SPECIAL REPORT

Fusion dreams delayed

International partners are likely to scale back the first version of the ITER reactor. **Geoff Brumfiel** reports.

ST PAUL-LEZ-DURANCE, FRANCE

ITER — a multi-billion-euro international experiment boldly aiming to prove atomic fusion as a power source — will initially be far less ambitious than physicists had hoped, *Nature* has learned.

Faced with ballooning costs and growing delays, ITER's seven partners are likely to build only a skeletal version of the device at first. The project's governing council said last June that the machine should turn on in 2018; the stripped-down version could allow that to happen (see *Nature* **453,** 829; 2008). But the first experiments capable of validating fusion for power would not come until the end of 2025, five years later than the date set when the ITER agreement was signed in 2006.

The new scheme, known as 'Scenario 1' to ITER insiders, will be discussed on 17–18 June in Mito, Japan, at a council meeting that will include representatives from all seven members: the European Union (EU), Japan, South Korea, Russia, the United States, China and India. It is expected to be approved at a council meeting in November.

Indeed, the plan is perhaps the only way forward. Construction costs are likely to double from the €5-billion (US$7-billion) estimate provided by the project in 2006, as a result of rises in the price of raw materials, gaps in the original design, and an unanticipated increase in staffing to manage procurement. The cost of ITER's operations phase, another €5 billion over 20 years, may also rise.

"Building ITER is like building the space station, but having to set up NASA and ESA in the process."

In fact, the ultimate cost of ITER may never be known. Because 90% of the project will be managed directly by individual member states, the central organization has no way of gauging how much is being spent, says Norbert Holtkamp, ITER's principal deputy director-general. "They won't even tell us," he says. "And that's OK with me."

Holtkamp says that the only way to get ITER built is to do the skeletal version first. Before scaling up to do energy-producing experiments, he says, "you really need to know whether the major components work. It's absolutely clear that this is the right approach." As to why Scenario 1 is being touted only now, Holtkamp says it took him time after joining the project to review the original schedule.

Fusion researchers say that Scenario 1 is preferable to the alternative: a permanent smaller machine that would never produce significant amounts of power. "You can't build a half ITER because then you'll just go on and on not quite knowing what the answer is," says Steven Cowley, director of the UK Atomic Energy Authority's fusion laboratory at Culham.

The project's rising price and lengthening schedule have angered some of ITER's members, who plan to finalize the schedule and budget by the end of this year. "People are pissed off," says a source close to the negotiations who requested anonymity because of political sensitivity.

ITER is the most ambitious fusion experiment ever proposed. At its heart is a doughnut-shaped device known as a tokamak (see graphic), which uses magnetic fields to squeeze and heat hydrogen isotopes to hundreds of millions of kelvins, until they fuse. The consequent fusion reactions release high-energy neutrons that can, in principle, be harnessed to generate electricity. Normal hydrogen will not generate enough fusion events to produce large amounts of power, but when scientists inject deuterium and radioactive tritium into the machine, it should generate roughly 500 megawatts of thermal power — around 10 times the amount of power needed to run it. Such an achievement would be long-sought proof that fusion power can work, although a commercial reactor would still be decades away.

A 180-hectare stretch of land has already been cleared for ITER.

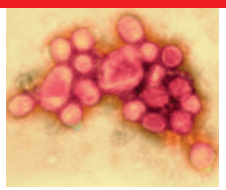
ITER

The machine's costs have doubled once before. Budgeted at US$6 billion in 1989, costs climbed to nearly twice that during the decade that followed. Angered, the US Congress withdrew the country from the project in 1999. The remaining partners — Europe, Russia and Japan — pressed ahead to redesign the machine to keep it within $6 billion.

Design scaled back

The redesign fell to Robert Aymar, a prominent French physicist who had overseen the French tokamak Tore Supra, in Cadarache. Aymar redesigned the entire device in just three years with a staff of 70 — half the size of the original design team. In addition to shrinking ITER to its present-day size, the team made other money-saving assumptions. The new design did not include the cost for auxiliary equipment and some spare parts, and it assumed that some buildings could be reused multiple times. The design was accepted by ITER's partners in 2001 as a way to keep within the $6-billion price tag, and used as a baseline when the United States rejoined and India, South Korea and China joined the project.

Aymar maintains that his redesign was never meant as a final blueprint for the machine, but to act as a guideline for ITER's members to decide who would contribute which portion. It did not



AMI IMAGES

UNEXPECTED ACTIVITY
Old antibodies may protect elderly from swine flu.
www.nature.com/news

assign costs to the values of various components, but used 'ITER units of account' to allow nations to negotiate which parts they would provide as their share. "What we provided was not a cost," he says. "We provided a value."

Some ITER partners say Aymar's design contained an appropriate level of detail. "It was a conceptual design," says Octavi Quintana Trias, director for energy at the European nuclear research organization Euratom, and an EU representative on the ITER council. "You will not develop and refine the design until you have a real commitment to go ahead."

But some US officials see things differently. "We thought that it was 80% designed and that you only had 20% to fill in, and it turned out to be more like 40%," says Raymond Orbach, former head of science at the US Department of Energy and until this year a US representative on the ITER council.

When the project was approved in 2006, the newly formed ITER organization set to work reviewing and completing Aymar's 2001 design, adding parts that included a set of superconducting magnets to control a type of instability not anticipated in the earlier design. The adjustments have cost time and money.

Agencies in the seven member governments are also struggling to set up the complex network that will eventually supply ITER with parts. Although the specifications for each piece can be set by the central lab, it is individual governments that will award contracts to industry and oversee production.

Who provides what is detailed through a series of procurement agreements, which have been slow in coming: 26 were originally scheduled to be ready by the end of 2008, but as of late May this year, only 17 had been signed. The delay is in part due to setting up domestic organizations that will award the contracts, says Niek Lopes Cardozo, vice-chairman of Fusion for Energy, the Barcelona-based body overseeing contracts to European industry. "Building ITER is like building the space station, but having to set up NASA and ESA [the European Space Agency] in the process."

During negotiations, each nation bargained for a stake in the most technically sophisticated parts of the machine, and, as a result, single components will be built with parts from several nations. For example, the 150,000 kilometres of superconducting wire for the magnetic coils will be produced in China, Japan, Russia, Korea, the EU and the United States.

Awarding contracts, setting up production lines and ensuring quality control across the seven partners will also require significantly more manpower than anticipated in 2001, when there were only three member states. Holtkamp says that the central project office will need up to 750 staff to do the job — a 25% increase over the original plan.

Nations could bring down the cost of the machine by swapping procurement agreements and consolidating production, but that's not politically realistic, says Kaname Ikeda, ITER's director-general. "The first objective is [for members] to get the experience of designing, fabricating and operating this machine," he says. Akeda adds that most seem willing to live with the cost increase, so long as they gain the knowledge needed to build a power-producing fusion reactor.

Member governments are preparing to shoulder the increase. Last year, the United States upped the estimated cost of its contribution to $2.2 billion — double the preliminary price. The EU, meanwhile, is grappling with increased spending to complete the buildings for the project. We are "trying to get rid of everything that is not indispensable," says Trias. "Each country has its own internal problems," adds Evgeny Velikhov, a Russian representative on the ITER council, although he adds that "Russia does not see any problem in fulfilling its obligation".

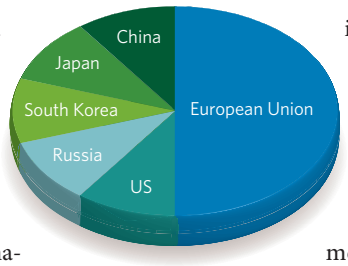
Those close to the project now see Scenario 1 as the only practical way forward. Under the plan, the reactor would initially be built without several crucial and expensive components, including an inner shielding wall and test bed for new materials such as lithium blankets that generate tritium for the machine, along with the diverter, a series of tiles at the bottom of the tokamak that shunts heat safely out of the device. Also gone will be expensive accelerators to pump neutral beams of fuel into the machine, and some radio-frequency devices designed to further heat the plasma. Without these components, ITER can handle only plasmas of hydrogen, not deuterium or tritium.

The plan would allow scientists and engineers to ensure that ITER works long before it is injected with tritium — a process that will make large sections of the machine inaccessible. "They want to see success at the end, and the way to success is this road," says Holtkamp. "There really is no other one." ■

Additional reporting by David Cyranoski

See Editorial, page 483.

INTERNATIONAL CONTRIBUTORS TO ITER



ITER