

degrees in the physical sciences and engineering. "This gap at the graduate level has been taken up by an influx of foreign students, but we are facing an overdependence on this talent pool . . .," the letter says. "Testimony from both private industry and the federal sectors expressed strong concerns about the pending retirement of a generation of physical scientists and engineers with few options for replacing them."

The report's final recommendation is a response to the increasingly inter-

disciplinary nature of science and the difficulty of coordinating programs that are overseen by several different federal agencies and funded by multiple congressional appropriations committees. PCAST calls for the creation of a classification system to "help assess the patterns of federal investment in R&D against its ability to meet national needs." The report also calls for more systematic monitoring of foreign science and technology efforts to ensure that the US stays competitive.

JIM DAWSON

Fusion Energy Panel Urges US to Rejoin ITER

Declaring that the fusion community "sees itself on the threshold of a giant step forward," the Department of Energy's independent Fusion Energy Sciences Advisory Committee has strongly endorsed a recommendation by its Burning Plasma Strategy Panel that the US negotiate to rejoin the multibillion-dollar International Thermonuclear Experimental Reactor project. The endorsement came at the end of an 11 September meeting in which FESAC reviewed the 48-page report titled *A Burning Plasma Program Strategy to Advance Fusion Energy* that recommended rejoining ITER or, as a fallback position, building a smaller US project called the Fusion Ignition Research Experiment (FIRE).

The recommendation that the US enter negotiations to rejoin ITER was enthusiastically embraced by Ray Orbach, director of DOE's Office of Science. Speaking before the National Research Council's Burning Plasma Assessment Committee a week after the FESAC meeting, Orbach said, "The issue for us is how do we approach providing power by the fusion process? Burning plasma physics should be the penultimate step to developing a burning plasma reactor. It's a strong statement, but I think we're in the position to . . . get fusion energy on the [power] grid in 35 years."

The NRC committee listened to two days of presentations about the current state of burning plasma physics and the strategy proposed by the FESAC panel. Orbach asked the NRC committee to deliver a report to him unusually quickly—by early December—so he can use it to support his case that the US rejoin ITER. Haste is necessary, he said, because ITER's current partners—Europe, Japan, Canada, and Russia—are working on a timetable for selecting a site for the

▶ A burning plasma is within reach and fusion could start providing electricity in as little as 35 years, according to several fusion researchers.

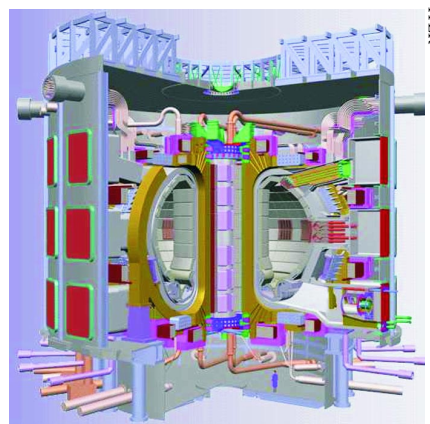
facility and expect a final decision in 2004. FESAC and Orbach agreed that the US should try to join ITER as a full partner and have some input into the site selection. To do that, Orbach said, "my perspective is the US should make a decision on whether to enter negotiations by the end of this year, or January or February of next year at the latest."

In a mid-September letter to Richard Hazeltine, chair of FESAC, Orbach asked FESAC to "develop a plan with the end goal of the start of operation of a demonstration power plant in approximately 35 years. The plan should recognize the capabilities of all fusion facilities around the world, and include both magnetic fusion energy (MFE) and inertial fusion energy (IFE), as both . . . provide major opportunities for moving forward with fusion energy." Hazeltine was asked to move quickly to get a preliminary report completed by early next month and a "more detailed plan upon which budgeting exercises can be based" by March 2003.

Orbach's push to move forward was based in part on a white paper prepared for FESAC by six fusion researchers who said if the US participated in ITER and aggressively maintained the rest of its fusion program, "it should be possible to begin operation of a practical demonstration power plant in approximately 35 years." The paper, *An Accelerated Plan to Develop Practical Magnetic Fusion Energy*, was written by Charles Baker, David Baldwin, Robert Goldston, Thomas Jarboe,

Stanley Milora, and Miklos Porkolab, all serving on the 47-member Burning Plasma Strategy Panel that wrote the official report to FESAC. The white paper notes that President Bush's National Energy Policy and energy bills on Capitol Hill all point to fusion as a clean energy source. "In parallel with these policy developments," the paper says, "progress in magnetic fusion energy scientific research has been rapid." The scientific results of the past decade, according to the report, "open a pathway to the demonstration of practical fusion electric power. With commitment of effort and focus on critical issues and well-identified milestones, this goal should be achievable."

Orbach tied the development of usable fusion to the global warming issue. To the NRC committee, he distributed charts showing how fusion can contribute to lessening carbon dioxide buildup by 2050. The 35-year goal of getting a demonstration fusion reactor working "is set by environmental needs," Orbach said. "If I could make it happen in 25 years, I would. I think the world needs alternative energy that is CO₂-free, for without it we are on a course with serious consequences." The resurgence of interest in a burning plasma program began with the initiation in 2000 of a series of workshops sponsored by the University Fusion Association. According to the FESAC report, a panel set up after the workshops to assess options "concluded that now is the time for the US to take the steps leading to construction of a burning plasma experiment, and that the funding for the experiment should be in addition to the core fusion energy science budget. . . ." At a July 2002



ITER IS BEING DESIGNED as a tokamak in which superconducting magnets confine and control a reacting deuterium-tritium plasma.

meeting of fusion scientists in Snowmass, Colorado, a consensus emerged that a strategy to boost burning plasma science should be developed; that task was done at an August meeting in Austin, Texas.

The burning plasma panel report to FESAC contains a series of "strategy recommendations":

► "Since ITER is at an advanced stage, has the most comprehensive science and technology program, and is supported internationally, we should now seek to join the ITER negotiations with the aim of becoming a partner. . . ." Becoming a full partner, the report says, will likely require funding of approximately \$100 million per year.

► "Since FIRE is at an advanced pre-conceptual design stage, and offers a broad scientific program, we should proceed to a physics validation review . . . and be prepared to initiate a conceptual design."

► "If ITER negotiations succeed and the project moves forward . . . then the US should participate. The FIRE activity should then be terminated."

► "If ITER does not move forward, the FIRE should be advanced as a US-based burning plasma experiment."

Although ITER and FIRE were the primary focus of the report, a smaller project proposed in Italy, called IGNITOR, was also considered by panel members. They concluded that if IGNITOR is built, the US should collaborate primarily through research participation.

The current DOE efforts are focusing on burning plasma because of the time pressure involved in rejoining ITER, but agency officials said the multibillion dollar National Ignition Facility will take care of inertial confinement fusion; NIF is at Lawrence

Livermore National Laboratory in California. Intended primarily as a way to maintain the US nuclear weapons stockpile, NIF will be "many times larger than any previous inertial confinement device," a recent DOE report noted. DOE supports several other inertial confinement fusion labs.

Orbach said the FESAC and NRC burning plasma reports will be central to a decision by President Bush on whether to rejoin ITER negotiations. Supporters of the program are aware that the budget is tight and it will be difficult to get \$100 million per year to support US involvement in ITER. The project's estimated cost in 1998, nearly \$10 billion, was a key reason the US withdrew. ITER has been scaled back to an estimated \$5 billion, the amount on which the \$100 million US contribution is based.

In addition to the federal budget being very tight, policymakers are highly skeptical about the promise of fusion. Having heard promises for the past 20 or 30 years that fusion was just 20 or 30 years away, FESAC and Orbach must persuade the administration and Congress that the science really has progressed.

"The skepticism is very real," said Anne Davies, director of the DOE's Office of Fusion Energy Sciences. The science has made enormous strides in the past 10 years, she said, "and I think we're absolutely ready to build a burning plasma experiment." But she noted that the cynics are still saying "we've heard that before."

Orbach is also concerned about the skeptics. "But we've never had a united [fusion] community before," he said. "Congress will listen . . . if we are united and give them a detailed timeline."

JIM DAWSON

Teaching Physics with Superheroes

How did Superman get to be so strong? What killed Spider-Man's girlfriend Gwen Stacy? How fast can the Flash run? Jim Kakalios, a condensed matter experimentalist and comics buff, analyzes questions like these from action comics to teach physics in a freshman seminar at the University of Minnesota-Twin Cities.

"Take Superman," says Kakalios. "What does it take to leap a tall building in a single bound?" To find out, Kakalios's students use Newton's laws of motion. "We calculate how much force is required," says Kakalios. That leads to the question, How did his legs get so strong? "Back in the 1930s,"

Kakalios says, "it was presumed that Superman was so strong because he was acclimated to Krypton's gravity." In the class, the gravitational force of Krypton—Superman's home planet—is calculated to be about 15 times that of Earth's. "We talk about Newton's law of gravity, and then we talk about how you would build such a planet, and not make it a gas giant. I bring in things from different parts of the physics curriculum, and show how interconnected everything is," says Kakalios. "It turns out that the only way we could figure out how to make such a planet, it would be very unstable—it would explode." It's an amusing twist, he adds, "that this is com-



pletely consistent with the comics."

Another example is the controversy over the death of Gwen Stacy, who was knocked off a bridge tower. Spider-Man may have been surprised to find her dead when he caught her in his web, but Kakalios's students weren't: By estimating the height of the bridge, Gwen's mass, and the time Spider-Man had to catch her, and then using conservation of momentum, says Kakalios, "it turns out the force has to be at least 10 Gs. If she experienced such a sudden jerk, it's not unreasonable that she would have broken her neck."

The Bernoulli principle, time travel, and the biological and physical feasibility and implications of shrinking to the size of an atom or growing into a giant are among the topics Kakalios's class tackles through comics. The comics don't get the science right all the time, says Kakalios,