Europe: Betting Heavily on Fusion

The European Community's fusion program stresses continuity—and it's about to belly up to the window and lay down a bundle on the next generation of fusion reactors

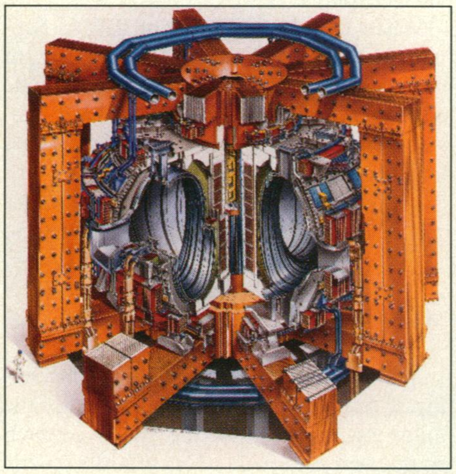
NUCLEAR FUSION OFFERS RELATIVELY SAFE, clean, and inexhaustible power—if it can be made to work. That remains a big if. The premier fusion reactor in Europe today, the Joint European Torus (JET) in Culham, England, still produces far less energy than it takes in, and most observers think fusion won't provide commercial energy until 2040. The long haul to commercial power generation is one reason Congress recently sliced $50 million off next year's fusion budget, the latest cut in a 44% decline in real terms since 1979 [see box on opposite page]. Congress's lack of enthusiasm, however, isn't universal. For example, the European Community (EC) is on the verge of voting a further 458 million Ecus ($640 million) for its fusion program over the next 5 years. A proposal detailing the next steps in the European fusion program has been enthusiastically received according to several European scientists.

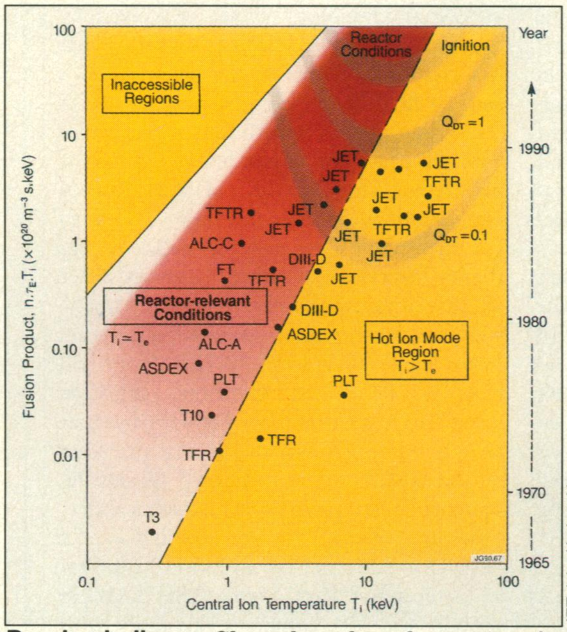
What accounts for the striking differences in the fate of fusion in Europe and the U.S.? According to Régis Saison, a French physicist working in the EC fusion program, "Europe is looking at the long term, which is sensible. We do not need fusion immediately. But we will."

At the moment Europe seems to be in a no-loss position regarding fusion. Not only is its program steaming ahead, but along with the United States, the Soviet Union, and Japan, Europe participates in ITER, the International Thermonuclear Experimental Reactor, currently at the conceptual design stage. Europe is now trying to decide whether to continue alone or commit its experience and planning stability to ITER. If it picks the international option—a decision that could come within the next few years—that might create a program and management structure Congress could support enthusiastically.

Fusion provides power by mimicking the nuclear reactions that power the stars. But the fuel—deuterium and tritium—undergo fusion only at temperatures in excess of 100 million °C, when the atoms have been converted into a plasma. The plasma will ignite and continue to release energy only if it is hot enough, dense enough, and effectively confined away from the reactor walls.

In the search for the required ignition conditions, JET has been relatively successful. The crucial measure of a reactor's effectiveness is the triple product: a combination of the temperature, density, and duration of confinement of the hot plasma. For break-even (the point at which a fusion reactor puts out more power than it takes in), a reactor needs a score of 1×10^{22}. JET's best score is 8×10^{21}, within 80% of break-even.





JET Joint Undertaking

Burning bullseye. *Chart shows how close various fusion reactors are to ignition. The Joint European Torus (JET) (above) is currently closest of all.*

The success of the European program, of which JET is the centerpiece, stems from its continuity—in structure and funding. The European Atomic Energy Community, which oversees the fusion program, was established in 1957, at the same time as the European Economic Community itself. Euratom subsequently signed agreements with the various national research bodies interested in fusion (including those of Switzerland and Sweden, which are not members of the EC). It has played a central role in guiding research into fusion, the only scientific topic in the EC in which all national efforts are integrated and coordinated within a Europe-wide program.

The EC pays 25% of the cost of running laboratories in the fusion program and 80% of JET. It contributes a further 20% to the capital costs of approved projects. "If the EC doesn't regard it as a priority, the home government is unlikely to either," says John Maple, spokesman for JET. Brussels, home of the Eurocrats who run the fusion program, is thus free to direct research and avoid duplication of effort. As a result, says Maple, Europe has "a balanced, well-coordinated, fairly well-disciplined program."

Part of that discipline has to do with timing. In sharp contrast to the United States, where the DOE fusion budget must be approved by Congress annually, the EC sets the budget for fusion every 5 years with a review every three. There is, however, a price paid for that continuity in terms of complexity: Proposals must shuttle between a Council of Ministers, the European Commission, and the European Parliament. Currently going back and forth is the latest review of the budget (which will carry the program to the end of 1994), as well as a bid to extend JET's working life to 1996.

The key payoff from stable funding is the capacity to plan for the long term. Europe's overall scheme has three steps that are intended to culminate in power generation. Step one is an extension of the current experimental work, at JET and elsewhere. The results from that effort will be fed into the design of the Next European Torus (NET), the reactor that is a major part of step two, a program Europe calls "Next Steps." NET is scheduled to begin construction in 1997, the year after JET's program is scheduled to end. Finally comes step three, the demonstration power reactor (DEMO) due to generate electricity in about 2025.

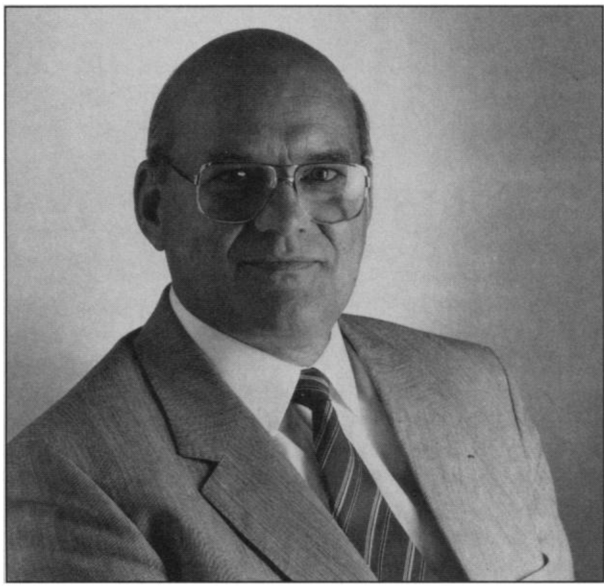
JET's role now is as an experimental device for improving methods of removing impurities from the plasma—impurities that make it difficult to keep the plasma hot enough for fusion. Then, in the final 9 months of JET's life, the physicists will introduce tritium into the plasma. "Once you put tritium in there, that's the last program you do," says Maple. The reason: Tritium creates energetic neutrons that render the entire apparatus radioactive. Before the program ends, physicists at the JET expect to achieve break-even, though not ignition. "Right now," says Maple, "we're putting a match under the bonfire and studying the smoke. But when we take the match away, the fire goes out. By 1996, we plan to have the fire smoldering."

JET's burning ambition is supported by other machines. Next door to JET, at the U.K.'s national fusion facility, a smaller machine is studying plasma instability. At Caderache near Marseilles, the French have built Tore-Supra, which uses superconducting coils for the magnets. In Germany, at Karlsruhe on the Rhine and Garching near Munich, fusion scientists are investigating the interaction between the plasma and the walls of the vessel, as well as different kinds of magnetic confinement. And at Ispra in northern Italy, researchers are working on various aspects of reactor safety in addition to technology.

The immediate objective of this pan-European collaboration is NET, a prototype ignition reactor. The choice of both site and design for NET are currently causing some headaches for the Eurocrats in Brussels. Political jostling has already begun among representatives from the United Kingdom, France, and Germany, all of whom want NET in their countries. One result of this political contretemps might be that the machine is actually built in Italy—which is the second choice of almost all the competitors.

The design of NET is the responsibility of a group of European fusion scientists at the Max Planck Institute for Plasma Physics in Garching. The design process is complicated somewhat by the existence at the same lab of the design team for the proposed International Thermonuclear Experimental Reactor. ITER is the outcome of a 1985 agreement between Ronald Reagan and Mikhail Gorbachev to pursue an international fusion program. Scientists from the United States and the Soviet Union, joined by collaborators from Europe and Japan, are busy planning their dream reactor.

As currently envisioned, ITER and NET would be the same size, use the same magnetic confinement, and contain the same sort of plasma. The difference is that ITER is supposed to be a technical testbed that would provide information on many aspects of the basic fusion reactor design during 10,000 hours of running time. NET has less lofty ambitions and plans to run for between



JET Joint Undertaking

Urge to merge. *Paul-Henri Rebut, architect of JET, would ultimately like to see Europe's fusion program combined with the international one.*

1000 and 2000 hours. During that time it will be used to study plasma ignition, but will not investigate in detail the capture of energy for power or the manufacture of tritium fuel. The difference means NET will be able to survive on brought-in supplies of tritium. ITER will have to manufacture its own, which will be technologically riskier and more expensive.

If both programs—NET and ITER—go ahead, there would clearly be a lot of redundancy. Paul-Henri Rebut, the French architect of JET who is now its director, is touting a solution to that problem—one that could put Europe in the driver's seat of the international effort. He's arguing that ITER should be more like NET and Next Steps, with the ultimate aim of combining the two programs. Rebut says ITER in its present form "has higher scientific, technical and management risks [than NET] and does not provide such comprehensive information."

His alternative is to split ITER into three components. An ignition device, two to three times the size of JET, would use tried and tested technology to study ignition in a tritium-deuterium plasma. This would be much like NET. A second, technological machine would investigate superconducting coils and other advanced technology, such as divertors, to remove impurities from the plasma needed for the DEMO reactor. And a separate materials testing laboratory would probe the effects of neutrons on the fabric of the reactor and minimize their impact.

Rebut says that his three-machine vision, which would substitute for the single ITER machine, is "well within the capability of world research." It would, he says, offer greater flexibility and more data. And it would cost the same to construct as the single ITER device—about $8.5 billion. His intention seems to be to bring international collaboration to what is, essentially, Europe's fusion program.

Rebut is currently trying to drum up support from the world scientific community before putting his proposals to the politicians. Europe's politicians, meanwhile, have agreed to allow Brussels to negotiate a new deal with ITER. A decision is urgent—since the current agreement ends this year. In the medium term, a decision must be taken on the location of the engineering design phase. Japan and the United States have already offered sites, and Europe plans to propose Garching.

Arguing for support of ITER by Europe is the cost, about $40 billion versus $70 billion if Europe goes it alone with the whole Next Steps program. Arguing against are organizational problems: "Given the different experience and social and political background of the four potential partners, getting a well focused effort to proceed quickly will be a major challenge," says Ettore Salpietro, a senior member of both the NET and ITER teams. Other partners in ITER might welcome Europe's experience—of coordination and collaboration as well as of fusion physics. But Europe is wary of abandoning its own, well-tried program for a new coalition.

For the moment, however, the beauty of Europe's position is that its fusion program can continue with or without ITER. "We have done [for ITER] only what we would have done in any case for NET," Christian Gourdon, a deputy director in the French fusion program, told *Science*. "If ITER is politically acceptable, fine, we go ahead. If not, fine, we go back to NET."

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