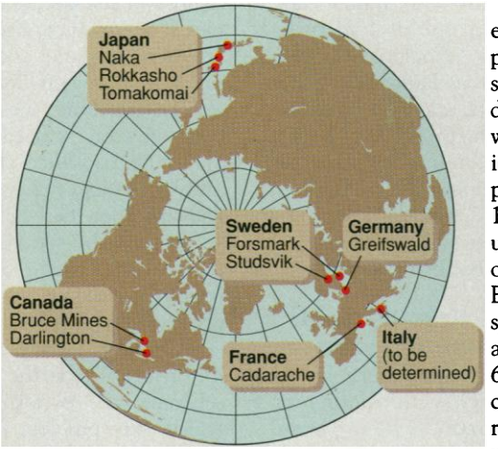
U.S. Power Outage Won't Dim ITER

The $8 billion International Thermonuclear Experimental Reactor is moving ahead—with or without support from the United States. Yet to be decided is where to put it, and how much each partner will pay

When the world's senior fusion managers met last month near Munich, Germany, talk about the $8 billion International Thermonuclear Experimental Reactor (ITER) project fit the buoyant holiday mood. Japanese officials reported that the Keidanren, the wealthy and influential association of major corporations, has expressed strong support for ITER's construction. Representatives of Europe's research ministers said their bosses were jockeying to propose potential sites for the reactor, which will aim to recreate within a tokamak-shaped containment vessel the force that powers the sun. The head of Moscow's renowned Kurchatov Institute, physicist Evgeni Velikhov, announced that Russian politicians are excited about the project even though money is extremely tight.

The U.S. delegation found itself the odd one out among the four partners, who are designing ITER to demonstrate the feasibility of commercial fusion energy. With the fusion program taking a political beating back home in Washington, James Decker, Department of Energy (DOE) deputy director for energy research, had little good news to relay to his colleagues. Worse, the other partners had ignominiously rejected an informal U.S. proposal to scale back ITER to cope with a declining U.S. fusion budget (see box). That leaves the United States with few alternatives. Says Decker: "With the present budget situation, the best we could be is a limited partner."

Surprisingly, the U.S. retreat from the project isn't spreading alarm among the ITER partners. A few years ago, it would have been almost inconceivable for a project of this magnitude to go forward without major U.S. input, but fusion researchers around the world agree that a diminished U.S. presence need not cripple ITER. That prognosis underscores the growing strength of Japan and Europe in the fusion field, as well as the flexible nature of the ITER partnership, which was founded on the assumption that the enormous cost would be divided fairly among the partners. With Asian countries new to the fusion scene such as Korea and China putting out feelers and the program's growing support within Japan, ITER Director Robert Aymar says that any holes left by the United States could be filled quickly. Asked if the program could proceed without the United States, Aymar doesn't hesitate. "Yes," he says, "I am very confident it could."



Favorable reaction. These six countries are vying to host ITER.

U.S. officials say they don't mind playing second fiddle. "We aren't going to be the ones who call the shots, if we ever were," says Anne Davies, who leads DOE's fusion efforts. "As the program becomes more international, other people will take the lead—and that's OK." In terms of sheer dollars, the United States is already a beat behind. Annual budgets for magnetic fusion of $600 million in Europe, and $500 million in Japan, dwarf the $244 million that Congress appropriated this year. And the impact of those numbers will likely show up in the laboratory before too long, admit U.S. scientists. "The U.S. will become a second-rate power in fusion research," says John Holdren, an energy professor at the University of California, Berkeley.

A slow burn

ITER has been a decade in the making, and is at least another decade away from being completed. The project has two goals: to demonstrate a controlled burn of a deuterium and tritium plasma that could provide sustained fusion power production, and to develop and test the advanced technologies needed for a commercial fusion power plant. The reactor will provide a big step beyond the current generation of fusion machines, such as the Princeton Tokamak Fusion Test Reactor and the Joint European Torus, which can produce fusion power only fleetingly. The project is too big for any single country to handle, so the four partners began discussing a joint effort in the mid-1980s.

As with any long-term relationship, however, it hasn't been easy to keep the ITER partnership from going sour. The first obstacle was a disagreement over where the design work should take place. No country was willing to defer to the others for fear that it would be put at a disadvantage in the competition for an actual construction site. In 1992, the partners compromised by setting up three sites—one in Garching, Germany; one in Naka, Japan; and one in San Diego. Each team is multinational and focuses on a specific technical mission, and each partner agreed to kick in about $300 million for the 6-year design phase. However, the complicated arrangement frustrated ITER's first director, French physicist Paul-Henri Rebut, who resigned in 1994.

ITER officials insist the organizational problems have been ironed out under Aymar, a French physicist who previously headed the multidisciplinary Institute of Fundamental Research in Paris. "The ITER council is generally satisfied with the technical and managerial ways of the new director," says Charles Maisonnier, a member of ITER's governing joint council and chief of fusion programs for the European Union (EU). The council members signaled their approval in December by unanimously backing an interim design plan that pegs ITER's hardware costs at about $7 billion, plus the $1 billion or so needed to pay the construction team. Aymar says work is slated to begin in late 1998, and could be finished by the end of 2008.

But before the first spade of earth can be turned, the partners must grapple with a host of complex questions. The current ITER agreement covers only the design; the council has now organized a special working group led by the EU's Ernesto Canobbia that will explore the basis of an agreement among partners for ITER construction. The thorniest issues, say ITER officials, are site selection and how to divvy up the multibillion-dollar construction bill.

Japan steps up

The original idea was for each of the four partners to contribute about 20%, with the host country paying a double share for the privilege of serving as home base. But the U.S. and Russian budget crunches are forcing ITER officials to think about a more flexible partnership, and neither of those two countries intends to propose hosting the facility. "We estimated [it would cost] $300

Advisory Panel Seeks Cost-Saving Solutions

"It's really bizarre—it is very *Alice in Wonderland*." That's how John Holdren, a member of the President's Council of Advisers on Science and Technology (PCAST) and energy professor at the University of California, Berkeley, describes the inability of the federal government to come up with a sustainable energy policy that includes fusion. But he might just as well have been describing the world in which the U.S. fusion program lives.

The problem for the Department of Energy (DOE) is how to maintain U.S. commitments to the International Thermonuclear Experimental Reactor (ITER) and continue a healthy domestic program despite a budget that was cut 33% this year and could be headed even lower. In June, Holdren led a PCAST panel that recommended a scaled-back approach to the $8 billion ITER (*Science*, 23 June 1995, p. 1691). But the idea was roundly criticized by the project's partners.

Later this month a new panel will report to the Department of Energy's (DOE's) Fusion Energy Advisory Committee (FEAC) on how best to carve up annual budgets far below what DOE anticipated just a year ago. And the head of that panel, Michael Knotek of Battelle Pacific Northwest Laboratories, doesn't expect the report will make him very popular, either. "This is no simple task, and we're not going to make everyone happy," he says.

Knotek and his colleagues have been asked to come up with a plan for a fusion program with annual funding of $200 million, $225 million, $250 million, and $275 million. This year Congress slashed the program's budget from $366 million to $244 million, effectively killing the next big U.S. machine, the proposed Tokamak Physics Experiment, and leaving many programs vulnerable. Knotek says his biggest challenge is reconciling ITER with a credible domestic program, adding that a $200 million a year budget offers "very little opportunity to put even $50 million into ITER." At the same time, he says, "we have to be a partner and play in the international arena."

Between the holidays and the recent Washington snowstorms, the FEAC panel has effectively had less than 2 months to do its work. But even with more time, other groups with a similar charge have found it tough sledding. The Holdren panel's recommendations for a scaled-down ITER were "preposterous and had no credibility in the international arena," fumes one ITER official. "Imagine the U.S. conjuring up a machine that the Europeans and Japanese have no interest in and suggesting that they build it." The chair of the ITER council, Russian physicist Evgeni Velikhov, was so alarmed that he wrote to Vice President Al Gore on 28 July asking the United States to maintain its commitment to the program. On 22 September Presidential Science Adviser Jack Gibbons wrote back that the United States intends to continue its ITER design work through 1998.

Even so, DOE managers dutifully studied PCAST's suggestion, and last month came up with a concept that would cost half as much but produce only a fraction of ITER's science and technology output. Anne Davies, DOE's fusion director, says the plan was technically sound, but no one wanted to hear about it. "It is important for the U.S. not to undermine ITER," says Velikhov.

Although Gibbons's letter commits the United States to seeing ITER through its design phase, it's the next step—building the reactor—that could prove fatal for DOE's shrinking budget. "It's the construction money that really kills you," one White House official says. "And we are bound by our budget situation."

Knotek is well aware that the U.S. push to reduce the federal deficit limits his panel's leeway. "We have to find a program that has no big mortgages," he says.

–A.L.

million a year to be a nonhost, and that's beyond our means," says Davies. Instead, ITER managers say the construction agreement likely will permit the United States and other countries to join at a lower percentage.

Although they are confident that this can be worked out in a way that will keep the project on track, some Japanese officials are unnerved by the likelihood of diminished U.S. participation. They are more accustomed to working with the United States than with Europe on an array of scientific projects. "The ITER project is so huge, and we expect U.S. involvement," one Japanese diplomat says. "Japan might find it acceptable if U.S. participation is marginal," says French physicist Michel Huguet, who heads the ITER site at Naka. "But they would probably find it very difficult if there were no U.S. participation at all."

Yet Japan's lack of oil and coal, its high rate of energy consumption, and its growing role on the international stage are pushing that country to the fore, according to fusion managers and researchers. "We are determined to positively and actively proceed on the ITER project," says Satoshi Tanaka, director for fusion energy at Japan's Atomic Energy Bureau. And in December, the powerful economic organization Keidanren set up a working group made up of more than 100 companies to promote construction of ITER in Japan. Paul Rutherford, a Princeton University physicist who also chairs ITER's technical advisory committee, says that is an important signal that leaders of Japanese industry see the potential long-term benefits of the project.

"The Keidanren is very strong financially, and they could help contribute funds," says Toshihiko Nomura, head of the Washington office of the Japanese Atomic Energy Research Institute (JAERI). "The Japanese government is constrained in its funding, and it looks to companies for help." However, warns one Japanese manager, support from the Keidanren "does not necessarily mean it will provide resources." Other officials associated with ITER say they have heard informally that Japan may be willing to pay as much as 70% of the project's construction costs in return for a site in Japan. Aymar dismisses such talk as "just noise," and Japanese officials caution that it is far too early to say how much the country would be willing to pay to host the facility. Even so, says Holdren, "it is becoming increasingly likely that the facility will be built in Japan."

Siting scramble

Even if that is true, the next question is where. Three factions in Japan have proposed different sites to be included in the official Japanese proposal, due in the next year. The country's fusion researchers, funded by JAERI, favor their current home at Naka, south of Tokyo, while a coalition of Hokkaido politicians are backing a location near the town of Tomakomai on the southern tip of that northern island. The Keidanren favors a site in northern Honshu in Aomori prefecture, which already is host to a number of nuclear facilities.

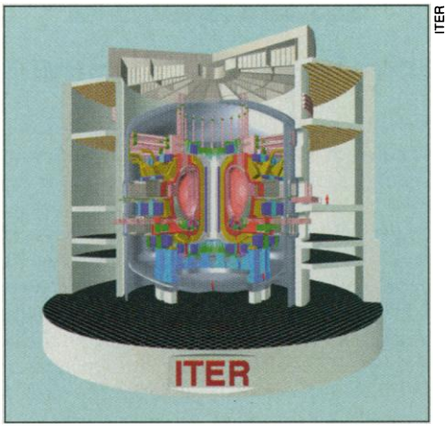
Although Japan may be a heavy favorite in the race to win the ITER prize, there is plenty of other competition. European countries—who coordinate their program through the European Union—are scrambling to propose their own sites; at the same time, they remain wary of the huge cost. France, Germany, and Sweden each have candidate locations, while Italy is nearing a decision on a site. The job of weighing the competing claims and selecting a preferred site falls to the European Union's commission and is likely to run through the end of the year, says Maisonnier.

Although the United States is too strapped

for cash to propose serving as host, its northern neighbor has emerged as a contender. A Canadian delegation that met informally at the Munich meeting with ITER officials discussed two sites—one very near to the source of tritium that ITER must use—neither of which is far from the U.S. border. While Canada lacks the financial resources to cover a large percentage of the facility's costs, its selection might be viewed as a welcome compromise between a Japanese and a European location, says one ITER official, as well as a geographic convenience for U.S. researchers.

Russia's absence from the siting competition should not be taken as a lack of interest in the project, say fusion scientists. "There is strong support for the program in Russia at all levels, from the president to the parliament," says Velikhov, although a quarter share of overall costs is beyond its means. As a sign of that commitment, he notes that Russia is helping to finance its stake in ITER design work with proceeds from the sale of enriched uranium to the United States. For construction, Velikhov says that Russia could contribute much in the way of theory and some materials.

Other countries relatively new to fusion could soon enter the field and fill the void left by Russia and the United States. China and Korea have made "informal inquiries" expressing interest in cooperation, says Aymar. And this winter a Korean official hopes to visit Naka to discuss the ITER project, according to Huguet. Korea already has big plans for a $300 million machine with superconducting magnets that would confine burning plasma for relatively long periods. Officials hope the facility can be completed by 2002 and that its operation will provide a stepping stone to ITER participation (*Science*, 22 December 1995, p. 1918).



ITER

Future fusion. A cutaway look inside the proposed international tokamak.

One funding scenario, says Ronald Parker, the U.S. physicist in charge of the Garching team, is for Japan to contribute about half or more of the cost of building ITER in Japan, with the United States and an array of European and Asian nations kicking in much smaller percentages. There's also plenty of room for industry; next week, business leaders from the United States, Japan, and Europe are gathering in San Diego to discuss what role they could play in the project.

The growing Asian interest in ITER could produce a dramatic shift in fusion research, difficult to imagine a decade ago, away from the United States and Europe and toward the energy-hungry and high-growth economies of east Asia. Such an outcome would be particularly painful for U.S. researchers, who for so long have been among the leaders in fusion research. "There is a psychological side to this, and it will pose quite a challenge for the U.S.," says Aymar. But ITER won't wait very long for the United States to adjust to its new supporting role. "We need to [move ahead] now," he warns, "or the whole field could disappear."

–Andrew Lawler

MATHEMATICS

Does Rochester Without Math Add Up?

The math community has been up in arms over a plan by the University of Rochester to do away with its graduate program in mathematics. Observers are especially upset because Rochester's special strengths are said to be in the sciences and economics, fields that depend heavily on math. "It's beyond belief," says physicist Marvin Goldberger, dean of natural sciences at the University of California, San Diego (UCSD).

The university, for its part, is as yet "not dissuaded" from its position, Dean Richard Aslin told *Science*. Authorities will, however, canvass the other science departments at Rochester and see if they are willing to make sacrifices necessary to keep the math department intact.

The flap began on 16 November, when university officials outlined to the faculty details of the "Rochester Renaissance," a sweeping plan to economize and downsize without sacrificing quality. It includes reducing the student body from 4500 to 3600, cutting the faculty by 10%, and eliminating four graduate programs: chemical engineering, linguistics, comparative literature, and math.

In a memo to faculty members, Dean Aslin explained that Rochester's math program is only of "modest distinction," has been getting "dwindling numbers of math graduate students," has "less than optimal" undergraduate instruction, and has "linkages with other departments and programs [that] are minimal." University officials have also cited graduate school rankings by the National Research Council (NRC), where Rochester's math department ranked 58.5, putting it in the 42nd percentile (*Science*, 22 September 1995, p. 1660). The number of tenured slots in the math department is therefore scheduled to shrink from 21 to 10, and four nontenured Ph.D.s will be hired to teach lower level math courses, says Aslin.

The math department has put out a detailed report defending the quality and quantity of its output. And it has been backed up by a storm of protests from mathematicians and other scientists around the country. The American Mathematical Society (AMS), which sent a "fact-finding committee" to Rochester last month, protested the plan in a 10 January resolution. (Details are at the AMS Web site: <http://www.ams.org/committee/profession/roch-ap1.html>.) The committee's chair, Salah Baouendi of UCSD, warns that Rochester may become the first "major institution with a physics graduate program that doesn't have a mathematics graduate program."

Goldberger, who headed the NRC panel that did the rankings, is also appalled by Rochester's decision. He points out that the department is small and specialized, factors that militate against getting a top rating. "I take much more seriously [than the ranking] the things I hear from other mathematicians," he says. Harvard University's Arthur Jaffe, president-elect of the AMS, for example, says that in algebraic topology, the university has "one of the top departments in the country."

Jaffe says the university's critics see a possible solution in a proposal by Rochester economist emeritus Lionel McKenzie, who calls for small sacrifices by science and social science departments to sustain the math department in its current form. Aslin says the university isn't jumping at the idea but is willing to float it. "One of the primary contentions that has been made is that ... successes in other [quantitative] disciplines depend upon having a Ph.D. program in math," says Aslin. "That's a testable hypothesis ... [so] we're putting it back to the Rochester community" to see if they are willing to make the necessary sacrifices.

Meanwhile, the AMS has put together a task force of scientists and mathematicians, headed by Jaffe, that is composing a letter to Rochester trustees to persuade them that closing the graduate program would be folly. Says the AMS: It would be "a tragedy for American mathematics." Aslin's response: "Give me a break. ... This is being viewed by AMS as a test case, and it must be because they're fearful of it happening elsewhere."

–Constance Holden