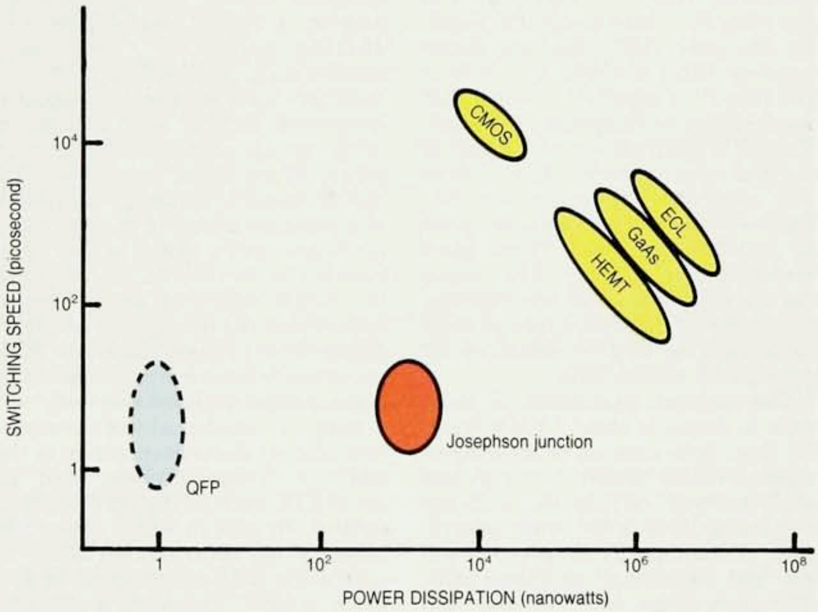
JAPANESE GIVE SUSTAINED AND SYSTEMATIC SUPPORT TO R&D

In the highly competitive global economic environment, much attention has recently been focused on Japan and its support of science R&D, especially that which is of potential benefit to industry. Japan can exert leverage on industrial R&D through funding from various governmental agencies. Two government organizations especially charged with involvement in industrial R&D are the Ministry of International Trade and Industry and the Science and Technology Agency. Nearly 40% of the roughly $13 billion spent by the Japanese government in 1989 on science and technology R&D went to MITI and STA, while about 47% went to the Ministry of Education, Science and Culture, known as Monbusho. On a recent trip to Japan, PHYSICS TODAY got a sampling of some of the ways the Japanese government, through MITI and STA, is supporting and stimulating research and attempting to transfer it to industry.

Going from the more traditional to the innovative, our sampler included the Electrotechnical Laboratory, a national lab; the International Superconductivity Technology Center, a focused, ten-year project; and the Exploratory Research for Advanced Technology program. Along the way we learned about Japan's effort to develop photovoltaics, its continuing program in digital Josephson devices and its national program on high-temperature superconductors.



Circuit elements for ultrafast computers should be able to switch in very short time intervals and generate very low levels of heat. Research on two elements that promise such performance—digital Josephson devices and the more speculative quantum flux parametron (QFP)—has been funded by the Japanese government. This diagram compares the characteristics of these elements with those of complementary metal oxide semiconductor (CMOS), emitter coupled logic (ECL), gallium arsenide (GaAs) and high-electron-mobility transistor (HEMT) devices. (Adapted from a diagram supplied by ERATO.)

ETL: A national lab

MITI, through its Agency of Industrial Science and Technology, supports 16 national research institutes that develop technologies with significant potential impact on both society and industry. These institutes are somewhat akin to the US national laboratories. We visited the largest of these—the Electrotechnical Laboratory, which supports about 560 scientists and engineers in its spacious facilities in Tsukuba, Japan's "Science City," about a two hour's drive northeast of Tokyo. Eight other national research laboratories belonging to AIST and about 30 other national research institutes are also situated in Tsukuba. ETL has been in its current location for 11 years, but it originated nearly 100 years ago as a testing laboratory for the Bureau of Electrocommunication.

The 16 functional divisions at ETL fall into four general areas: electronics, standards and measurements technology, information technology and energy technology. Special projects dealing with such topics as energy conservation, photovoltaics, remote sensing of Earth's resources, and computer and robot systems draw researchers from a variety of divisions. One of the efforts in which ETL is participating is the Sunshine Project, which was begun by MITI after the oil crisis of 1974 to support research on alternate energy sources at national laboratories and in the private sector. ETL's material science division, headed by Kazunobu Tanaka, conducts research on amorphous silicon materials for solar cells as part of a ten-year-old subprogram of the Sunshine Program. Tanaka told us that this particular MITI subprogram is unusual in that it formally involves university participation. Previously MITI had regularly funded national laboratories and industry in its projects but had not included sizable budgets for university research. (The rivalry between MITI and the Ministry of Science, Education and Culture runs high.) Tanaka welcomes the contact with academia, especially as the nature of the research at ETL becomes increasingly fundamental.

The long-term goal of the R&D program on photovoltaics under the Sunshine Project is to supply 2–3% of the total electricity demand in Japan by the year 2000. Because Japan receives direct sunlight only 50% of the time, it is especially critical that solar energy be comparatively cheap. The MITI program aims to bring the current costs of photovoltaics—about 700 yen/watt (approximately $5/watt)—to the more competitive price of 100–200 yen/watt. Those goals translate into varying 1992 targets for the efficiencies and fuel degradation rates of different types of solar cells, such as 10–12% efficiency for amorphous silicon cells.

The current production of solar cells in Japan is about 10 MW/year. Of that, 70% consists of amorphous silicon cells for consumer uses such as solar-powered calculators, and the remaining 30% is for power generation, predominantly supplied by single- and polycrystalline silicon cells. The government effort in solar cell research—which includes funding research in some private companies—is much larger than that of the private sector, although industry tends to support more research on amorphous silicon than on other photovoltaic materials.

About one-sixth of the budget for solar cell research at ETL is devoted to crystalline silicon, and the remainder to amorphous silicon, where one large challenge is to control better the light-induced degradation. Yutaka Hayashi, head of the device synthesis section, told us about efforts in his group to relate material properties to the performance of solar cells. Tanaka himself focuses on understanding the relationship between the preparation method (such as plasma chemical-vapor deposition) and the microscopic properties of the resulting materials via a variety of process diagnostic tools.

Superconductivity at ETL

We also spoke with Koji Kajimura, who heads the ETL's physical science division. Speaking as the chairman of the Liaison Committee on Superconductivity Research at ETL, Kajimura summarized the wide scope of the lab's research on low-temperature, oxide and organic superconductors, which is being pursued by 110 scientists and engineers in various divisions. The lab's involvement in superconductivity research began nearly 30 years ago, with work on superconducting wires and magnets for magnetohydrodynamic power generation. Today the lab is still involved in applications to power generation, through work on high-field pulsed superconducting magnets for a tokamak reactor and an effort to develop a 70-MW model superconducting generator. Regarding smaller-scale applications, ETL researchers have worked on Josephson integrated circuits and Josephson-array voltage standards for over 15 years. Much effort is naturally directed toward materials synthesis and characterization of the new oxide materials, and a group of five theorists led by Jun Kondo, discoverer of the Kondo effect, is attempting to understand the mechanism of superconductivity in these materials. ETL continues to have a strong interest in organic superconductors as well.

Susumu Takada, chief of the superconductivity electronics section in the electron devices division, told us about ETL work on digital Josephson devices, an area in which Japan has forged ahead since the US leader in such work, IBM, discontinued its program in 1983. This work is part of a ten-year MITI program on supercomputers that is just coming to an end. ETL has focused its efforts on niobium nitride, and about five years ago transferred its techniques for making tunnel junctions in this material to the three industries in the MITI program—NEC, Fujitsu and Hitachi. Fujitsu announced last year that it had developed a 4-kilobit memory cell. Takada told us that ETL had developed a 1-kilobit Josephson memory in which 98% of the cells can be accessed by the peripheral circuit.

Analog Josephson devices are studied in the metrology fundamentals division of ETL, and Masao Koyanagi, a section chief in that division, told us something about that work. Researchers there are also working on a SQUID for biomagnetism measurements, developing a Josephson potentiometer for use as a voltage standard and studying the quantized Hall effect to use as a resistance standard. ETL is participating in joint research with the US National Institute of Standards and Technology to develop precise measurement devices based on oxide superconductors.

Kajimura explained to us that the coherence length (10 Å) of the new high-temperature superconductors has so far precluded making Josephson junctions from them: The thickness of the insulating layer in a Josephson device must be less than this formidably short coherence length. However, the electron devices division has explored the properties of a device made from a normally conducting material (rather than an insulator) sandwiched between two superconducting layers. Researchers measured a current–voltage curve similar to the Josephson effect, although the mechanism for current flow across the junction in this case would not be tunneling, as in a real Josephson device, but a proximity effect, in which superconductivity is induced in the normal conductor.

Last fall the Japanese Technology Evaluation Center sponsored by the US National Science Foundation sent a panel of US researchers on a tour of Japanese superconductivity facilities, which included ETL and the International Superconductivity Technology Center. The panel, led by Mildred Dresselhaus (MIT), found the Japanese national labs to have more practical goals and less basic research than their counterparts in the US. The JTEC report cited national labs such as ETL for their ten-year record of technology transfer in large-scale superconductivity applications. That contrasts with the situation in the US, where, according to a recent report by the US Office of Technology Assessment on "High-Temperature Superconductivity in Perspective," the technology transfer between the Federal laboratories and US industry has not been very effective. At the same time, the JTEC panel concluded that in basic science, the interaction among groups in different Japanese organizations in industry, university and national laboratories is not as strong as in the US. Both the JTEC and OTA reports asserted that Japanese R&D on superconductivity was strengthened, especially in materials research, by the sustained and systematic government support. The JTEC group concluded that Japan and the US are currently comparable in basic experimental studies and materials research, although the Japanese are improving rapidly and competing strongly with the US.

ISTEC: A MITI program

In the mid-1970s MITI began a series of finite-duration projects directed toward very specific goals in the electronics industries. The first was the VLSI project from 1976 to 1980, a period that coincided with Japan's surge of influence in that branch of microelectronics. Another of these national projects—in optoelectronics and optical communications—concerned another field in which Japan is now a leader. Often in such programs the MITI money is matched by a company many times over.

Shoji Tanaka, who presided over the VLSI project, was asked in 1988 to help direct a new MITI project in response to the discovery of high-temperature superconductivity—the International Superconductivity Technology Center. (See the article by Shoji Tanaka in PHYSICS TODAY, December 1987, page 53.) ISTEC's main mission—to conduct its own studies of the field—is carried out at its Superconductivity Research Laboratory, which Tanaka directs.

ISTEC is supported largely by 46 industrial firms, which have each paid an initial fee of 100 million yen (about $700 000) and annual dues of 12 million yen (about $86 000) to be full supporting members. So far all supporting members are Japanese, despite invitations to foreign companies. These full members each send two of their scientists and engineers to the research facility for several years. The work done at ISTEC is limited to basic technologies, far from commercialization, so issues involving property rights are minimized. Any patents that do result will be shared by ISTEC and the company whose employee was involved. Of the technical staff of 87 now at the Superconductivity Research Laboratory, 12 hold PhDs and 41 have earned master's degrees. Because they are so young, Tanaka feels they are flexible and mix easily. One scientist told us he values his time at ISTEC, where he can do more fundamental work than at his home base.

In addition to the full-support members ISTEC has attracted 67 firms, including nine foreign companies, as ordinary-support members. They pay 2 million yen both initially and annually to gain access to both information and symposia sponsored by ISTEC.

Tanaka outlined for us the work done in each of the six divisions, one of which is located in Nagoya. The organic superconductor group consists of Tanaka and three colleagues he brought with him from the University of Tokyo.

Welcome mat for foreign scientists

Until recently, only a handful of American scientists and engineers had ever been to Japan for research stays longer than three months. Yet, on a recent trip to Japan, PHYSICS TODAY found that scientists at ETL, ISTEC and ERATO were all eager to involve US researchers in their programs. They pointed to a number of programs that support visiting scientists from abroad. Kazunobu Tanaka at ETL believes that young US postdocs, with their energy and initiative, set a very positive example for their Japanese counterparts. ERATO's overseas representative Alan Engel told us that ERATO aims to have the strong mix of cultures that seems to characterize the best and most creative labs worldwide. ERATO's goal is to have about 30% participation by foreign scientists, and by August the program will have nearly 30 foreign participants among its approximately 180 researchers, with 7 coming from the US. So far US researchers have not exactly flocked to these exchange programs, apparently because they are deterred to some extent by language and cultural barriers and by the professional risk of spending a year or more in Japan before finding permanent employment.

Beginning in 1988, the National Science Foundation, in cooperation with Japan's STA, Monbusho and the Ministry of Foreign Affairs, began offering 60 postdoctoral research positions each year in Japan, and additional support for more senior researchers. In the last two years, NSF has nominated more than 100 US researchers for those programs. Recently the number of US scientists going to Japan each year has sharply increased, but many more could be supported, according to Douglas McNeal, an international analyst at NSF. To enable physicists and other scientists from the US to interact more easily with Japanese researchers, NSF also offers support for study of the Japanese language. In addition, this year for the first time NSF and its Japanese counterparts are sending 25 US graduate students to Tsukuba for a summer program that combines language study with research in one of the national labs there. Both NSF and the hosting Japanese agencies hope thereby to foster long-term cooperation between the summer interns and their Japanese colleagues.

—BARBARA GOSS LEVI

ERATO: Exploratory research

While ISTEC and other MITI-sponsored programs pool the resources of industry to stimulate research with commercial potential, other government-sponsored research programs in Japan are taking steps down less traditional paths in an effort to foster more creative and interdisciplinary research. One such program, called Exploratory Research for Advanced Technology, assembles teams of about 15–20 researchers to pursue five-year projects that are open ended, with no stated "deliverables." Some of the projects involve higher risks than industry would normally accept. Often the projects are interdisciplinary—an approach that counters the vertical structure of most Japanese companies. While most ERATO participants come from industry, some are from the universities so the projects enhance communications between two groups that in Japan traditionally have remained relatively isolated from each other. (Professors at national universities, for example, are government employees and not allowed to consult for industry.)

In Tokyo, PHYSICS TODAY chatted with Genya Chiba, who directed ERATO from its inception until recently and who is also a vice president of its sponsor, the Research and Development Corporation of Japan (JRDC). (Since our visit, Isao Usui has succeeded Chiba as ERATO's director.) JRDC is a statutory corporation of the Japanese government that was created in 1961 by the Science and Technology Agency to foster technology transfer from academia to industry and to establish stronger links between them. JRDC in turn founded ERATO in 1981. A similar effort—the Frontiers Research Project—was initiated in 1986 by RIKEN, an institute for physical and chemical research that also falls under STA. Although ERATO commands about half of JRDC's annual budget of roughly $70 million, its projects are not on the scale of MITI's.

About half of ERATO's projects have been directed toward physics and the other half toward biology. Several of the initial projects, such as ultrafine particles (see the article by Chikara Hayashi in PHYSICS TODAY, December 1987, page 44), perfect crystals, and amorphous and intercalation compounds, dealt largely with materials science. In reviewing the intercalation compounds project as part of a JTEC evaluation of ERATO in 1988, John Rowell (Conductus Inc) noted that it gave Japanese researchers valuable experience in materials synthesis techniques, a mastery of which is largely absent in the US.

The physics-related ERATO projects

begun in the past two years are the quantum wave project, exploring the quantum behavior of electrons in nanometer-scale semiconductor devices; the microphotoconversion project, investigating the use of lasers to control chemical reactions in extremely small regions; the electron wavefront project, studying the ways to exploit the information in the phase of an electron to explore the structure of biopolymers as well as semiconductors (see the article by Akira Tonomura in PHYSICS TODAY, April 1990, page 22); and the atomcraft project, aimed at creating and analyzing material structures at the atomic level.

Perhaps the most speculative ERATO project has been one labeled the quantum magneto flux logic project. The project director, Eiichi Goto of the University of Tokyo, had developed a computer element known as the flux parametron in 1953. The advent of small superconducting Josephson junctions opened the possibility of applying Goto's concept to the design of computer devices sensitive to a single quantum of magnetic flux. The ERATO group is exploring how to realize the promise these devices offer of high switching rates with low power consumption—a promise that, in Rowell's view, may make these devices one of the more practical options for the oxide superconductors, which must operate at high temperatures. (See the figure on page 59.) Alan Engel, overseas representative for ERATO, told us that the group has reached 4.5-GHz operation and may end up with a 20-gigaflop scalar processor by the end of the project. (Other computers with that speed are parallel processors.)

Every year ERATO begins three new five-year projects, with $2–3 million annual funding for each. Chiba likened an ERATO project to a form of performing arts, with JRDC serving as producer, a dynamic and well-known scientist as the director and a team of young scientists as the performers. The project director plays a critical role as mentor to the younger scientists. Chiba typically selects a director who can excite the team and builds the project around him. Because the average age of the performers is about 31 years, Chiba termed ERATO a "playground for youngsters." —BARBARA GOSS LEVI

CHERNOBYL AFTERMATH TO BE ASSESSED BY INTERNATIONAL EXPERT TEAM

In 1964, in one of the first major studies of reactor safety in the United States, a team of scientists at Brookhaven concluded that a worst-case meltdown accident in a 1000-MW light water reactor could affect an area that "might be equal to that of the state of Pennsylvania."

The Brookhaven study assumed no containment or confinement structure, so that there was no barrier to the dispersal of radioactive materials, whereas in the accident that took place at Chernobyl on 26 April 1986, the reactor did have a containment—admittedly a weak one. On the other hand, the accident at Chernobyl was even more severe than the one postulated in the Brookhaven study, in that slow-neutron reactions in an overmoderated graphite–water reactor went out of control, causing the plant to explode. The initial explosion was more nearly comparable to a chemical explosion than to that of an atomic bomb in terms of its energy, which was roughly equivalent to the cohesive energy of the containment. That initial explosion, together with at least one follow-on explosion, thrust a large proportion of the plant's radioactive inventory into the atmosphere.

The scientific and medical communities have yet to determine just how large an area was severely affected by the Chernobyl accident, and in just what way the area was affected. But a spate of troubling recent reports in the world press suggest that the lingering impact of the accident has been very severe indeed.

Partly as a result of such reports, a major international study has been organized, the Ukrainian and Byelorussian governments have issued urgent appeals for international assistance, and all Soviet-built power reactors—including plants that are not of the same type as the Chernobyl units—are under continuing review.

Renewed concern

The fourth anniversary of the Chernobyl nuclear power plant explosion was an occasion this year for renewed concern about the consequences of the accident. The anniversary was declared a day of mourning in the Ukraine, and tens of thousands turned out for a service in Kiev, the capital of the Ukraine, which is located about 80 miles south of Chernobyl. In Byelorussia, another area severely affected by fallout from the explosion, the 35 000 workers at the Gomselmash engineering works in Gomel walked off the job for the day, demanding that the region be declared a disaster zone.

For *Le Monde*, the prestigious daily paper published in Paris, the anniversary was an occasion to raise questions in a front-page commentary piece about whether Soviet authorities were keeping the commitments they made immediately after the accident to take adequate remedial measures and to report to the world fully and openly on what they were doing.

Almost as if in response to such questions, it was announced on 7 May that a major expert study has been launched under international auspices to evaluate what the USSR has done to date and what it plans to do in the years ahead. The study is being done in response to a request the Soviet government made last October to the International Atomic Energy Agency in Vienna, seeking organization of a group of international experts to assess "the concept which the USSR has evolved to enable the population to live safely in areas affected by radioactive contamination following the Chernobyl accident, and . . . the effectiveness of the steps taken in these areas to safeguard the health of the population."

Scope of study

The study has been organized by the IAEA in cooperation with the Commission of the European Communities, the Food and Agricultural Organization, the UN Scientific Committee on the Effects of Atomic Radiation, and the World Health Organization. About 100 experts from all over the world will be involved in the study, which is to be done over a period of about six months starting immediately. At the end of that time, a report will be made to the world community. Itsuzo Shigematsu, director of the Radiation Effects Research Foundation in Hiroshima, Japan, heads the study team.

Specialist teams will address the following tasks:

▷ Historical portrayal of the events leading to the current situation and description of the current status

▷ Corroboration of assessments of the environmental contamination