

universities. Private foundations also are contributing to the NSF Innovation Corps program, dubbed I-Corps.

But many companies have developed long-term one-on-one relationships with one or more universities. John Deere has partnered with universities for two decades, says Jerry Duncan, the company's manager of university R&D relations. As Deere began getting into research on how people interact with machines, Duncan realized it would be less expensive and take less time to use capabilities already available at Georgia Tech. Deere later joined a University of Pennsylvania research project that was developing a digital human model with Department of Defense support. The company now uses that model, known as Jack, in the design of new products and in harvester-operator training simulators. Today, Deere has ongoing partnerships with Iowa State University, Carnegie Mellon University, the University of Illinois at Urbana-Champaign, and Georgia Tech. A dozen ISU graduates have gone to work at Deere, and the company has hired students from the other schools. "It's not just the training and education and knowledge that they have at the moment, it's the potential that they have over a long period of time," Duncan says. He notes that partnerships give companies a far better opportunity to spot talent than they get through job interviews.

In May, Brown University and General Motors signed an agreement in which the automaker is to provide \$2 million over five years to Brown's Collaborative Research Laboratory on Computational Materials Science. The center, supported by GM for the past 10 years, develops simulations that predict

the mechanical properties of materials used in automotive applications, such as the behavior of aluminum during the forming and evolution of aluminum-silicon alloys.

Irreplaceable funding

Industry should be careful not to regard universities as a source of short-term applied research, cautions Clyde Briant, vice president for research at Brown. Briant says that academic institutions, unlike corporations such as General Electric, where he worked for 18 years, are not set up to do applied work. To develop a product in industry, he says, "You really need a whole support team. You have to have people who deeply know the problem, and you've got to quickly judge if you've got a solution, and understand the economic impacts." Those aren't skills that are readily available on campus.

Academic research administrators warn that industrial support will never be sufficient to supplant federal funding. "There is simply no substitute for the type, the quality, and the scale of federal funding. It's the key to the innovative engine of this country," says Stephen Forrest, vice president for research at the University of Michigan. Despite 10 years of effort to attract more industry funding, the fraction of UM's \$1.3 billion research portfolio paid for by industry has been stuck at 5%, he laments, the same as a decade ago. Adds Mel Bernstein, vice provost for research at Northeastern University, "We understand the clear pressures on the federal budget. But there really is no substitute for the kind of support the federal government provides."

David Kramer

W7-X will operate in a steady-state mode, confining a fusion plasma for 30 minutes at a stretch. Stellarators, like tokamaks, rely on magnetic fields to confine plasmas. But a stellarator's donut shape does not have a symmetrical cross section. That makes it harder to design but gives it advantages for attaining steady-state operation because, unlike in a tokamak, the plasma in a stellarator does not carry a strong current.

Modern simulation techniques were used to design the W7-X. Its heat diverters, 70 superconducting coils, and other features are optimized to confine the plasma, prevent the escape of helium nuclei that result from fusion reactions, prevent particle impurities from entering the plasma, and create a stable magnetic field with minimal toroidal current. The stellarator is designed to confine plasmas of up to 100 million K. "This machine is going to go into uncharted territory," says W7-X scientific director Thomas Klinger. "[The plasma] will be hotter and denser than other plasmas generated in a stellarator device. We want to demonstrate that optimized stellarators can perform as well as a tokamak of the same size." The only stellarator of comparable size is the Large Helical Device in Japan.

Part of the US contribution to the W7-X consists of trim coils for fine-tuning the plasma edges, which are sensitive to small perturbations in the magnetic field. The trim coils will be made by the Princeton Plasma Physics Laboratory (PPPL) and Oak Ridge National Laboratory. Los Alamos National Laboratory is also part of the W7-X collaboration, for which US partners are also working on R&D and code development to analyze results. The trim coils "were a very much wanted missing item. We discovered that this instrument was utterly needed and was not in the budget," Klinger says.

The US commitment is about \$8.8 million over three years, or annually around 1% of the US fusion budget. The total cost of building the machine and diagnostics instruments is €346 million (\$493 million); the full construction cost, counting salaries, buildings, and everything else, is in the €1 billion range. Germany is footing most of that, with contributions from the local host government and the European Union.

Poland is the other key partner in the construction process. In addition to cash and in-kind contributions worth more than €5 million, Poland has sent a team—transferred from the Large Hadron Collider at CERN—to work on assembling the W7-X.

US narrows fusion research focus, joins German stellarator

Tight money leads to increased emphasis on tokamak plasma physics and the shuttering of some exploratory experiments.

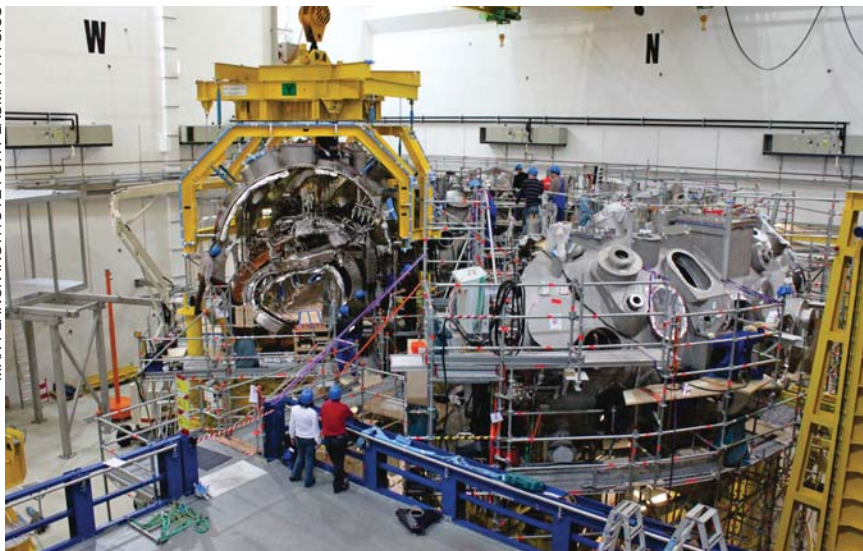
Joining the Wendelstein 7-X (W7-X) stellarator project in Greifswald, Germany, affords the US the opportunity to participate in a premier fusion facility. The project aims to prove that a stellarator could perform as a reactor and generate energy.

The move also fits with the US Department of Energy's redirection of fusion plasma research to science relevant to ITER, the international fusion test reactor under construction in France. Accordingly, DOE has canceled some

small, non-tokamak experiments. Edmund Synakowski, DOE's Office of Science associate director for fusion energy sciences, describes the shift as going away from "exploring such alternative configurations for their own sake" to research that "can contribute to our understanding and optimizing the tokamak configuration and configurations closely related to it."

Superconducting stellarator

Slated to start experiments in 2015, the



Weird geometries characterize stellarator fusion machines. The Wendelstein 7-X, under construction in Germany, consists of identical magnet modules that give the torus a fivefold periodicity.

The partners hope that the US contribution to the W7-X is the start of a long-term partnership that will grow to include US universities. "Stellarators were invented in the US. All the know-how available is welcome," says Klinger. Noting that the US "is not pursuing fusion aggressively compared to the rest of the world," PPPL deputy director for research Michael Zarnstorff says that participating in W7-X is a "unique opportunity to attack critical fusion questions."

"The gorilla in the room"

US fusion scientists are glad to join the W7-X. The US invests less in fusion research than Europe does, and US facilities are being outpaced by new experiments in Asia. "There is a general theme to take advantage of the fusion plasma facilities abroad," says PPPL director Stewart Prager. "At the same time, to make progress in fusion generally, and to benefit from ITER, unquestionably the gorilla in the room, a strong US program is imperative."

Noting that "budget realities make it unlikely that the U.S. will construct a major new domestic facility for some time," William Brinkman, director of DOE's Office of Science, in July charged the department's Fusion Energy Sciences Advisory Committee (FESAC) with looking into international collaboration opportunities in "long-pulse, steady-state research in superconducting advanced tokamaks and stellarators." He also told the committee "to elucidate the research needed to fill the gaps in materials science and technology required to sustain fusion plasma

operations and to harness fusion power." Both assessments are due in January 2012.

Meanwhile, though, some in the US fusion community are dismayed about the cutting of non-tokamak experiments, such as the \$1.2-million-a-year Levitated Dipole Experiment at MIT. Inspired by planetary magnetospheres, the LDX uses a central superconducting dipole to confine high-temperature plasma in steady state without large external magnets. Columbia University's Michael Mauel, a principal investigator on the experiment, told FESAC in March that "discovery research like LDX is important to the vitality of our field because it is not a tokamak or a stellarator."

A couple of researchers would not go on record criticizing the cancellations for fear that DOE would retaliate in future funding competitions. But Tom Jarboe, a plasma physicist at the University of Washington, Seattle, where the TCS (Translation, Confinement, and Sustainment field-reversed configuration experiment) was cut, says, "I think that any experiment that does not have a toroidal field was axed. We should explore a lot of ideas. The tokamak is not to the point that we know it will make economical fusion." Stephen Dean, director of the nonprofit Fusion Power Associates, puts it more strongly: "The damage to the US innovative confinement concepts fusion program by terminating the LDX and other non-tokamak experiments far exceeds any benefit that might accrue from the minimal support provided to Wendelstein."

Toni Feder



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