and control (I&C) technologies for nuclear power plants is of considerable interest to the nuclear industry throughout the world now. This interest derives from two considerations. The first is that the I&C systems are the windows into the status of the nuclear plant. Since the Three Mile Island accident, the industry has been trying to improve the ability of the operators to grasp the safety status of the plant, particularly during operational upsets. The advent of computer-based monitoring and display systems has provided opportunities for advancements which, hopefully, will improve the ability of the operators to understand the plant status, and therefore, improve the operator's ability to make the best decisions during the plant transients which might otherwise become accidents.

The second consideration is that the nuclear industry is being driven toward computer-based instrumentation and control systems. The driving forces are: (1) decreases in reliability of aging analog-based I&C; (2) lack of spare parts because the suppliers have moved on to digital hardware; (3) the promise of higher reliability of digital technologies; and (4) the lure of expanded capabilities of software-based systems.

Other industries have preceded the nuclear industry in the use of computer-based I&C. The possible consequences of failure of safety systems in nuclear power plants has resulted in a great deal of conservatism in the nuclear industry. Although this conservatism affects the design and regulation of nuclear safety systems, it also influences the design of control and information systems for nuclear power plants. Because of this conservatism, the nuclear industry moves very slowly to make changes in designs.

Other countries have many years of experience with digital systems in nuclear plants, whereas the United States has relatively little experience. As the United States embarks on the evolution from analog to digital I&C technologies, the designers should take advantage of the best technologies and lessons learned around the world. Also, the exportability of U.S. nuclear I&C technology will be related to its status compared to that in competing countries.

Because of these considerations, the National Science Foundation and the Department of Energy commissioned U.S. specialists to make assessments of instrumentation and controls (I&C) technologies used in nuclear power plants in: (1) Japan; (2) Western Europe and the former Soviet Union; and (3) Canada. These studies included reviews of the literature from 1988 through 1991 on the subject, followed by visits to some of the leading organizations in the field of nuclear I&C in the countries of interest. These studies have been published by the National Science Foundation.

The purpose of this summary is to provide a consolidated summary of the conclusions of these studies. This will present a high level contrast of the most advanced I&C technologies for nuclear power in the countries studied. Countries visited by panelists include France, Germany, Russia, Czechoslovakia, Norway, Canada and Japan. All of these countries are moving toward increasing use of digital computers in information and control systems.

The author has combined results of previous assessments. The summary also contains updates based on recent developments published in the literature (through May 1993) and discussed in recent high level meetings and conferences. This blending of earlier results with newer information required judgement by the author. The results in this section, therefore, should be considered the conclusions of the author alone, although the conclusions were reviewed by all of the panelists listed on Page 153.

For the purposes of this report, I&C is defined as:

- the instruments which interact with the processes in the plant
- the cables carrying the signals from the instruments
- the signal conditioning equipment which modifies the signals into forms useful to the communication channels
- the architecture supporting the transport of signals and data within the plant
- the control room
- the man-machine interfaces
- the procedures
- the control equipment
- the control algorithms
- the computer software used in the monitoring, control, safety, communication and display systems

Safety systems in nuclear power plants require a level of qualification of I&C substantially higher than in monitoring, control, communication and display systems.

Furthermore, the level of qualification of safety system I&C seems to be more rigorous than in any type of process system known to the panelists participating in these studies.

SUMMARY OF CONCLUSIONS

Western Europe, Japan and Canada are significantly ahead of the United States in the research, development and implementation of new products in nuclear I&C. Table 26 shows Western Europe to lead the rest of the world in the categories of: Control Room Design; Transition to Computer-based Technology; Computer-based Operator Support Systems; Control Strategies; and Standards & Tools. The Japanese and Canadian nuclear industries generally are second and third, respectively, in the development and use of new products in modern I&C. The differences in research activities among the countries studied are not as dramatic as the differences in product development and product implementation. In terms of Basic Research, the United States is only slightly behind the world leaders. The reason Western Europe, Japan and Canada lead in the use of modern I&C technology in nuclear plants may be due to the fact that the nuclear programs in these areas of the world have had many more years of funding stability than those in the United States.

The United States is beginning to accelerate its Advanced Development and Product Implementation in the nuclear I&C area. For example, Westinghouse has recently signed a contract to supply instrumentation and control systems to the two-unit Temelin plant in the Czech Republic. Westinghouse also is performing a significant amount of the I&C work at Sizewell B, the new (and only) Pressurized Water Reactor (PWR) in the U.K. Another example where U.S. nuclear vendors are beginning to move forward in I&C is the case of the Advanced Boiling Water Reactor (ABWR). General Electric has been working with Toshiba and Hitachi in the design of the modern I&C in the highly automated ABWRs under construction now in Japan at Kashiwazaki-Kariwa. Upgrades to the I&C in existing U.S. plants are giving the U.S. industry the chance to apply some modern digital I&C now. These real-life experiences will help the United States move forward in the use of digital-based modern I&C.

Even these efforts, however, will fall short of placing the U.S. industry on an even level with the Western Europeans, Japanese and Canadians who continue to build many more plants than the U.S. industry and, therefore, continue to have many more opportunities to utilize advances in the I&C field.

The former Soviet Union was found to be strong analytically in I&C, but at a disadvantage because of low availability of newer, more powerful computers and computer chips. Especially in product development and implementation, the former Soviet Union seemed to lag behind the other countries studied, as shown in Table 26.

TABLE 26
Ranking of World I&C Technologies for Nuclear Power

	United States	Western Europe	Canada	Japan	Former Soviet Union
Control Room Design					
Basic Research	4	1	2	3	5
Advanced Development	4	1	3	2	5
Product Implementation	4	1	3	2	5
Analog-Digital Transition					
Basic Research	3	1	2	4	5
Advanced Development	4	1	2	3	5
Product Implementation	4	2	1	3	5
Support Systems					
Basic Research	4	1	3	2	5
Advanced Development	3	1	2	4	5
Product Implementation	4	1	3	2	5
Control Strategies					
Basic Research	5	1	3	2	4
Advanced Development	5	1	3	2	4
Product Implementation	5	2	3	1	4
Architecture					
Basic Research	1	2	3	4	5
Advanced Development	1	2	3	4	5
Product Implementation	4	1	3	2	5
Instrumentation					
Basic Research	*	*	*	*	*
Advanced Development	*	*	*	*	*
Product Implementation	*	*	*	*	*
Standards & Tools					
Basic Research	4	1	3	2	5
Advanced Development	4	1	3	2	5
Product Implementation	4	1	3	2	5

1 means most advanced, 5 means least advanced
* no significant difference

DETAILED FINDINGS

Control Room Design

Conventional nuclear power plant control rooms are normally large rectangular rooms which have wall panels of dials, gauges, strip chart recorders, alarm lights and switches. The operators normally are standing when they make control changes in the plant, having to walk from panel to panel to read strip chart recorders and to turn switches. During operational upsets, hundreds of alarms and lights alert the operators about certain limits being exceeded. A great deal of training is necessary for the operators to be able to discern what has happened and what should happen next. For example, even though they had substantial training, the Three Mile Island operators could not determine the nature of the notorious accident at their plant, and made mistakes responding to the situation.

The advent of inexpensive, powerful computers with high resolution monitors has allowed designers to consider control room concepts in which the wall panels are replaced by computers. All countries studied, with the exception of Russia and Czechoslovakia, are working on control room concepts which include a cockpit type area for the operator(s). This type of control room is called cockpit-type because it resembles, to some extent, the cockpit in an airplane. Computer-based workstations surround the operator in such a manner that he does not have to move from his seat to monitor and control any of the plant's major systems.

Because there is such a large quantity of information which the operator might need, there is a concern that the operator might lose the big picture while searching through the instruments and computer-based displays surrounding him in a cockpit type control room. To avoid this, most new control room designs include a large diagram of the plant on one of the control room walls to present to all observers the status of the plant's major systems and alarms.

How these new control room design features will be used, and the definition of the roles of the human operators in these newer, more automated plant designs has been the subject of wide debate. In Japan and Germany, the trend is to use more automation, whereas in France the emphasis in their newest designs is on computer-displayed operating procedures to guide the plant operators. In U.S. and Soviet plants, the emphasis is on using digital systems to help the operator identify problems, decide on the appropriate corrective actions, and aid in the execution of those actions. Most reviewers agree that each type of approach can produce required safety and reliability goals, but which approach provides the best overall safety and reliability is unknown. The field of cognitive engineering may provide good insights into questions about the roles of operators in highly automated systems and what types of support systems to give the operators to support these roles. Japan, the United States, the former Soviet Union, and the Scandinavian countries seem to be taking the lead in the application of cognitive engineering to nuclear plant control room design and man-machine interfaces.

France is the undisputed leader in advanced control room design, with the new "N4" plant control room being built at Chooz B considered the most advanced in the world. Design work began in the early 1980s. France constructed a full-sized simulator of this type of control room design and performed several years of tests on it to validate the design concept. Framatome and Electricite de France led this work. The OECD Halden Reactor Project in Norway is a leader in a lot of European control room research and development, especially in the human factors area.

The Japanese government and nuclear industry have worked together on several projects involving control room layouts and operator workload. The Japanese MITI established the Institute of Human Factors in the Nuclear Power Engineering Test Center in 1987 to study human factors and human reliability. Also in 1987, the Japanese utilities' Central Research Institute for the Electric Power Industry (CRIEPI) established a Human Factors Center to develop countermeasures for reducing human errors in operation and maintenance of nuclear power plants.

In the design of its new CANDU plants, Atomic Energy of Canada Limited (AECL) has performed important analyses of human performance factors.

The United States does not have national R&D programs on control room design, although the Department of Energy programs on the Advanced Liquid Metal Reactor (ALMR) and the Modular High Temperature Gas-cooled Reactor (MHTGR) have done some high level conceptual designs of new control rooms.

Analog to Digital Transition

The designs of nuclear power plants operating today in the United States use 1960's technology. This old technology uses analog type systems, which employ continuous current, voltage or pneumatic signals. In a typical plant, there are more than 100 such systems, making the plant difficult to maintain at times. In some older plants, 70% of the I&C equipment is no longer supported by a vendor, because today most I&C equipment is of a digital format. In this format, the analog signal is converted to a binary form which is compatible with computer-based equipment.

All countries studied are moving toward more use of digital systems. France, Canada and Japan have been using digital I&C in nuclear power plants for many years. The French have applied digital technology extensively in upgrading their 900 and 1300 MWe plant control and protection systems. They have increased the use of digital technology even more in their new 1500 MWe reactor concept, called the N4. In the United States, the Electric Power Research Institute (EPRI), a private research institute funded by a consortium of U.S. electric utilities, has undertaken an initiative to perform the R&D necessary to support the replacement of old analog-based I&C with newer computer-based I&C.

The biggest problem facing the nuclear industry in the evolution toward digital technologies is verification and validation (V&V) of digital-based, extremely high reliability systems. No methods exist today to predict (or assure) software reliability with the same confidence as with hardware systems. Several countries have encountered costly delays in bringing new nuclear plants on line due to unexpected problems in verification and validation (V&V) of digital-based systems.

In Canada, Ontario Hydro has had over 25 years of experience with various forms of digital technology in CANDU nuclear plants. Each new plant has had a greater scope of digital technology than the last. This evolution worked very well until Ontario Hydro built its newest plant, Darlington. The reliability and performance statistics of earlier reactors were outstanding, with most of their newest 8 units included in the top 25 reactors in the world. But with Darlington, the Canadian licensing authority, Atomic Energy Control Board (AECB), undertook a more stringent review of the software engineering processes (mainly V&V) than on the previous plants. As a result, operation of Darlington's first two units was delayed, with a resulting economic burden on the utility.

In the U.K., Nuclear Electric (the British nuclear utility - government supported) estimates that about 500 man-years of effort have gone into the design and V&V of the 100,000 lines of computer code in the safety system of Sizewell B, which has the U.K.'s first software-based primary protection system.

The Germans have the most automated plants in the world, with the most advanced being the ISAR plant designed by Siemens. The Japanese nuclear plants have implemented the most advanced computer-based control strategies.

Computerized Operator Support Systems for Fault Management

These systems include signal validation, fault detection, diagnosis and mitigation. A significantly greater effort is being expended in Western Europe, Japan and Canada than in the United States to develop and deploy advanced fault management systems. There are several technological advances in these countries already available in software form that would be helpful to support operators in U.S. plants.

An example of problems with today's operator support systems is the case of alarms:

1. During any significant transient, there are hundreds of alarms sounding and alarm lights lit in the first few minutes. Important indications of abnormal conditions are masked by many less important alarms. This reduces the ability of the operator to locate the most relevant alarms quickly.

2. Alarms are frequently caused by the action of the operator, making it difficult to understand which alarms are due to an important initiating event and which are due to the operator action.

3. Some alarms are due to out-of-service components undergoing maintenance, rather than an unsafe operating condition.

4. In today's systems, alarms generally are not received in a predictable order during fault conditions. The first alarm seen by the operator may not be the original fault, but only a secondary consequence of some event.

5. To prevent spurious alarms, the tolerance bands are relatively broad. The initiating event may be under way for some time before the alarm is activated.

There are important new developments in the integration of computerized operator support systems designed to address problems. One of these is the Integrated Surveillance and Diagnostic System (ISADS) under development and prototyping at Halden, Norway under the sponsorship of the OECD. This system provides a graphical interface for the user and a high-level manager for eight different computerized operator support systems. In the GRADIENT project sponsored by ESPRIT, there is an integrated framework for a set of expert systems under development at the ABB Heidelberg Research Center. GRADIENT establishes a communication framework for a set of expert systems that reason about the status of the plant and advise the operator. There also is important R&D in this area In Germany's government funded research laboratory *Gesellschaft fur Reaktorsicherheit* and in France's government research laboratory *Centre d'Etudes Nucleaires de Cadarache* and the French utility *Electricite de France* laboratory *Directiones, Etudes, et Recherches.*

Control Strategies and Techniques

The degree of automation is higher in European, Japanese and Canadian plants than in present U.S. plants. The French generate 70 percent of their electricity with nuclear power. Because of this, they have worked hard to make the plants able to automatically match power output with power demand (load following). The French PWR safety systems are very similar to the U.S. systems. Both France and the United States have developed digital systems to improve safety system performance. The French experience base with their digital safety system design, called SPIN, is much larger than in the United States; the French use the SPIN system in 23 plants.

The Germans also have load-following capability. The panel concluded that the German plants are the most automated in the world. The German KONVOI plants have a unique "limitations" system, which takes automatic action to try to prevent the plant from getting into a situation where the safety system would have to act.

This unique system almost always prevents the plant from ever reaching the trip conditions.

Russian research into control theory is analytically advanced as compared to control theory studies in other countries. The Russian safety system for the VVER-type plants is designed to give very large margins between action limits and the true level of safety concern. Although the technology of the control and safety system seems to be of the older analog type, the strategy for limitation and protection systems seems very robust and conservative.

Architecture

In the case of I&C, the term "architecture" means the arrangement of control components, sensors, display devices, networks, cables and communication devices. It also includes the arrangement of information (or data) and software. The I&C architecture is very important to the success of a nuclear power plant design. The development and testing of a system's I&C architecture may be more expensive than the cost of the I&C system.

There are many types of architecture, each of which has advantages and disadvantages. The designer chooses the type of architecture best suited to meet all of the requirements of the system. There are several types of issues which must be addressed. In the United States, individual computing systems have been dedicated to solving individual problems, resulting in "islands of computing" which cannot communicate with other areas of the plant. In the French and Japanese plants, these "islands" are much more integrated. As a result, the architectures of these power plants usually consist of a combination of several types of simpler architectures into a more complex, larger whole. U.S. designers are now dealing with the problems of developing similar architectures.

France has had the most experience in architecture for digital I&C in nuclear plants. However, the French recently have had significant project delays at their newest plant, Chooz B, due to problems with their newest I&C system architecture. Even with many years of experience with digital architectures, the original French designer was unsuccessful in this latest project and was replaced. The same French designer was under contract to supply part of the Sizewell B architecture, but was also replaced on that contract. The problem seems to have been the increased amount of functionality put into the I&C design, without proving first that the architecture could handle the increased communication traffic.

Nuclear designers and researchers around the world have watched the French experience carefully, and have started activities to avoid similar experiences. In the United States, the EPRI has established a program to develop a plant communications and computing architecture plan (PCCAP) methodology. This methodology is planned to be implemented at the Calvert Cliffs Plant.

Activity in R&D, design and implementation of new I&C architectures is a little more intense in Europe than in the United States, due to real-life problems being faced there now.

Instrumentation

The kinds of instrumentation addressed in the studies were:

- nuclear detectors to measure neutrons, gamma and x-rays
- temperature and pressure sensors
- instrumentation systems to measure vibration, leakage and fatigue
- systems to monitor for failed fuel elements
- sensors to measure gas concentration (hydrogen concentration in containments)

Overall, the instrumentation and instrumentation systems used in all countries visited operate on the same principles. The requirements for plants in the countries studied vary somewhat, leading to differences due to design tradeoffs rather than technological breakthroughs. For this reason, Table 26 shows all countries at about the same levels of research, development and product implementation.

Standards and Tools

Standards are generally used by the engineering community to help assure quality of the systems designed. Nuclear designers are employing more computer-based systems I&C to ensure safe operation and economic performance. Standards for the use of computer-based systems in nuclear power plants have been developed in the international community to a greater degree than in the United States.

The West Europeans are leading the world in the development and use of standards in the design of microprocessor-based safety systems. They adhere to the International Electrotechnical Commission (IEC) Standard 880, *Software for computers in the safety systems of NPP's*, and IEC 987, *Programmed digital computers important to safety for NPP's*. The U.S. nuclear industry does not have a standard that is equivalent to IEC Standard 880 or the guidelines in Critical Computer Systems 2. However, there is an effort to develop an equivalent standard. This effort is the revision to ANSI/IEEE/ANS 7-4.3.2-1982, "Application Criteria for Programmable Digital Computer Systems in Nuclear Power Generating Stations." The Canadians developed their own standards originally because there were no sufficient standards when they first started application of digital technology in nuclear plants.

Computer-Aided Software Engineering (CASE) tools reduce the potential for errors in the final software because of the discipline provided by use of the tools. Computer-aided software engineering tools are being used more in Western Europe and Japan than in the United States for design, development and testing of software for nuclear plants. The Europeans are ahead in research on the use of formal design methods to design and qualify safety-critical software for nuclear plants.

PANELISTS WHO CONTRIBUTED TO ASSESSMENTS

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2. J.D. White et al., *WTEC Panel Report on European Nuclear Instrumentation and Controls*, December 1991, available from National Technical Information Service, U.S. Dept. of Commerce, NTIS Report # PB92-100197.

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3. R.E. Uhrig and R.J. Carter, *WTEC Monograph on Instrumentation, Control and Safety Systems of Canadian Nuclear Facilities*, July 1993, available from National Technical Information Service, U.S. Dept. of Commerce, NTIS Report # PB93-218295.

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Executive summaries of these three reports follow.

INSTRUMENTATION, CONTROL, AND SAFETY SYSTEMS OF CANADIAN NUCLEAR FACILITIES

July 1993

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SUMMARY

This report updates a 1989-90 survey of advanced instrumentation and controls (I&C) technologies and associated human factors issues in the U.S. and Canadian nuclear industries carried out by a team from Oak Ridge National Laboratory (Carter and Uhrig 1990). The authors found that the most advanced I&C systems are in the Canadian CANDU plants, where the newest plant (Darlington) has digital systems in almost 100% of its control systems and in over 70% of its plant protection system. Increased emphasis on human factors and cognitive science in modern control rooms has resulted in a reduced work load for the operators and the elimination of many human errors. Automation implemented through digital instrumentation and control is effectively changing the role of the operator to that of a systems manager.

The hypothesis that *properly introducing digital systems increases safety* is supported by the Canadian experience. The performance of these digital systems has been achieved using appropriate quality assurance programs for both hardware and software development. Recent regulatory authority review of the development of safety-critical software has resulted in the creation of isolated software modules with well defined interfaces and more formal structure in the software generation. The ability of digital systems to detect impending failures and initiate a fail-safe action is a significant safety issue that should be of special interest to nuclear utilities and regulatory authorities around the world.

BACKGROUND

Throughout the world, the nuclear power industry is currently developing advanced control and operator interface systems based on innovative applications of digital computers. Significant changes in the operation of nuclear power plants can be expected from the use of computers for automation and operator aids. Over the past two decades, the Canadian nuclear power plant vendor AECL (Atomic Energy of Canada, Ltd.) and utilities have demonstrated digital instrumentation and control systems to be effective in monitoring and controlling the CANDU (Canada

Deuterium-Uranium) nuclear power plants and in providing the degree of safety margin needed to protect both the plant and the public. The Canadian experience of improved performance and increased safety, while using commercial-grade computers and components, has demonstrated a cost-effective approach to the implementation of digital systems in both control and safety systems. The ability of these digital systems to detect impending failures and initiate a fail-safe action is a significant safety issue that should be of special interest to utilities and regulatory authorities around the world.

CONCLUSIONS

Canada has by far the most experience in the world with advanced (digital) instrumentation and control (I&C) systems for nuclear power plants. Darlington, the newest CANDU plant, has digital systems in almost 100% of its control systems and over 70% of its plant protection system. The control and plant protection systems use commercial-grade digital components, qualified in much the same way analog components are qualified, plus testing for electromagnetic interference and seismic qualifications. AECL, in plants outside Ontario, has had 36 programmable logic controllers (PLCs[1]) in operation in three CANDU plants since 1982 (over 300 system years) with no incidents of spurious plant trips due to any kind of PLC malfunction and no incidence of failure to trip when required. When a digital component or system begins to degrade, the self-checking features immediately put the system in trip mode and alert plant personnel, who in all cases have been able to identify and replace the faulty component within two hours. This performance has been achieved using a software quality assurance program that meets the IEEE and IEC standards, but does not include extraordinary measures to prevent common mode software design errors.

It is very difficult to compare the status of I&C systems in Canadian and U.S. nuclear facilities, because they have developed under very different technical and regulatory environments. The CANDU reactors are large because they use natural uranium. Digital control systems are required to operate at the rated power levels, where xenon has an influence on the neutron flux distribution and stability. U.S. nuclear reactors use enriched uranium and are substantially smaller. As a result, the influence of xenon on the spatial distribution of the neutron flux is limited, and analog control systems are deemed to be adequate. Necessity and sound engineering have made digital control systems acceptable in the CANDU reactors.

Extensive experience with digital systems in control of early CANDU reactors demonstrated the inherent advantages (reliability, flexibility, stability, etc.). Hence, it was a logical next step to introduce digital systems into safety systems. As a result

[1] The terms "PLC" (programmable logic controller) and "PDC" (programmable digital controller) are often used interchangeably, depending on the context.

of Canada's very favorable experience in using digital systems in both control and safety systems, the percent of such systems using digital technology has grown rapidly (see Figure 25). The ability to easily automate many test and calibration functions, to the point of using every other cycle for testing in safety systems, has resulted in significant advantages and safety improvements to the CANDU power plants over plants using analog systems. Indeed, the Canadian use of digital safety systems in nuclear power plants, without analog backup systems, is almost unique in the world.

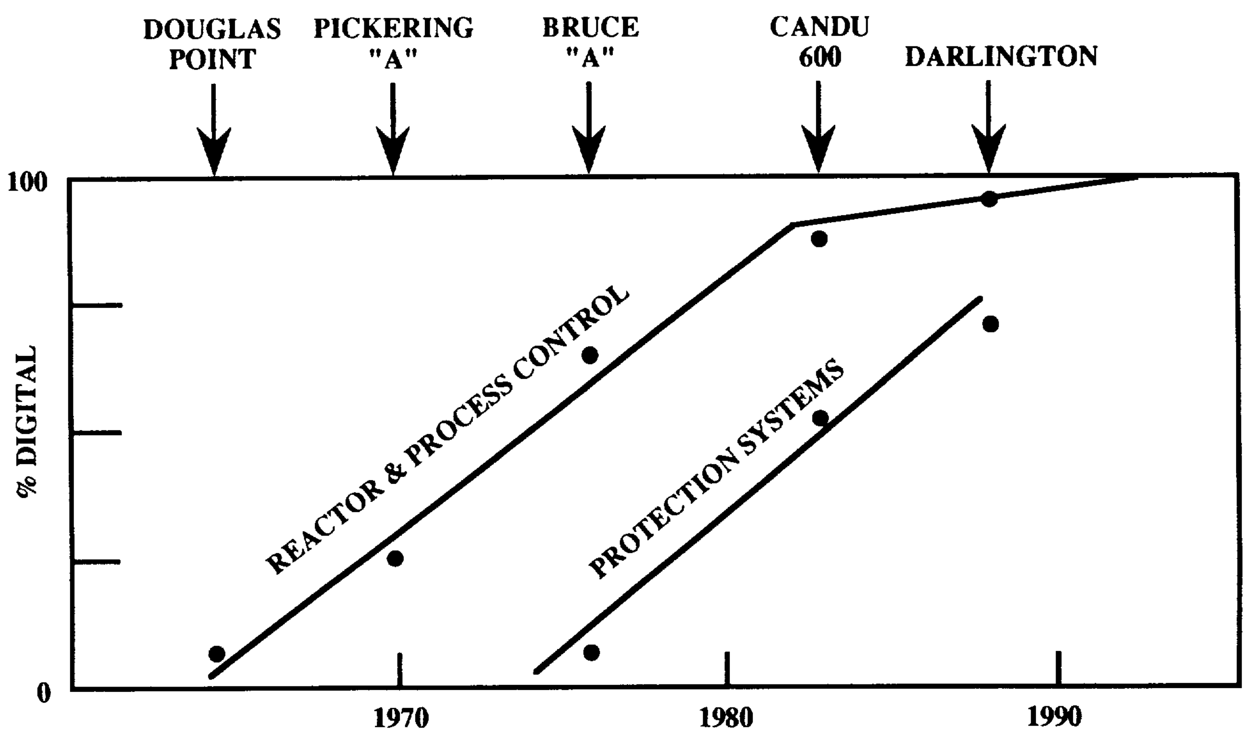

Figure 25. Trend Toward Digital Control and Protection in CANDU Pressurized Heavy Water Reactor Nuclear Steam Supply Systems (PHWR NSSS). (Source: Atomic Energy of Canada, Ltd.)

In the United States, digital control was not originally deemed a necessity to operate nuclear power plants safely, and vendors utilized traditional analog systems for both control and safety. Once the overall design of power plants evolved to a certain level, the rapid growth of the industry (over 100 plants in 25 years) often made regulatory approval of changes difficult. By the time the advantages of digital systems became apparent to U.S. vendors and utilities, they were a decade or more behind the Canadians as far as experience with digital systems was concerned. Although there are exceptions, most U.S. nuclear I&C vendors today utilize digital systems that emulate the function of the analog systems they replace, and make the units *plug compatible*, physically, electronically and functionally.

Table 27 compares I&C systems in U.S. and Canadian nuclear power plants. For the reasons discussed above, the I&C systems in the Canadian plants are well ahead of those in the United States in most categories. Furthermore, there is little expectation that the situation will change significantly in the near future. (However, a recent Electric Power Research Institute (EPRI) initiative could change this situation substantially by the end of the century.) A major contributing cause is that there have been no new orders for nuclear power plants from U.S. utilities since the accident at Three Mile Island. Nevertheless, there is considerable effort being expended in the United States for I&C systems for the next generation of nuclear power plants (SBWR, AP-600, ALWR, and MHTGR). Since many U.S. vendors are associated with foreign vendors (Combustion Engineering is owned by ABB Atom, B&W is 51% owned by Framatom, and General Electric has a very close association with both Toshiba and Hitachi), it is expected that much of the European and Japanese experience in advanced I&C could be available to U.S. vendors for the next generation of nuclear power plants in the United States. Canadian I&C technology is also available in the United States, and AECL is an active competitor in bidding for digital I&C systems (e.g., digital feedwater control systems) in U.S. nuclear plants. AECL has also submitted a letter of intent to the U.S. Nuclear Regulatory Commission to submit the 450 MWe CANDU-3 design for standard design certification under 10 CFR part 52.

The hypothesis that *properly introducing digital systems increases safety* has been supported by the Canadian experience. The safety significance of the performance of digital vs. analog systems is a critically important issue, and it undoubtedly will become more important with aging and obsolescence of hardwired analog components. The use of flexible digital systems permits reallocation of the testing function to the computer, with an attendant increase in reliability and safety. Mounting evidence of the superior performance of digital systems provides a basis for all regulatory authorities to allow utilities worldwide to introduce digital-based systems where it makes sense to do so. The most important step needed for such action is a clear definition by regulatory authorities of the validation and verification requirements and acceptance criteria for both digital hardware and software.

TABLE 27
Comparison of Canadian and U.S. Nuclear I&C Systems
(See Key, p. 44)

	RESEARCH		DEVELOPMENT		IMPLEMENT.	
	Status	**Trend**	**Status**	**Trend**	**Status**	**Trend**
Digital Instrumentation	0	=	+	->	+	->
Man-Machine Interface	0	=	+	=	+	->
Advanced Control	0	=	0	->	+	->
Control Room Design	+	->	+	->	+	->
Regulatory Acceptance	+	->	+	->	+	->
Artificial Intelligence	0	=	+	->	+	->

EUROPEAN NUCLEAR INSTRUMENTATION AND CONTROLS

December 1991

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BACKGROUND

A panel of U.S. specialists conducted a study of instrumentation and controls (I&C) technology used in nuclear power plants in Europe. These findings relate to the countries visited and to pressurized water reactor (PWR) nuclear power plants. The panel visited France, Germany, the Soviet Union, Czechoslovakia, and Norway.

SUMMARY

The U.S. is behind in the application of advanced instrumentation and controls in nuclear reactors. All European countries that operate nuclear power plants, as well as Canada, Japan, and the U.S., are moving toward use of digital computers, especially microprocessors, in information and control systems. The operator's role varies by country. Japan and Germany are moving toward a high degree of automation, whereas in France the emphasis is on computer-generated procedures with the decision to enable being made by skilled operators. In U.S. and Soviet plants, the emphasis is on using digital systems to help the operator identify problems, decide on the appropriate corrective actions, and aid in the execution of those actions.

The U.S. is behind in the development and experience of using digital systems in nuclear plants, and in the use of fault diagnosis and signal validation systems. The hardware for digital systems used in all countries comes mostly from U.S. computer companies, but the lack of deployment of digital systems in U.S. nuclear plants has

kept the U.S. behind in developing experience in computer system architecture for nuclear I&C systems. The Europeans are also ahead in the use of computer assisted software engineering (CASE) tools and in the development of standards. European instrumentation for nuclear power plants is similar to that in the U.S., although some special instrumentation is being developed.

An advantage to being behind is that the U.S. can learn from the mistakes of those ahead. The digital systems' programmability can entice the user to add complexities that can evolve into problems. Efforts must be made to maintain simplicity.

Qualitative Comparisons

The panel made a qualitative comparison of the U.S. and Europe in instrumentation and controls for nuclear power plants. Table 28 shows the standing of the countries visited relative to the U.S.

TABLE 28
Europe Compared to the United States in Nuclear Power Plant I&C
(See Key, p. 44)

	BASIC RESEARCH		ADVANCED DEVELOPMENT		PRODUCT IMPLEMENT.	
	Status	Trend	Status	Trend	Status	Trend
Control Room Design	+	=	+	->	+	->
Analog-Digital Trans.	0	=	+	->	+	->
Support Systems	+	->	+	->	+	->
Control Strategies	+	=	+	->	+	->
Architecture	-	<-	-	<-	+	->
Instrumentation	0	=	0	=	0	=
Standards & Tools	+	=	+	=	+	->

As shown in Table 28, Europe is ahead of the U.S. and moving ahead further in implementation of products in all seven categories, with the possible exception of instrumentation. In the area of advanced development, Europe is also ahead except for architecture and instrumentation. In basic research, Europe is ahead in four of the seven categories; however, for analog-to-digital transition and for instrumentation, the U.S. is about equal, and the U.S. is ahead in architecture. In other words, U.S. computers are being purchased and utilized in all countries that the panel visited, but the development and implementation of the computers for nuclear power plant instrumentation and control is more advanced in Europe.

Evolution of Automation in Nuclear Power Plants

There is a move in every country designing nuclear power plants to improve the plant's availability, safety, ease of operation and/or acceptability by the public and regulators. The appropriate balance of automation and manual operation is the subject of considerable debate in the U.S. and Europe today. Most researchers agree that today's technology would support digital automation of all the major systems in a power plant. One of the concerns, however, is how to verify and validate the required software.

In the U.S., the transition from today's nuclear control systems to more automated future designs is likely to occur in phases. One of the purposes of this study was to determine where the European concepts were in terms of evolution of I&C. The U.S. transition may be described in terms of four levels (see Fig. 26). The solid diamonds represent a plant that is operational; empty diamonds represent plants that are not yet operational.

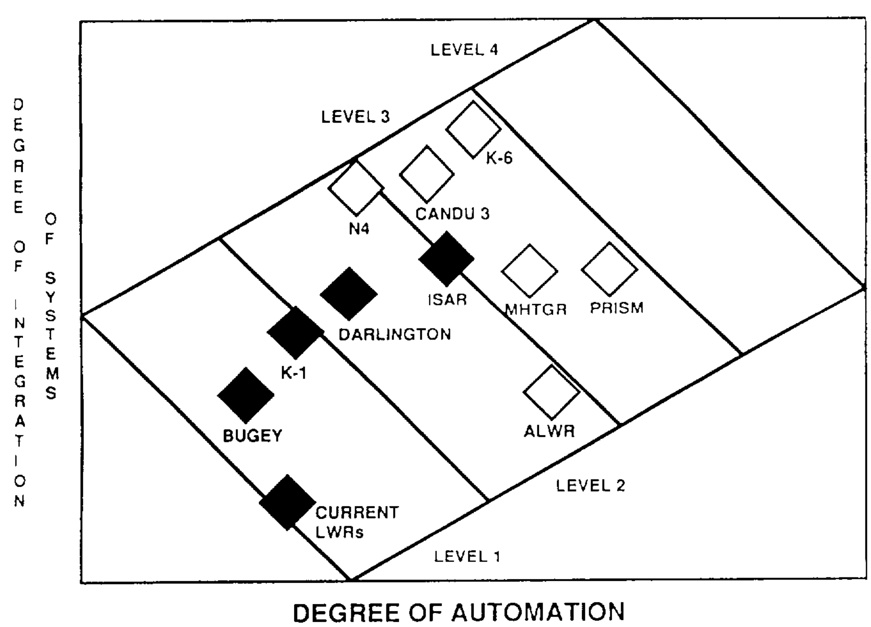

Figure 26. Nuclear Plant I&C State of the Art

In level 1, some of today's analog controllers will be replaced with more reliable digital controllers performing basic proportional-integral-differential (PID) control. This phase of evolution is already under way in the U.S. Generally, digital implementations of control systems on U.S. reactors have been one-for-one replacements of the original analog systems and have not taken full advantage of recent technological developments. As the chart shows, the panel thinks U.S. LWRs are in the beginning of level 1. The French plant Bugey is a little further advanced but also in level 1, while the Japanese Tokyo Electric Power Company's Kashiwazaki-1 and -2 are at the interface with the next level.

Level 2 of the predicted transition will include automation of routine procedures like plant start-up, shut-down, refueling, load changes, and certain emergency response procedures. Significant assistance will be given to the operator through computer-based expert systems and control room displays of plant status. Control will be implemented with digital technology. The newly completed Darlington plant in Canada is at level 2, as are the U.S. Advanced Light Water Reactor (ALWR) and the newest French plant (the N4 class). The German ISAR-II is between levels 2 and 3.

Level 3 is a significant advance toward automation with the operator interacting with and monitoring an intelligent, adaptive supervisory control system. Smart sensors will be expected to validate signals and communicate with fault-tolerant process controllers. Control strategies will be adaptive, and very robust to off-normal conditions. Advanced LMR (PRISM) concepts and MHTGR concepts being studied by the U.S. DOE will have these capabilities. The newest Canadian concept, the CANDU 3, is placed in this category, as is the Japanese Advanced Boiling Water Reactor (ABWR).

Level 4 would be characterized as total automation of the plant, with an intelligent control system aware of operational status and in interactive communication with the operator to keep him apprised of any degraded conditions, likely consequences of these conditions, and possible strategies for minimizing deleterious consequences. At this point most plant functions will be automated and robotized including maintenance and security surveillance.

The control and information system will be an integral part of not only the total plant design, but also the national network of commercial power plants. The control system computer will learn from the network relevant information concerning other plants and component operational experience, and will alert the operator if that experience is relevant to his plant. No U.S. design has gone this far in incorporating advanced technology and automation. The Japanese Frontier Research Group on Artificial Intelligence is working on conceptual definition of a plant of this type. In the evolution of higher levels of automation, the designers will try to improve all aspects of nuclear power plants, including safety and reliability. Progress in all countries should build on successes and experiences in other countries.

NUCLEAR POWER IN JAPAN

October 1990

Kent F. Hansen, Massachusetts Institute of Technology (Panel Chair)

Wallace B. Behnke, Commonwealth Edison (retired)

Sheldon B. Cousin, Stone & Webster Engineering Corporation

Ersel A. Evans, Battelle Pacific Northwest Laboratory

Donald R. Olander, University of California at Berkeley

Victor H. Ransom, Purdue University

James D. White, Oak Ridge National Laboratory

SUMMARY

The JTEC panel on nuclear power in Japan examined the status and direction of nuclear power-related research and development in Japan in six areas: the nuclear fuel cycle, nuclear materials, instrumentation and control technology, CAD/CAM, nuclear safety research, and nuclear plant construction. The panel based its report on a review of literature and a one-week trip to Japan in January 1990 during which panel members visited numerous Japanese laboratories and other nuclear facilities. The panel found that the nuclear power industry in Japan was at an advanced state of development; Japan had become technologically self-sufficient. Long-term goals of the Japanese program included closure of the complete fuel cycle and pursuit of the liquid metal fast breeder reactor as the future base system.

The Context of Nuclear Power in Japan

The panel found the Japanese program of nuclear power research and development to be blessed with many benefits, including a strong, consistent federal commitment to nuclear power; an adequate supply of R&D funds; a stable set of priorities for R&D; a well-developed distribution of responsibilities between the public and private sectors; and a highly capable group of agencies engaged in R&D. In 1955, Japanese policymakers, recognizing that their nation lacked indigenous energy sources, made a commitment to develop nuclear power as the most likely vehicle for achieving a self-reliant electric energy supply system. This key decision has remained a cornerstone of Japanese energy policy.

The structure in which the nuclear program evolved included a well-developed long-range plan, a clear distribution of obligations among plan participants, a strong utility industry capable of constructing and operating plants and learning from its experiences, a strong supply sector capable of designing plants and developing the designs toward the ultimate goal, and a commitment to adequate funding for nuclear R&D to ensure the quality and completeness of the effort. Other factors became important, but none were displaced or downgraded. Public opinion grew negative toward nuclear power, particularly after Chernobyl. Safety grew increasingly important in Japan. The industry devoted considerable resources to ensuring safe operations and conducting safety research. But this added emphasis came as an addition to ongoing efforts, not as a replacement.

The Research and Development Focus

The Japanese nuclear research program is dominated by light-water reactor (LWR) technology, the nuclear fuel cycle, and advanced reactors. These three areas consumed about $1.5 billion in 1989 R&D funds. LWR technology is supported mainly by the electric utilities and the vendors. Research focuses on improvements in plant safety and in economics. They are working to develop improved, extended burnup fuels for nuclear power plants. Another important area is controls and instrumentation, including advanced control room design. Longer-range research focuses on developing advanced LWRs of both the boiling water reactor (BWR) and pressurized water reactor types.

Closure of the nuclear fuel cycle is a priority for the Japanese. They do not wish to rely on external suppliers for enrichment services or reprocessing services. This R&D is being done primarily at government research laboratories. Government expenditures on the fuel cycle were $280 million in 1989, and the utility contribution was $200 million. The largest expenditure, about $180 million, was for reprocessing. The Japanese, foreseeing a need for plutonium in their future breeder economy, are committed to having all of the reprocessing technology developed and in place in advance of the widespread deployment of fast breeder reactors (FBRs). The long-term goal of the fuel cycle research is complete self-sufficiency, with the ability to handle enrichment, fuel fabrication, reprocessing, and waste storage; the near-term goal is to require only uranium ore and to be self-sufficient in all other aspects of the cycle.

The largest nuclear R&D expenditures are for the advanced reactor program, which accounted for $775 million in 1989. The FBR received $650 million, or nearly 85 percent of the total advanced reactor budget. The key project is the *Monju* reactor. Similar in design to the Clinch River Breeder, the *Monju* reactor is a 280 MWe liquid metal fast breeder reactor. At the time of the panel visit, construction was about 80 percent complete, with initial criticality scheduled for 1992.

SPECIFIC R&D COMPARISONS

Nuclear Fuel Cycle

Japan is committed to the complete fuel cycle -- uranium mining, conversion, enrichment, irradiation, reprocessing, and waste disposal. Unlike the U.S., Japan includes plutonium utilization and uranium recycling in its nuclear program as a matter of national policy. As part of the effort to develop a complete fuel cycle, the Japanese participate aggressively in international cooperative efforts. Such efforts encompass university and national laboratory programs and cooperation with government and industry organizations worldwide to achieve the best engineering and most effective commercialization for all parts of the fuel cycle.

Nuclear Materials

Japanese materials research began from a base that incorporated much initial U.S. research. Japan's LWR plants have higher energy availability than U.S. plants for several reasons, including improved materials. Because of their careful control of water chemistry and materials selection, the Japanese have had very few problems with Intergranular Stress Corrosion Cracking in their BWRs or steam generator problems in their PWRs. The Japanese are conducting research on extended-life fuels for both the BWRs and PWRs with the objective of extending the operating cycle to eighteen months without suffering fuel failures. Meeting this goal would increase plant availabilities to over 80 percent. The Japanese also have demonstrated interest in load following, and considerable effort is underway to develop and test long-lived fuel that could be cycled in power. Advanced reactor materials research is primarily directed toward breeder fuels and work related to U-Pu fuels for use in LWRs. A small amount of research is being done on high-temperature, gas-cooled reactor fuels.

Instrumentation and Controls

Application of improved instrumentation and controls (I&C) to nuclear power plants appears to be much farther along in Japan than in the U.S. The panel attributed this progress to Japan's long, productive R&D commitment and its healthy industry. The Japanese have demonstrated particular interest in several specific technologies. National labs, vendors, and universities have vigorously pursued work in artificial intelligence and expert systems, with applications in component diagnostics and operator support systems. Fiber optics are being used in some existing plants and will be used in new plants. The subject of man-machine interfaces was receiving a great deal of attention in Japan. Research was focusing on clarification of human behavioral characteristics, systematic applications of behavioral information, and organizational and systems aspects of human error experience.

The panel found no evidence that Japan was ahead of the U.S. in basic research. Indeed, the U.S. retains a lead in several areas, including information theory and advanced computer languages.

CAD/CAM Technology

CAD/CAM technology has reached comparable levels of development in Japan and the United States. Both nations are using CAD/CAM to develop three-dimensional models of conceptual designs of new plants. Common databases are being used by different designers for technical areas such as reactor physics, thermal hydraulics, and piping. The Japanese nuclear power program provides the opportunity to incorporate application into the design and fabrication activities because real plants are being developed and built.

The Japanese are actively pursuing further development of CAD/CAM systems. Near-term goals include full 3-D design capability, common databases, and interactive communication with designers. Longer-term goals include detailed design, procurement documents, and manufacturing specifications. Databases would be generated for the as-built system for use during plant operation. The panel felt that the United States remained the leader in conceptualizing and developing software, CAD/CAM systems, database management programs, system integration, and nonnuclear-related applications. The tendency in Japan was to purchase completed packages and adapt them for use in specific applications.

Nuclear Safety

Concern about nuclear plant safety has permeated the design and operation of nuclear plants in both the U.S. and Japan. However, there are significant differences between the two nations in safety R&D. In Japan, safety is seen as a matter of such great importance that even minor events must be avoided. As a consequence, much safety R&D in Japan focuses on operational issues. In the U.S., the key element of safety research is severe accident scenarios.

Japan's government R&D is closely tied to support of regulatory activities. Large-scale test facilities are maintained for research in thermal hydraulics, two-phase flow, and seismic testing of components and systems. Results from the research are used to validate computer models of systems behavior. In general, the panel found the U.S. ahead of Japan in conceiving and developing such codes. However, the Japanese enhance the codes more completely, using experimental data for validation. The Japanese emphasize human factors in nuclear safety R&D. Vendors use research results to improve control room design and support systems evaluation. The Japanese have been slow to enter the field of probabilistic safety assessment because of the view that, since severe accidents will not occur at their plants, they have no need for Level 3 capability. Nevertheless, the issue was under active study at the time of the panel's visit. In Japan much applied AI work is conducted by federal labs, utilities, and vendors, though there is little coupling to academia.

Nuclear Power Plant Construction

Japan has been more successful than the U.S. in holding down the cost of constructing nuclear power plants. Institutional, regulatory, and cultural differences account for the higher cost of U.S. construction. Japan has also achieved effective nuclear regulation with far less disruption and delay in construction and licensing than has occurred in the United States. Japan's improvements in the construction process include (a) shop fabrication of very large modules that are shipped to the site and installed; (b) substantial completion of detailed engineering drawings before start of construction; (c) fully computerized, comprehensive construction sequence plans; and (d) comprehensive quality assurance programs with detailed inspection, but performed to minimize interference with construction. Japan was at an early stage in applying robotics to field construction at the time of the panel's visit.

Japan spends more on construction-related R&D than the U.S., and is more effective at transferring new technology into construction. Japan's nuclear industry is applying the latest design improvements and new technology from R&D to construction. The only opportunities for U.S. manufacturers and A/E firms to apply developments have been in overseas projects, such as those in Korea. Without new construction activity, the U.S. could lose parity with Japan in construction-related R&D and associated infrastructure. These trends could lead to higher electricity prices for U.S. consumers and an increased competitive disadvantage for U.S. manufacturers in global markets.

VI. BIOTECHNOLOGY

BIOPROCESS ENGINEERING IN JAPAN

May 1992

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BACKGROUND

The goals of the JTEC report on bioprocess engineering were to assess the status of bioprocess engineering and biotechnology, as well as to compare trends in the U.S. and Japan in areas relating to the biotechnological processes. The panel also sought to assess major differences between the U.S. and Japan in bioprocess engineering research and development.

SUMMARY

In Japan, biotechnology activities occur primarily in large companies; few if any small biotech start-ups are apparent. Many Japanese companies with major efforts in biotechnology began in other fields of manufacturing. The product portfolio of the present Japanese biotechnology market is similar to that in the United States. Total sales increased 48 percent in 1990, to a total of $2.187 billion.

Molecular Biology

Japanese research in molecular biology and biological sciences is similar to that in the U.S. Japanese research is directed towards both prokaryotic and eukaryotic organisms. However, the panel did not notice any novel prokaryotic expression system under development in Japanese laboratories. Systems used for protein expression in prokaryotic organisms are similar to those employed in the United States. There is a very noticeable emphasis in Japan on research using eukaryotes, particularly in animal and mammalian cell systems. Lastly, the dominant opinion in Japan is that, for human therapy, murine antibodies will not be the major targets. Instead, humanized antibodies will be their choice.

Upstream Bioprocessing

Bioprocess engineering R&D philosophy in Japanese laboratories dealing with upstream technologies, such as recombinant protein production in bacteria and animal cells, differs from that in the U.S. The Japanese do not appear to emphasize the use of basic engineering principles for process development or process scale-up. Instead, the emphasis is much more biological, including screening, selection, and medium development. Also, automation in upstream technology is being developed extensively to reduce the human interface. One observation concerning Japan's upstream manufacturing technologies is the similarity to what they have acquired or licensed from the U.S. In the long run, Japan could move ahead of the U.S.

Downstream Bioprocessing

In downstream processing, the panel saw no new advances in product isolation and purification. Chromatographic media and methodology development is being carried out by Japanese companies that supply chemicals, biologicals, equipment and process expertise to the biomanufacturing sectors. There is noticeably intense activity in the area of in-vitro protein refolding. Many industrial laboratories have a heavy focus on protein refolding, but the panel learned little about their progress.

University Training and Education

Research training and education for biotechnology and bioprocess engineering in Japanese universities is different from that in the U.S. Most Japanese research and educational programs are not driven by engineering principles and are located in other disciplines. Japanese university programs focus on applied research, which contrasts with the basic orientation of U.S. efforts. Lastly, the involvement of industrial and foreign investigators in Japanese university laboratories is extensive.

Bioprocess Engineering

Bioprocess engineering R&D by Japanese companies is not driven by generic engineering principles, a situation similar to that found at Japan's universities. Process development activities are often performed directly at the manufacturing site rather than within the company's R&D laboratories.

Many Japanese government agencies support and perform basic and applied research in bioprocess engineering and biotechnology. The agencies help identify directions for Japan's biotechnology R&D. Government support for R&D is often long-range, with a typical planning horizon of ten years. The government has fostered development of an international network in advancing Japan's biotechnology program.

Future Trends

Japanese industry is focused on molecular biology efforts to use prokaryotic organisms for producing therapeutic proteins. Japanese industry has targeted recombinant products that the U.S. has already developed. It is evident that Japan plans to be a world player in the use of prokaryotes to compete in the pharmaceutical market.

The Japanese biotechnology industry has targeted animal cell cultures as vehicles for the production of therapeutic proteins. Due to their acquisition of U.S. cell culture processes, the Japanese are also in an excellent position to improve existing manufacturing methods. Japan's bioprocess engineering efforts will be competitive with and could even surpass those of the U.S. in the years to come.

There is a large research effort in Japan on protein engineering. However, the basic principles, software, and hardware presently employed are mostly from abroad. Japan has traditionally dominated many areas of bioprocess engineering and biotechnology; there is no sign that they have decreased their efforts in these areas. However, there is no counterpart when compared with the U.S. in the development of those potentials in biotechnology manufacturing systems. The Japanese biotechnology sector is rapidly entering into bioprocess manufacturing by using know-how either acquired or licensed from the U.S. This will reduce process development time and costs significantly, and speed Japan's market entry.

Qualitative Comparison Between the U.S. and Japan

The JTEC panel prepared a qualitative comparison summarizing the present status and future trends in the U.S. and Japan in various areas relating to biotechnological processes (see Table 29).

TABLE 29 – Japan Compared to U.S. in Biotechnology Processes

(See Key, p. 44)

	Status	Trend
MOLECULAR BIOLOGY		
product discovery	–	<–
genetics	–	<–
MICROBIOLOGY		
screening	+	–>
strain development	+	–>
fermentation technology	+	–>
UPSTREAM BIOPROCESSING		
process development	0	=
engineering science	–	<–
monitor & control	+	–>
bioreactor scale-up	–	<–
DOWNSTREAM BIOPROCESSING		
solid-liquid separation	0	=
cell disruption	0	=
membrane technology	–	=
affinity chromatography	–	<–
ion exchange chromatography	–	=
size exclusion chromatography	0	=
HPLC	0	=
protein refolding	–	=
BIOCATALYSIS		
enzyme discovery	+	–>
enzyme science	–	–>
enzyme engineering	+	–>
industrial implementation	+	–>
OTHER MANUFACTURING ISSUES		
containment	–	<–
cGMP	–	<–
technology management	+	–>
EDUCATIONAL STATUS		
basic training	–	<–
applied training	+	–>
engineering vs. science	–	<–
faculty biotech knowledge	–	=
UNIVERSITY/GOVERNMENT/INDUSTRY INTERACTION		
university-industry	+	–>
university-government	+	–>
government-industry	+	–>
overall	+	–>

APPENDICES

A. PROFESSIONAL BACKGROUND INFORMATION

JTEC/WTEC STAFF BIOGRAPHIES

The JTEC/WTEC staff at Loyola College includes: Dr. Michael DeHaemer, Principal Investigator and Director; Dr. R.D. Shelton, Co-Principal Investigator and ITRI Director; Mr. Geoff Holdridge, JTEC/WTEC Staff Director and Series Editor; Mr. Bobby Williams, Assistant Director and JTEC/WTEC Comptroller, Ms. Aminah Batta, Editorial Assistant, and Ms. Catrina Foley, Secretary. Biographies of the Loyola staff are included below.

Aminah Batta

Aminah Batta is Editorial Assistant for JTEC/WTEC reports and other publications. In this capacity, Ms. Batta compiles draft reports, implements editing changes, assists in graphics layout, and acts as liaison between panel members and the JTEC/WTEC office in matters pertaining to report preparation and publication. Prior to holding this position, Ms. Batta worked for over two years as the JTEC/WTEC Administrative Assistant, before resigning to continue her education.

Ms. Batta received her B.S. degree in African Cultural History and Computer Science from the State University of New York at Brockport and her M.S. degree in African History from Morgan State University in Baltimore, Maryland. She is currently working towards her Doctorate in Latin American/Caribbean History at Howard University in Washington, D.C.

Michael DeHaemer

Michael J. DeHaemer is Principal Investigator and JTEC/WTEC Director. He has been associated with the program since 1991, having joined as WTEC Director when the scope of technology assessment expanded to Europe and Russia. On the faculty of the Sellinger School of Business and Management at Loyola College, Dr. DeHaemer is Chair of the Information Systems and Decision Sciences Department and teaches Information Technology and Strategy, Expert Systems, and Human-Computer Interface Design. He is founder and Director of the Lattanze Human-Computer Interface Laboratory and is a research specialist in speech systems for computer input and output. His research interests also include business applications of artificial intelligence and technology assessments.

Dr. DeHaemer is a former Captain in the U.S. Navy and nuclear submarine commander. He received a B.S. in Physics from the University of Notre Dame, M.S. in Operations Research from the Naval Postgraduate School, and holds an M.B.A., an M.S. in Industrial Engineering and a Ph.D. in Management Information Systems from Rensselaer Polytechnic Institute.

Catrina Foley

Catrina Monique Foley presently holds the position of Secretary in the JTEC/WTEC office. She has been part of the JTEC/WTEC team since 1991.

Ms. Foley graduated from Palmer Business School in Baltimore, Maryland in 1991, where she received a certificate of achievement in Office Automation. In 1988 she graduated from Robert D. Edgren High School of Misawa, Japan. Currently an undergraduate student at Baltimore City Community College in Baltimore, MD, Ms. Foley is planning to transfer to a four year college to obtain her B.A. degree in Japanese Linguistics.

Geoffrey Holdridge

Geoffrey M. Holdridge, as JTEC/WTEC Staff Director, is in charge of the day-to-day operation of the JTEC/WTEC program, including both the Loyola staff and JTEC/WTEC's off-site contractors. As JTEC/WTEC Series Editor, Mr. Holdridge is also responsible for final editing, review reconciliation, quality control, and production of all JTEC/WTEC final reports. Mr. Holdridge has been managing JTEC and WTEC operations at Loyola in various capacities since 1989. Prior to coming to JTEC, Mr. Holdridge served as a special assistant to the Division Director for Emerging Engineering Technologies (EET) at NSF, where he helped manage the JTEC program at NSF. In an earlier assignment in the Division of Policy Research and Analysis at NSF, Mr. Holdridge was responsible for researching and drafting reports to the Office of Management and Budget (OMB) on renewable energy and energy conservation technologies. In a special assignment for the EET Division in 1987-88, Mr. Holdridge prepared a report on the long-term industrial consequences of a loss of U.S. competitiveness in the commodity memory chip market as part of NSF's contribution to an inter-agency study on the status of the U.S. semiconductor industry. Mr. Holdridge has also worked as Staff Consultant for the National Academy of Sciences' Panel on the Impact of National Security Export Controls in International Technology Transfer (also known as the Allen Panel). Mr. Holdridge holds a B.A. in History (specializing in 20th Century East Asia) from Yale University.

R.D. Shelton

Robert Duane Shelton has led international technology assessments since 1984, as science policy analyst at NSF, and now as ITRI Director. He is also program manager of the U.S. Department of Transportation contract funding the new ITRI

Transportation Technology Evaluation Center (TTEC). His degrees are in electrical engineering from Texas Tech (MCL), MIT (as NSF Fellow), and University of Houston. Dr. Shelton worked at Texas Instruments, Inc. on electronics R&D, and at NASA in performance analysis of the Apollo space communications system and of TDRSS -- the system currently used for Shuttle communications. He was a professor at the University of Houston, University of Louisville, Texas Tech University, and now Loyola College. During this time, he has served as principal investigator on 35 grants, has written 58 technical papers and one book, and has chaired 57 M.S. and 3 Ph.D. thesis committees. He has chaired academic departments of applied mathematics, computer science, and now the Department of Electrical Engineering and Engineering Science at Loyola. His current research interest is science policy analysis: international technology assessment, high-technology trade problems with Japan, and national strategies for engineering education.

Bobby Williams

Bobby A. Williams, JTEC/WTEC Assistant Director and Comptroller, joined the JTEC/WTEC staff in early 1990. Prior to that, he worked in Washington as an economist. He spent several years as a branch chief, responsible for research and reporting on both industrial and macroeconomic developments in China. Publications include an assessment of China's oil industry for the Joint Economic Committee of Congress.

Mr. Williams holds B.A. and M.A. degrees from Berea College and Washington University (St. Louis), respectively, where he was an all-but-dissertation Ph.D. candidate in economics. His professional interests center on the Japanese and Chinese economies. More generally, he is interested in economic history, particularly the roles of technical and institutional change as agents of growth.

OTHER CONTRIBUTORS/CONTRACTORS

In addition to the Loyola staff, ITRI depends on the services of a number of other contributors to the program. These people provide assistance and advice to the program through subcontracts.

Dr. George Gamota, Senior Advisor to JTEC/WTEC, is the Director of the Mitre Institute, the Mitre Corporation. His experience includes senior R&D positions in industry, academia and government. He was Director for Defense Research in the Carter Administration. He has also served as Professor of Physics and Director of the Institute of Science and Technology at the University of Michigan, and, prior to that, as a Research Scientist at Bell Laboratories.

Mr. Cecil Uyehara of Uyehara International Associates and Mr. Gene Lim of SEAM International provide advance work in Japan under contract to JTEC. Mr. Joseph

Conn, Mr. John Mikula, and Mr. Henry Gillen of American Trade Initiatives, Inc. provide advance services in Europe and the former Soviet Union. Finally, Arnett Holloway and Karen Hagerman are currently providing manuscript editing services.

LIST OF SPONSORS

Paul Herer, Senior Advisor for Planning and Technology Assessment in NSF's Engineering Directorate, is in charge of the JTEC/WTEC program at NSF. The 15 JTEC and WTEC studies active in 1992 and 1993 also boasted sponsorship by several other programs at NSF and by 11 other branches of the Federal Government. The representatives of these agencies with whom we worked most closely, and who assisted us in defining and organizing the 1992 and 1993 studies, are listed below. Institutional affiliations listed are those that applied at the time of the studies.

Robert Billingsley, Defense Technical Information Center
Norman Caplan, NSF
Y.T. Chien, NSF
Ken Chong, NSF
Joseph Clark, NTIS
Jerry Covert, Wright Patterson Air Force Base
Steven Cross, ARPA
Andrew Crowson, Army Research Office
Ramon DePaula, NASA Headquarters
Christine E. Fisher, Department of Defense
Jillian Evans, NASA Goddard
John Evans, NASA Headquarters
Craig Fields, DARPA
Don Freeburn, Dept. of Energy
Kaigham J. ("Ken") Gabriel, ARPA
Phyllis Genther-Yoshida, Dept. of Commerce
Lance Glasser, ARPA
Frederick Heineken, NSF
Frank Huband, NSF
George Jordy, Dept. of Energy
Tom Kusuda, Dept. of Commerce
Charles Lee, Air Force Office of Scientific Research
Marshall Lih, NSF
Louis Martin-Vega, NSF
Paul Maupin, Dept. of Energy
Henry McGee Jr., NSF
David McLaine, Wright Patterson Air Force Base
James McMichael, Air Force Office of Scientific Research
Howard Moraff, NSF
Nicholas Naclerio, ARPA
David Nelson, Dept. of Energy

Emily Rudin, NSF
Linton Salmon, NSF
David Slobodin, ARPA
Marko Slusarczuk, DARPA
Charles Stuart, ARPA
Dick Urban, ARPA
Charles Wayne, DARPA
Gio Wiederhold, ARPA

OTHER PARTICIPANTS

In addition to the funding sponsors listed above, JTEC and WTEC studies also included non-funding participation by 10 other Federal agencies and private institutions, as indicated in Table 30. The individuals named in the table participated in foreign site visits for the listed studies, but were neither sponsors nor panel members. Funding from their parent organizations was in most cases limited to support for their travel with the panel. However, in many cases the participation of these people was an invaluable addition to the study, both for their unique institutional perspectives and for the many excellent site reports they contributed to our final reports.

TABLE 30
Other Organizations and Individuals Participating in JTEC/WTEC Studies 1992 and 1993

JTEC/WTEC STUDY	ORGANIZATION(S) PARTICIPATING	NAMES
Machine Translation	Scan C2C, Inc.	Tom Satoh
Bioprocess Engineering	National Institutes of Health Department of Agriculture National Research Council	Marvin Cassman Nelson Goodman Oscar Zaborsky
Database	Office of Naval Research	David Kahaner
Displays (Japan)	Dept. of Commerce/ITA NASA-Ames Research Center	Heidi Hoffman James Larimer
Knowledge-Based Systems	Office of Naval Research	David Kahaner
Polymer Composites Manufacturing	Army Research Laboratory National Science Foundation	Dana Granville Bruce Kramer
Research Submersibles	Office of Naval Research	James Sampson
Electronic Packaging	Jet Propulsion Laboratory NIST	Phillip Barela George Harman
FSU Displays	McDonnell-Douglas Aerospace	Robert Rice

LIST OF JTEC/WTEC PANELISTS, 1992-94

JTEC and WTEC panelists are also chosen for their unique backgrounds, with a view to achieving a balance of institutional perspectives in the panel membership. The following list of panelists from JTEC and WTEC studies active between 1992 and February of 1994 demonstrates the extent to which we have achieved this balance in the past two years.

JTEC Panel on Machine Translation in Japan
Jaime Carbonell, Carnegie Mellon University (Co-Chair)
Elaine Rich, MCC (Co-Chair)
David E. Johnson, IBM Research
Masaru Tomita, Carnegie Mellon University
Yorick Wilks, New Mexico State University
Muriel Vasconcellos, Pan American Health Organization

JTEC Panel on Database Use and Technology in Japan
Gio Wiederhold, Stanford University (Chair)
Nick Farmer, Chemical Abstracts Service
Charles Bourne, Dialog
Sushil Jajodia, George Mason University
Toshimi Minoura, Oregon State University
Diane C.P. Smith, Xerox Corporation
John Miles Smith, Digital Equipment Corporation
David Beech, Oracle Corporation

JTEC Panel on Bioprocess Engineering in Japan
Daniel Wang, MIT (Chair)
Arthur E. Humphrey, Lehigh University
Michael R. Ladisch, Purdue University
Stuart E. Builder, Genentech, Inc.
Stephen W. Drew, Merck & Co.
Alfred Goldberg, Harvard Medical School
Randolph Hatch, Aaston, Inc.
Duane F. Bruley, University of Maryland

JTEC Panel on Display Technologies in Japan
Lawrence E. Tannas, Jr., Tannas Electronics (Co-Chair)
William E. Glenn, Florida Atlantic University (Co-Chair)
Malcolm Thompson, Xerox Corporation
Thomas Credelle, Apple Computer
William Doane, Kent State University
Arthur H. Firester, David Sarnoff Research Ctr.

JTEC Panel on Material Handling in Japan
Edward H. Frazelle, Georgia Institute of Technology (Co-Chair)
Dick Ward, Material Handling Industry (Co-Chair)
James M. Apple Jr., Coopers & Lybrand
Alvin R. Voss, IBM
Glenn Petrina, Defense Logistics Agency
Howard A. Zollinger, Zollinger Associates, Inc.

JTEC Panel on Separation Technologies in Japan
C. Judson King, University of California at Berkeley (Chair)
George E. Keller II, Union Carbide Corporation
H.S. Muralidhara, Cargill
Milton E. Wadsworth, University of Utah
William Eykamp, Consultant
Edward L. Cussler, University of Minnesota

JTEC Panel on Knowledge-Based Systems in Japan
Professor Edward Feigenbaum, Stanford University (Chair)
Penny Nii, Stanford University
Peter E. Friedland, NASA Ames Research Center
Herbert Schorr, University of Southern California
Howard Shrobe, MIT
Bruce B. Johnson, Andersen Consulting
Robert Engelmore, Stanford University (Editor)

NASA/NSF Panel on Satellite Communications Systems and Technology
Joseph N. Pelton, University of Colorado (Co-Chair)
Burton I. Edelson, George Washington University (Co-Chair)
Neil R. Helm, George Washington University
William T. Brandon, Mitre Corporation
Charles W. Bostian, Virginia Tech
Vincent W.S. Chan, MIT Lincoln Laboratory
E. Paul Hager, George Mason University
Christoph E. Mahle, COMSAT Laboratories
Edward F. Miller, NASA Lewis Research Center
A. Landis Riley, Jet Propulsion Laboratory
Robert K. Kwan, Jet Propulsion Laboratory
Raymond Jennings, National Telecommunications and Information Agency

WTEC Study on Instrumentation, Control, and Safety Systems of Canadian Nuclear Facilities
Robert E. Uhrig, Oak Ridge National Laboratory & the University of Tennessee
Richard J. Carter, Oak Ridge National Laboratory

JTEC Panel on Advanced Manufacturing Technology for Polymer Composite Structures in Japan

Dick J. Wilkins, University of Delaware (Chair)
Moto Ashizawa, Ashizawa Associates Composites Engineering
Jon B. DeVault, ARPA
Vistasp M. Karbhari, University of Delaware
Joseph S. McDermott, Consultant
Dee R. Gill, McDonnell Aircraft

WTEC Panel on Research Submersibles and Undersea Technologies in Finland, France, Russia, Ukraine, and the United Kingdom

Richard J. Seymour, Texas A&M University (Chair)
D. Richard Blidberg, Northeastern University
Claude P. Brancart, Draper Laboratories
Larry L. Gentry, Lockheed Missiles & Space Co., Inc.
Algis N. Kalvaitis, NOAA
Michael J. Lee, Monterey Bay Aquarium Research Institute
John B. Mooney Jr., USN (Ret.)
Don Walsh, International Maritime, Inc.

Civil Engineering Research Foundation (CERF) Task Force on European Constructed Civil Infrastructure Systems and R&D (WTEC Panelists Only)

Richard L. Tucker, Construction Industry Institute (WTEC Chair)
John Fisher, Lehigh University
J. L. Harrison, Fluor Daniel, Inc.
Victor Li, University of Michigan
Tom Pasko, Federal Highway Administration
Michael Gaus, State University of New York at Buffalo

JTEC Panel on Micro-electro-mechanical Systems in Japan

Kensall Wise, University of Michigan (Chair)
Richard S. Muller, University of California at Berkeley
Henry Guckel, University of Wisconsin at Madison
Joseph M. Giachino, Ford Motor Company
G. Benjamin Hocker, Honeywell, Inc.
Stephen C. Jacobsen, University of Utah

JTEC Panel on Electronic Packaging in Japan

Michael J. Kelly, Georgia Institute of Technology (Chair)
William Boulton, Auburn University
John Kukowski, Rochester Institute of Technology
Gene Meieran, Intel Corporation
Michael Pecht, University of Maryland
John Peeples, NCR
Rao Tummala, Georgia Institute of Technology

WTEC Panel on Advanced Display Technologies in Belarus, Russia, and Ukraine
William Doane, Kent State University (Chair)
Patricia Cladis, AT&T Bell Laboratories
Chris Curtin, Silicon Video, Inc.
James Larimer, NASA-Ames Research Center
Marko Slusarczuk, USP Holdings, Inc.
Jan Talbot, University of California at San Diego
Zvi Yaniv, Advanced Technology Incubator, Inc.

JTEC Panel on Optoelectronics in the United States and Japan
Stephen Forrest, Princeton University (Chair)

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