Speed matters. It has taken just over 5 years and $37 million to complete China's new tokamak, according to the Institute of Plasma Physics.

ENERGY ALTERNATIVES

Waiting for ITER, Fusion Jocks Look EAST

China is breaking new ground with a fusion test bed that will tide researchers over until the ITER megaproject comes online

HEFEI, CHINA—The official launch of the International Thermonuclear Experimental Reactor (ITER) project next week will mark a coming of age for fusion research in Asia. When the $11 billion effort was initiated in 1985, ITER's four original backers—the United States, the European Union, Japan, and the Soviet Union—accounted for nearly all worldwide research into harnessing fusion, the process that powers the sun, to produce energy. But now the three newest ITER partners, China, South Korea, and India, are showing that they didn't just buy their way into one of the biggest physics experiments since the Manhattan Project: They are contributing crucial expertise as well.

The first new Asian fusion tiger out of the gate is the Institute of Plasma Physics (IPP) of the Chinese Academy of Sciences, which in March completed testing a machine that has never been built before: a fully superconducting tokamak. This toroidal vessel isn't the largest or most powerful device for containing the superhot plasma in which hydrogen isotopes fuse and release energy. But until India and South Korea bring similar machines online (see sidebar, p. 993), it will be the only tokamak capable of confining a plasma for up to 1000 seconds, instead of the tens of seconds that machines elsewhere can muster. ITER, expected to be completed in Cadarache, France, in 2016, will have to sustain plasmas far longer to demonstrate fusion as a viable energy source. But researchers from China and around the world will be able to use IPP's Experimental Advanced Superconducting Tokamak (EAST) to get a head start on learning to tame plasmas for extended periods. "This will make a big contribution for the future of fusion reactors," declares Wan Yuanxi, a plasma physicist who heads EAST.

Fire when ready. EAST will fill a crucial gap for fusion researchers until ITER is built, says Director Wan Yuanxi.

Fusion research over the next decade will be probing the physics of steady-state plasmas like those promised by ITER, says Ronald Stambaugh, vice president for the Magnetic Fusion Energy Program at General Atomics in San Diego, California. "EAST will play a big role in that," he says. Others credit IPP for building its advanced tokamak fast, in just over 5 years, on a shoestring $37 million budget. That's a fraction of what it would have cost in the United States, says Kenneth Gentle, a plasma physicist and director of the Fusion Research Center at the University of Texas, Austin. "That they did this in spite of the financial constraints is an enormous testimony to their will and creativity," adds Richard Hawryluk, deputy director of the Princeton Plasma Physics Laboratory.

IPP adroitly fills a generational gap. Fusion power will rely on heating hydrogen isotopes to more than 100 million degrees Celsius, until they fuse into heavier nuclei. The leading design for containing this fireball is the tokamak, a doughnut-shaped vacuum chamber in which a spiraling magnetic field confines the plasma. Ringlike metal coils spaced around the doughnut—toroidal field coils—and a current in the plasma produce this spiraling field. Additional coils in the center of the doughnut and along its circumference—poloidal field coils—induce the current in the plasma and control its shape and position.

Early tokamaks had circular cross sections and copper coils, which can only operate at peak power in brief pulses before overheating. ITER will be far more sophisticated. It will have a D-shaped cross section, designed to create a denser plasma that can generate its own current to supplement the induced current, reducing energy input. And coils will be superconducting. (No major tokamak has had superconducting poloidal field coils.) At temperatures approaching absolute zero, superconductors carry current without generating resistance, allowing more powerful magnetic fields that can be maintained longer.

Researchers want to try out a D-shaped, fully superconducting test bed before scaling up to ITER, which will be two to three times the size of current tokamaks. The Princeton Plasma Physics Laboratory had planned to build such a device. But a cost-conscious U.S. Congress killed their $750 million Tokamak Physics Experiment in 1995. EAST and the two other Asian tokamaks under construction intend to fill this gap.

"We recognized this was an opportunity for us to make a contribution for fusion research," Wan says. For support, he tapped into China's worries about its growing demand for energy. "There is no way we can rely entirely on fossil fuels," he says. China's government approved EAST in 1998.

IPP faced an enormous challenge. The institute, founded in 1978, had built a few tiny tokamaks in the 1980s and got a hand-me-down, partially superconducting tokamak from Russia's Kurchatov Institute in 1991. EAST would be a totally different beast. "We didn't have any experience in the design, fabrication, or assembly of these kinds of magnets," Wan admits. Neither did Chinese manufacturers.

Industrial partners supplied parts of the tokamak, including the vacuum vessel. But the superconducting coils and many other high-tech components would have been too expensive to import. "We had to do [these] ourselves," says the tokamak's chief engineer, Wu Songtao. So Wu's team bought precision milling machines, fabricated their own coil winders, and built a facility to test materials and components at cryogenic temperatures. "They literally built a whole manufacturing facility on site," says Hawryluk.

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IPP physicists and engineers passed a major milestone earlier this year, when they tested the entire assembled device, cooling the 200 tons of coils to the operating temperature, 4.5 kelvin. They discovered only minor, fixable glitches, Wan says, and are now undertaking the necessary tweaks and installing shielding materials and diagnostic devices. In August, they plan to inject hydrogen and fire up EAST's first plasma.

With the tokamak passing its cool-down test, Wan says the team was "finally able to get a good night's sleep." They are now planning experiments to explore how to control D-shaped plasmas. Tugging a plasma into a specific shape can create instabilities, Gentle says. Control is all the more difficult because superconducting coils respond poorly to current fluctuations. IPP will probe these issues. "That's where the science is going to be extremely valuable," says Hawryluk.

EAST has limitations. The most significant is that, unlike ITER, it will not attempt a burning plasma, in which at least half the energy needed to drive the fusion reaction is generated internally. ITER will use a combination of deuterium and tritium (hydrogen isotopes with, respectively, one and two neutrons in the nucleus), which fuse at a lower temperature than other gases, to achieve a burn. Because radioactive tritium requires specialized and expensive handling systems and shielding, EAST will use only hydrogen or deuterium.

That limitation is hardly dampening enthusiasm for the hot new kids on the block. IPP researchers, says Hawryluk, "have already put themselves on the fusion community map."

–DENNIS NORMILE

With reporting by Gong Yidong.

Asian Fusion

India, Korea, and possibly Japan are joining China in building next-generation tokamaks. These machines seek to fill a research gap on the road to the International Thermonuclear Experimental Reactor (ITER) by employing all-superconducting coils to study the physics of confining plasmas for long durations, which current tokamaks can't do.

■ India's Institute for Plasma Research is now commissioning its Steady State Superconducting Tokamak. An engineering test at cryogenic temperatures turned up problems that are now being addressed. Institute plasma physicist Y. C. Saxena says they are hoping to try a second engineering test later this month. If that goes well, they will attempt their first plasma in the summer. The $45 million project, launched in 1994, is the smallest of the new tokamaks. But Saxena says they believe they can help unravel the physics of long-lasting plasmas.

■ The most ambitious machine is the Korean Superconducting Tokamak Reactor (KSTAR), being built by the National Fusion Research Center in Daejeon. KSTAR relies on superconductors made from the more advanced niobium-tin alloy that ITER will employ. The $330 million project was delayed because of Korea's late-1990s economic crisis. Project Director Lee Gyung-su says they are now aiming for first plasma in early 2008.

■ For several years, Japan's Atomic Energy Agency has been studying the possibility of upgrading its JT-60 tokamak to be fully superconducting. Japan may get funding for the upgrade from the European Union as compensation for its assent on the agreement to build ITER in France. An agency spokesperson says key decisions are under negotiation. **–D.N.**

SCIENTIFIC OPENNESS

Should Academics Self-Censor Their Findings on Terrorism?

Some government-funded researchers believe their papers require special handling. But others say that creating such a gray area undermines academic freedom

Last year, after Detlof von Winterfeldt and his colleagues at the University of Southern California (USC) in Los Angeles finished a study on the likelihood and impact of a dirty bomb attack by terrorists on the Los Angeles harbor, they omitted some important details from a paper they posted on the Internet. Although the team had used no classified material, von Winterfeldt felt that self-censorship was prudent given the subject matter. It's also in line with draft guidelines being considered by the U.S. Department of Homeland Security (DHS), which funds the Center for Risk and Economic Analysis of Terrorism Events that he directs. "We were still able to present the methodology behind the analysis fully and effectively," he says. "It made perfect sense to make those changes."

But some scientists say that stance conflicts with academic freedom, and that the public deserves access to anything not explicitly classified. They worry that the actions of the USC researchers could serve as a model for restricting the conduct and dissemination of university research. Their concerns are tied to an ongoing effort by the Bush Administration to draw up common standards across federal agencies for withholding information under the rubric of sensitive but unclassified (SBU) material.

"The only appropriate mechanism for controlling information is classification," says Steven Aftergood, who runs the Project on Government Secrecy for the Federation of American Scientists. "If we want to gain the benefits of university research on problems of national security, we need to conduct it openly. Imposing restrictions short of classification is a slippery slope that will ultimately paralyze the academic process."

Universities have traditionally drawn a sharp line between classified and unclassified information, refusing to accept the ill-defined SBU category. Yet, in a 28 March meeting at the U.S. National Academies, DHS officials and directors of the six university centers funded by the agency discussed draft guidelines to control the dissemination of sensitive information generated by their research. The guidelines were developed by the center directors in collaboration with DHS officials. The academies agreed to be host because of their ongoing interest in the topic.

Besides recommending the scrubbing of papers before publication, the guidelines would have center directors decide whether proposed research projects are likely to produce sensitive information—loosely defined as information not easily available from public sources and/or of potential use to terrorists. Projects that fit that description would be subject to additional scrutiny. The results, says the document, could include "producing different version(s) of the findings for 'For Official Use Only' and for public dissemination, declin[ing] the proposed work, or mov[ing] it to a classified environment."

The guidelines simply acknowledge "the reality of a changing world," says Melvin Bernstein, acting director of DHS's Office of Research and Development, which helped set up the university centers with 3-year renewable grants. "There's an increasing recognition in the university community that there could be circumstances when researchers need to be careful about what can be disseminated."

Although Bernstein says it's too early to know whether the guidelines will become official policy, they appear consistent with a presidential directive issued last December ordering common standards across the

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