Big Science Is Booming in Japan

A steady budget and scientific consensus have allowed Japan to build up an impressive array of large, cutting-edge research facilities. And more are on the way

Last week, *Science* examined the plight of big science in the United Kingdom. This week, we provide a very different view from Japan.

TOKYO—Twice in a span of 5 months, a handful of prominent physicists from around the world will have come here to discuss machines capable of shaping the future of their discipline. In December the scientists explored a proposed $700 million Japan Hadron Project, a proton synchrotron that will produce vast quantities of K mesons in hopes of observing some of the rarest forms of particle decay. In April a different group of researchers will review plans for a $600 million Radioactive Isotope (RI) Beam facility that would use unstable nuclei to study basic nuclear physics, materials science, and radiobiology. Each one-of-a-kind machine is expected to fill an important niche in the global scientific infrastructure, and both will be built in Japan.

These meetings demonstrate how important Japan's intellectual and financial muscle have become to the health of international science. That support is evident in the number of major-league projects in astronomy, oceanography, and physics recently completed or in the pipeline. Scientists expect that list to grow, thanks to a planning process that lets the community set its priorities without outside interference and a steadily increasing science budget that accommodates new capital projects once an earlier generation of facilities goes on line.

That benign and orderly process is remarkable in the scientific world, says former U.S. presidential science adviser D. Allan Bromley. Speaking to his Japanese hosts at a recent symposium on the future of Japanese science sponsored by the Japan Society for the Promotion of Science, Bromley remarked, "You may have noticed a tinge of green among your U.S. colleagues as you described your well-funded, long-range plans for science. That's envy."

Indeed, Japan has compiled such an impressive record of nurturing "big science"—at a time when other countries are pulling the plug on domestic facilities and backing away from international commitments—that even its own scientists are impressed. "This is the first time I've seen such [governmental] interest in science and technology," says neurobiologist Masao Ito, president of the influential Science Council of Japan. "And everywhere, there are voices calling for the government to double its investment in research, if possible within 5 years."

Japanese scientists caution that the picture for big science is not as rosy as it may seem to scientists overseas. Ito notes that overall governmental spending on research in Japan still trails that of the United States as a percentage of gross domestic product, and the country's stratospheric cost of living means budgets don't stretch as far. In addition, the bulk of the new money is going into research grants, postdoc positions, and other areas that have been badly neglected.

But scientists are confident that the growing support will eventually mean bigger facilities budgets, too. Their hope rests on a solid foundation—a realization among government and business leaders, says Ito, that the seeds for Japan's industrial technology must come increasingly from the nation's own basic research. In fact, they are hoping Japan's willingness to spend on science will bring them the next international prize in high-energy physics, a new linear collider.

Consensus and competition

How has Japan managed to carry out such an impressive building program? Apart from adequate funding, the key element is the process that scientists follow to win approval for their dreams. And that process differs in important ways at the two agencies that fund most large projects, the Ministry of Education, Science, Sports, and Culture (Monbusho) and the Science and

A BIG-SCIENCE BUILDING BOOM

Name of Facility	Sponsoring Institution(s)	Cost (¥100=$1)	Completion Date	Purpose
Heavy-Ion Medical Accelerator in Chiba (HIMAC)	National Institute of Radiological Sciences	$326 million	Summer 1994	Only heavy-ion accelerator dedicated to medical use
Kaiko	Japan Marine Science & Technology Center (JAMSTEC)	$50 million	Spring 1995	The world's deepest diving submersible
Super-Kamiokande	Institute for Cosmic Ray Research, University of Tokyo	$100 million	April 1996	Unique solar and atmospheric neutrino observatory/proton decay experiment
Super Photon Ring 8-GeV (SPRing 8)	The Institute of Physical and Chemical Research (RIKEN)	$1 billion	Fall 1997	At 8 GeV, it's the world's most powerful synchrotron
Large Helical Device	National Institute for Fusion Science (Monbusho)	$486 million	End of 1997	Largest helical fusion device will study steady-state plasmas leading to a fusion reactor
KEK B-Project	National Laboratory for High-Energy Physics (KEK)	$350 million	Fall 1998	One of several B-meson "factories" exploring asymmetrical behavior among particles and antiparticles
Subaru	National Astronomical Observatory	$400 million	2000	This 8-meter telescope in Hawaii will be the world's largest single-mirror optical telescope
Japan Hadron Project	National Laboratory for High-Energy Physics (KEK)	$700 million	2002 or later	Proton synchrotron will produce kaons and support work on neutrino oscillation
RI Beam Factory	The Institute of Physical and Chemical Research (RIKEN)	$600 million	2003 or later	This superconducting synchrotron will produce the world's most intense beams of unstable nuclei

SOURCES: MONBUSHO, STA, INDIVIDUAL INSTITUTIONS

JAERI/RIKEN

On top. SPRing-8, in the hills north of Kobe, hopes to run circles around the rest of the world's light sources.

Technology Agency (STA).

At Monbusho, the emphasis is on building scientific consensus. For physics projects, the process begins with the Nuclear Physics Committee or the High-Energy Physics Committee. These committees have no formal affiliation with Monbusho or any scientific society, and are elected by all who care to vote. "If you declare yourself to be a physicist, you can join the committee or vote [for a representative]," says Sakue Yamada, director of the University of Tokyo's Institute for Nuclear Studies and a force behind the Japan Hadron Project. This approach allows scientists at more than 100 national universities and research institutes to reconcile their priorities before Monbusho gets involved.

A project must win the support of both committees, as well as a further string of bodies attached to the Science Council of Japan, the nation's most prestigious scientific group. "All the decisions are made among ourselves, and then we go to the government," Yamada says. Disagreements are not unusual—"the discussion over projects can be quite intense," says physicist Kozi Nakai, a professor at the Science University of Tokyo—but everyone falls in line once the committee makes up its mind. "We don't vote in these committees; we have to reach a consensus," says Hirotaka Sugawara, director-general of the National Laboratory for High-Energy Physics (KEK). And that consensus usually carries the project through the necessary steps for final approval.

There are fewer obstacles to success at STA. With only a few institutes competing in any single field, the first step is for an institute to draw up its own agenda. After that, in a procedure that even those involved say is not always clear or consistent, negotiations are held among the institute, an STA nuclear power advisory committee, and STA officials. The result is a decision that is taken through the rest of government.

Although Monbusho and STA serve different constituencies, there is a healthy rivalry between them. And scientists are not above taking advantage of that competition. For example, soon after the Institute of Physical and Chemical Research (RIKEN) won support from STA for a ring cyclotron in the early 1980s, Monbusho approved funding for a ring cyclotron at Osaka University.

But sometimes there can be only one winner. That's when the bureaucrats get involved. In the mid-1980s, for example, both KEK, which is under Monbusho, and RIKEN, which is affiliated with STA, wanted to build large-scale synchrotron radiation sources. But the Ministry of Finance wouldn't approve competing billion-dollar-class machines. It's still a matter of debate as to how an STA project, the SuperPhoton Ring 8-GeV (SPRing 8), gained the upper hand. But all parties agree that officials at the highest levels of both agencies got involved in reaching a decision.

Even at that level, however, the competition did not involve elected officials. Hiromichi Kamitsubo, the RIKEN official overseeing the SPRing 8 project, says that local politicians may plead for a completely new facility to be located in their district. But they rarely try to influence which projects should go ahead, he says.

Ready—and out in front

The Japan Hadron Project and the RI Beam factory provide good examples of how Japan plans its big-science facilities, as well as the important role of compromise and sheer luck. The Japan Hadron Project was conceived a decade ago by nuclear physicists as a way to use K mesons, or kaons, to irradiate conventional nuclei for studies in basic nuclear physics. They also wanted to study charge-parity (CP) violation, or why there is a subtle difference between the behavior of particles and antiparticles. Great quantities of kaons must be produced to study this phenomenon, and the Japanese sought a facility that would produce more kaons than any other accelerator in the world.

At the same time, however, KEK was planning a B-meson factory to attack the CP violation question from a different angle. Yamada says that both schemes had general support. But KEK's B factory was half the price of the $700 million hadron project, and other countries were planning their own B factories. So the decision was made to compete with the rest of the world by pushing ahead first with the B-factory project.

While the hadron project was waiting in line, the Canadian government approved preliminary plans for a kaon factory at the

Researchers, Book Your Flights

"People go where the facilities are," says Leon Lederman, 1988 Nobel laureate in physics and director emeritus of the Fermi National Accelerator Laboratory in Illinois. For an increasing number of researchers, the critical facilities are in Japan.

Super-Kamiokande, a $100 million neutrino observatory and proton decay experiment built in a mine, has lured 45 scientists and graduate students from 10 U.S. universities and institutes to a remote mountain village (*Science*, 3 November 1995, p. 729). The attraction, says Henry Sobel, a University of California, Irvine, physicist and member of the U.S. group, is "a very exciting experiment with lots and lots of physics."

Another facility with a long list of collaborators is the $350 million B factory project at the National Laboratory for High-Energy Physics (KEK) in Tsukuba. More than 100 collaborators from seven countries are joining their Japanese colleagues to tackle one of the hottest mysteries in physics today—asymmetrical behavior between particles and antiparticles. Although U.S. and European labs are also gearing up to explore the problem, Stephen Olsen, a physicist from the University of Hawaii and a collaborator at KEK, says "this project has the best chance of doing it first."

Cutting-edge facilities like these are believed to be at least partly behind a recent sharp jump in the number of foreign scientists, engineers, and academics coming to Japan. The figure—which includes those attending meetings and making visits of varying lengths—has nearly doubled in just 3 years and stands at 27,923 in 1994, according to Ministry of Justice statistics.

Once they take up work, most foreign researchers report being received with open arms. Jack Miller, staff scientist in the life sciences division at Lawrence Berkeley National Laboratory, says officials of the National Institute of Radiological Sciences "went out of their way" helping him apply for time on that agency's Heavy-Ion Medical Accelerator in Chiba (*Science*, 12 May 1995, p. 797). The hospitality extends beyond the lab. Sobel says that his Super-Kamiokande researchers have become regulars at a local sushi bar. "When we go in there, people are buying us drinks and trying to communicate," he says.

The transition is not always easy. "The language is a real barrier," says Miller. Cross-cultural collaborations "take a certain degree of determination on both sides," says Olsen, who admits that recruiting is a problem. "But once people get over here it's generally a positive experience," he says.

–D.N.

Tri-University Meson Facility (TRIUMF) near Vancouver, British Columbia, on the condition that other countries contribute to the project. The Japanese group decided to shelve its plans and join the Canadians. But TRIUMF never attracted sufficient outside funding, and the plan was formally dropped in 1994.

Japanese scientists quickly revived their project, garnering support from the grassroots committees. They hope to submit the proposal to Monbusho within the next year. Yamada expects a positive response, an optimism based not just on the value of the science but also because the B factory and the Subaru telescope in Hawaii will be completed in time to shift their construction budgets to the Japan Hadron Project.

The heart of the hadron facility, which will be built on the grounds of KEK in Tsukuba, will be a 50-GeV proton synchrotron forming a 1500-meter-diameter ring. Yamada says the proton beam will have both a higher energy and three times the intensity of any accelerator in operation. And that "will open experimental programs that are particularly difficult to pursue at this moment," says Peter Barnes, director of physics at Los Alamos National Laboratory. In addition, a stream of kaons that have decayed into neutrinos will be directed at Super-Kamiokande, 250 kilometers away, in an experiment to see if neutrinos have mass (*Science*, 3 November 1995, p. 729).

Visionary beams

RIKEN took a different route in deciding to put the study and use of radioactive isotope beams at the heart of its accelerator research program. This new area of research was pioneered at Lawrence Berkeley National Laboratory in the late 1980s by a group of primarily Japanese researchers. The core of the Berkeley group is now continuing the work at RIKEN, using RIKEN's existing heavy-ion accelerator complex. The new facility aims to be recognized as the world's leading center for radioactive isotope beam research.

RIKEN's existing heavy-ion accelerator complex, completed in 1990, features an intermediate-energy 540-MeV ring cyclotron. In a technique known as projectile fragmentation, a beam of heavy ions colliding with particles in a target produces exotic, unstable isotopes. If the primary beam has sufficient intensity, or a high number of particles per second, enough isotopes can be produced to form a secondary beam.

While RIKEN's present facility can only accelerate elements with an atomic mass of 60 or less, the new facility will attempt to accelerate "every element from hydrogen to uranium," says Yasushige Yano, director of RIKEN's cyclotron laboratory. Doing that will require adding a new superconducting cyclotron. Yano says that about 2000 of these short-lived radioactive isotopes have been identified but that theorists predict there could be as many as 5000. "When we complete this machine, we will be able to add another thousand to the chart," Yano says.

The RI beam factory would also form the new isotopes into beams, whose characteristics vary with its component ion or isotope. Although there are only about 200 stable ions that can be accelerated, Yano says, the use of thousands of unstable nuclei will allow researchers to explore phenomena that are now difficult or impossible to study.

KEK

D. NORMILE

Big plans. Clockwise, Hirotaka Sugawara of KEK, Yasushige Yano of RIKEN, and Sakue Yamada of Tokyo University see global benefits from Japan's support of new facilities.

"The vision [for the RI beam factory] is technologically well beyond what is being done elsewhere," says John Schiffer, a physicist at Argonne (Illinois) National Laboratory who has reviewed plans for the facility. "It's very exciting science," he adds.

A linear future?

So far, Japan's scientists have managed to hold their projects to a size that could be financed entirely from Japan's own science budget. But with the confidence gained from the growing list of world-class projects and the backing of a solidly growing budget, what may be the next step in the country's evolution into a global science powerhouse is taking the lead in developing a large international project. And many think Japan just might do that with a linear collider.

Scientists at KEK in Japan, the Stanford Linear Accelerator Center (SLAC) in California, and DESY in Germany are already working together on a linear collider 10 times more powerful—and almost that much larger—than the existing Stanford Linear Collider at SLAC (*Science*, 17 November 1995, p. 1115). To achieve that energy, however, the machine must be about 25 kilometers in length. Next year, proponents are hoping to begin lobbying governments for support, with construction to start in 2001. The bill could top $3 billion.

That price is well beyond what Japan's scientists can usually count on for facilities. But scientists here are uncomfortable following the United States in another big science project after the fiasco of the canceled Superconducting Super Collider (SSC). In their view, U.S. officials pressured Japan to make a major contribution to the SSC even though the time had passed to have a commensurate voice in designing the project. Then Congress killed the project anyway.

Japanese policy-makers also remember their roller-coaster ride as a partner in the international space station, and they are well aware of the latest example of U.S. equivocation—the $10 billion International Thermonuclear Experimental Reactor. While Japanese scientists are too polite to put it this bluntly, Nobel laureate Leon Lederman, director emeritus of the Fermi National Accelerator Laboratory, admits, "we have not been good international partners, and we have a pretty dismal record in keeping promises."

KEK's Sugawara says the uncertainty of counting on the United States to follow through on big projects has led to calls within Japan's scientific community to go it alone on a linear collider. That's still a minority view, however, he says. "I don't think it's proper to have a project of this size be a national project," he says. But he notes that such international facilities are typically sited in the country willing to pick up the largest share of the cost. And given present trends, "we are in a better [budgetary] position," he says.

SLAC Director Burton Richter hopes that isn't the case. "I think our Congress and our Administration, after a few years of jockeying over balancing the budget, are going to have to start thinking a little more deeply about our research policy," he says. Sugawara also thinks the present mood of the U.S. Congress could change. "It's the character of the American people to want to be number one in everything," he says. He says he could even imagine the SSC being revived once U.S. politicians see the Europeans building the Large Hadron Collider and Japan hosting the next linear collider.

Until that happens, however, U.S. scientists may have more green on their faces than in their budgets, as their Japanese colleagues move ahead on big science.

–Dennis Normile