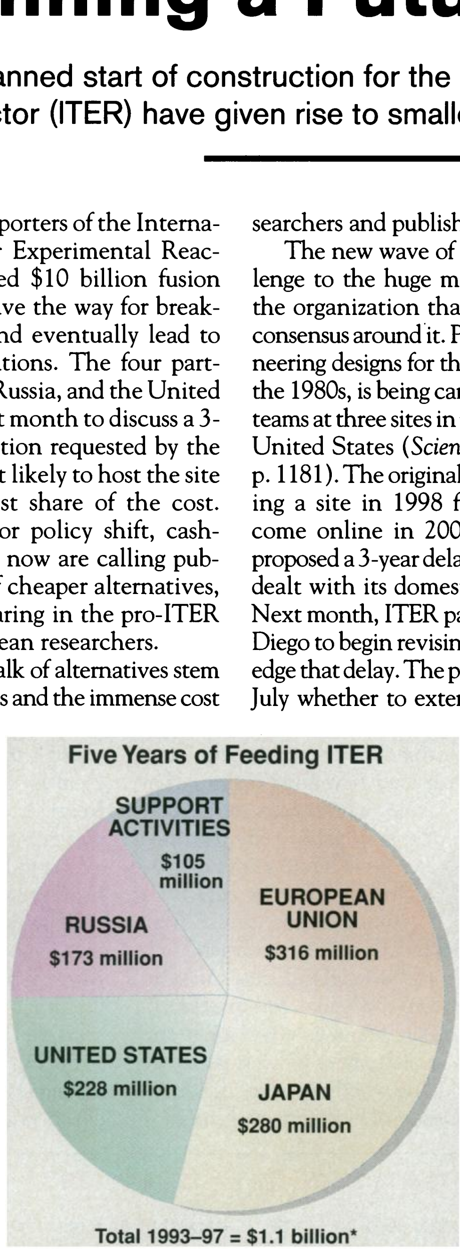
Planning a Future Without ITER

Delays in the planned start of construction for the $10 billion International Thermonuclear Experimental Reactor (ITER) have given rise to smaller, cheaper alternatives in fusion research

It's a dark time for supporters of the International Thermonuclear Experimental Reactor (ITER), a proposed $10 billion fusion project intended to pave the way for breakthroughs in physics and eventually lead to commercial power stations. The four partners—Europe, Japan, Russia, and the United States—will meet next month to discuss a 3-year delay in construction requested by the Japanese, who are most likely to host the site and put up the largest share of the cost. Meanwhile, in a major policy shift, cash-strapped U.S. officials now are calling publicly for exploration of cheaper alternatives, while cracks are appearing in the pro-ITER stance taken by European researchers.

The delay and the talk of alternatives stem from technical questions and the immense cost of the reactor, say officials familiar with the program. Rather than risk all their chips on the $10 billion ITER design, a growing number of U.S., European, and Japanese researchers are willing to consider less ambitious efforts. That willingness is most obvious in the United States, which has already stated it will be only a junior partner were ITER to go ahead.



* Includes personnel and infrastructure, but not funding for national basic physics programs

SOURCE: ITER

Until now, the U.S. Department of Energy (DOE) has actively discouraged any discussion of alternatives to avoid ruffling the feathers of its partners. But now, "everything is back on the table for discussion … including the most fundamental decisions any project makes," says Charles Baker, the ITER U.S. Home Team leader and an engineering professor at the University of California, San Diego. Baker says there are "indications" that the international coalition might eventually be receptive to changes. Anne Davies, head of fusion research for DOE, adds that "the boiling has gotten to a point that we should not keep a lid on the pot. People want to talk about 'what if.' " Even once-solid bastions of ITER support in Europe and Japan are holding discussions on alternatives, according to researchers and published documents.

The new wave of debate is the latest challenge to the huge machine—and perhaps to the organization that built an international consensus around it. Preliminary work on engineering designs for the machine, conceived in the 1980s, is being carried out by international teams at three sites in Germany, Japan, and the United States (*Science*, 18 November 1994, p. 1181). The original schedule called for picking a site in 1998 for ITER, which would come online in 2008, but last spring Japan proposed a 3-year delay in any decision while it dealt with its domestic economic problems. Next month, ITER partners will gather in San Diego to begin revising their plans to acknowledge that delay. The partners must decide by 20 July whether to extend so-called engineering design activities at a lower funding level over the next 3 years.

Officially, Japan and the European Union have rebuffed suggestions that the project might have to be scaled down or completely retooled. "We are now in the stage of final design, which ought to be continued as much as possible without pause," says Hiroshi Kishimoto, director of the department of fusion plasma research at the Japan Atomic Energy Research Institute (JAERI). "Pursuing other possibilities can't be considered." Adds one researcher who asked not to be identified: "The official line in Europe is that we should … not be distracted by alternative schemes."

Coming together

ITER would be far and away the largest ever tokamak, a doughnut-shaped vessel threaded with magnetic fields lines that confine high-temperature plasma. The torus itself would be 16 meters across and would be nested in a tangle of machinery and electronics rising 30 meters high. If that magnetic cage were to trap the plasma for long enough, the resulting fusion reactions might cause it to ignite in a self-sustaining thermonuclear fire that could be closely studied. Other aspects of the project would look at reactor-specific issues like the use of gigantic superconducting coils to produce the magnetic fields and the survival of wall materials when exposed to the hellish heat of a thermonuclear plasma.

The device has long been billed as crucial for demonstrating the feasibility of a working reactor, and many fusion researchers remain convinced that it offers the surest route to fusion-powered electricity generation. "To the best of present knowledge, a fusion reactor capable of sustained ignition requires parameters similar to the present ITER design," says Jean Jacquinot, associate director at the Joint European Torus (JET).

But some U.S. scientists and policy-makers have long argued for alternative approaches. In 1995, for example, a review by the President's Committee of Advisors on Science and Technology recommended downsizing the project in light of tightening budgets. The Europeans and Japanese rejected those suggestions, saying they could handle most of the $10 billion cost on their own. Then this fall, a U.S. fusion review panel (*Science*, 24 October 1997, p. 563) recommended slashing support for ITER design studies and exploring much cheaper ways to demonstrate the feasibility of fusion power. Those recommendations triggered the change of heart among U.S. fusion officials, says Baker.

Hermann Grunder, director of the Thomas Jefferson National Accelerator Facility in Newport News, Virginia, and chair of the DOE-chartered panel that made the recommendations, pronounced himself "delighted" with the shift from a single-minded U.S. policy on ITER. "Let's take this [delay] and get in touch with each other in the [U.S. fusion] community," says Grunder. "We can come together one way or another" on a new strategy, he says.

The Grunder panel anticipated a rich stew of possibilities for what it sees as an essential near-term step: a burning-plasma experiment, perhaps without all the engineering bells and whistles involved in designing commercial reactors. The options include a worldwide collaboration to explore novel magnetic configurations (*Science*, 28 July 1995, p. 478) whose superior confinement properties—if they could be maintained for longer than the transient bursts so far achieved in tokamaks—might lead to a less expensive reactor. Or the field could build relatively small ignition devices while assigning ITER's technological missions to a number of labs.

The advanced-confinement studies, say numerous sources, could be undertaken at the JT-60U tokamak in Naka, Japan, or, after some upgrades, at Britain's JET—which obtained early evidence for the modes and continues to look into their transient version. Success on these machines, which are the world's largest existing tokamaks, might allow for a relaxation of ITER's design and shave perhaps $1 billion to $3 billion off its pricetag while preserving its main goals, says L. John Perkins, a Grunder panel member at Lawrence Livermore National Laboratory in California.

According to Perkins and detailed Japanese publications on the topic, one version of a superconducting Japanese machine that was in the conceptual design stages a year ago, called JT-60 Super Upgrade, would search for advanced-confinement modes in an initial phase of operation using an ordinary hydrogen plasma. In a second phase, experimenters could add deuterium and tritium—the fuel that would power an actual reactor—and check whether the modes could improve fusion performance and perhaps even lead to ignition. Such an effort would cost in the general range of several billion dollars. The superconductors could permit an exploration of that burn for thousands of seconds or even in steady state. JAERI's Kishimoto confirms that such a device has been considered, but says it has been shelved in favor of ITER.

For further savings on an ignition device that some see as a lower cost replacement for ITER, researchers could turn to a simpler experiment in which ITER's size is replaced with extremely powerful magnetic fields. In the broadest terms, the trade-off is possible because the confinement of heat depends on the radius of an ion's orbit around a magnetic field line compared to the machine size. The higher the magnetic field, the smaller the "gyroradius." These powerful fields would be produced with cooled copper coils rather than ITER's expensive superconductors. Large electric currents would, however, heat such coils and limit them to roughly 10-second bursts of ignition, rather than the planned 1000-second pulses possible with the heavily shielded superconductors.

Some researchers believe the small devices have a better chance of actually achieving any fusion burn than ITER would because of the powerful magnetic fields and the engineering flexibility of the copper coils, both of which could be exploited to suppress plasma instabilities. And although the short ignition pulses couldn't look at reactor-specific issues like the cycling of particles off the wall, the essential physics of an ignited plasma could be studied for the first time. "We shouldn't be building things bigger; we should be making them smarter," says Dale Meade, head of advanced fusion concepts at the Princeton Plasma Physics Laboratory (PPPL) in New Jersey. In any case, "we do not yet know enough to build an attractive fusion reactor," says Meade.

"The idea is to do a physics experiment," agrees Bruno Coppi of the Massachusetts Institute of Technology (MIT). Coppi leads a long-standing project called Ignitor that would be a front-runner for this approach. Components of the project have already been constructed in various labs in Italy. "Why build larger machines that probably have a lower probability to ignite?"

If such an experiment were built, say researchers, the cost would range from several hundred million dollars for the extremely compact Ignitor to a couple billion dollars for a revival of PPPL's Burning Plasma Experiment (BPX), killed for funding reasons in the early 1990s. Costs of a BPX-like device could be held down by using the existing power supplies and infrastructure at, say, JET, after its current mission ends, or in the test cell at PPPL's Tokamak Fusion Test Reactor—which lost its federal funding last year. "It is clear that [using JET for such a project] would be an attractive option if it were not possible to proceed with ITER," says a European fusion researcher.

IGNITOR PROJECT

Clamping down. Steel "C-clamps" like this one would brace Ignitor's magnetic-field coils against large stresses.

Several sources say that such options have been presented to the JET scientific council, where they were rejected. Ron Parker of the ITER Joint Work Site in Garching, Germany, says that little interest in alternatives exists in that country, while work on Ignitor, supported mainly by the government of Italy, continues at several industrial and academic sites there. And for ITER supporters like Parker, who aren't persuaded that such inexpensive devices will answer enough questions about reactor design, the numbers don't add up. "If world fusion programs cannot collectively afford a machine like ITER, which offers the possibility to carry our a comprehensive physics program in ignition physics," says Parker, "will they spend their resources on a machine that costs say half as much, has higher engineering and physics risk, carries out a much more constrained physics program, and does not in any way lead to a reactor?" And there are technical concerns as well. JET's Jacquinot cautions that less expensive approaches carry a higher risk: "Reactor designs of smaller size are not based at present on adequate experimental and theoretical evidence." But Coppi points to successful work in confining heat and plasma particles with small, high-field tokamaks at MIT.

International differences

Officially, European and Japanese support for ITER remains strong. But some scientists believe that facade may mask a deeper concern. "I think that everyone recognizes that the likelihood [of ITER being built] is diminishing," says Grunder panel member Gerald Navratil of Columbia University. "We can have frank discussions in private with people in Europe, but it's almost impossible to get them to talk about it even with a few others present," Navratil adds. "People can get into serious difficulty if they take positions out of line with official policy."

In the United States, the problem is not so much hostility toward the program as the reality of politics and the budget. "It's hard to find a champion in Congress for a program that sends money overseas," says one congressional staffer. House appropriators last summer nearly slashed ITER's $55 million request in light of the construction delay. "I don't think they'll be sorry to see the end of ITER," says another House aide.

For ITER supporters, such pressures are particularly damaging in light of the Grunder panel's recommendation to scale back U.S. support to as little as $15 million in the 1999 fiscal year that begins 1 October. "The Grunder panel findings will inform the budget request," one DOE official says. Other government sources say new DOE Undersecretary Ernest Moniz cut the pending $250 million fusion request for FY '99 made by DOE's energy research office by about $20 million, most of which came out of the U.S. ITER contribution. If that level is approved by the White House—which seems likely—and upheld by Congress, it would leave overall fusion funding steady but chop the ITER portion substantially.

As the debate about funding and alternative approaches heats up, ITER's supporters insist that the project remains on track. "Introducing changes [at this stage] would be confusing," says Hiroshi Shibata, acting director for fusion energy at Japan's Science and Technology Agency. Adds ITER director Robert Aymar, "Everybody has his own dream, and there is a fast succession of dreams in the U.S. For the other partners, it's hard to follow."

–James Glanz and Andrew Lawler

With reporting by Dennis Normile in Tokyo.