ORNL, Princeton partners in five-year fusion project

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Knowledge gained by Oak Ridge National Laboratory researchers and colleagues through an initiative to begin this fall could answer several long-standing questions and give the United States a competitive edge in the design of future fusion power plants.

The $10 million five-year Department of Energy SWIM (Simulation of Wave Interactions with Magnetohydrodynamics) project combines the talents and massive computing capabilities of ORNL with resources at Princeton Plasma Physics Laboratory and several other institutions. The goal is to study high-performance fusion plasma and perform comprehensive simulations that are essential to the development of fusion.

Magnetized fusion plasmas contain electrons and the fusion fuel -- ions of deuterium and tritium. Plasma contained within a fusion device behaves very differently depending on the shape of the magnetic field and distribution of the electric current. Because no material can withstand the 100 million degree temperature of the plasma, it is the magnetic field that actually contains the plasma. Being able to control the plasma is critical to the success of fusion as a source of energy.

"High-power radio frequency electromagnetic waves can heat plasmas to the astronomical temperatures required for fusion and they can also exert control," said Don Batchelor, who heads the theory group in ORNL's Fusion Energy Division. "For example, waves can either produce instability or prevent instability depending on how they are used. Consequently, understanding and being able to predict the effects of radio frequency waves remains one of the key challenges."

Batchelor and colleagues plan to use computer modeling to develop a better scientific understanding of the interaction between plasma stability and radio frequency power, and to be better able to design radio frequency systems to control the instabilities inherent in plasma. Such an achievement would be huge and would remove one of the barriers to obtaining fusion power, which offers the potential of a virtually limitless source of energy with none of the disadvantages of today's energy sources.

In a distinct departure from past strategies to understand magnetically confined plasmas, the SWIM project emphasizes an integrated approach. This method, Batchelor notes, is much like those used for climate-change predictions and takes into account the many interactions and complexities inherent in plasma physics and in nature.

"We are bringing together two areas of fusion physics that have previously been studied separately," Batchelor said. "As with systems biology or climatology, the science of the whole of what takes place in a fusion plasma is far richer than the science of the pieces, and we simply cannot understand the organism, the evolution of climate or the plasma until we understand the couplings between the various contributing phenomena."

The project builds upon the successes of DOE's Scientific Discovery through Advanced Computing programs by taking several of the most advanced fusion computer codes, combining them to provide a unique tool in the worldwide fusion program and running them at the National Leadership Computing Facility at ORNL's Center for Computational Sciences.

The Center for Computational Sciences, established in 1992 as a DOE high-performance computing research center, is a designated user facility with several missions, including to help solve grand challenges in science and engineering. Last year, DOE designated ORNL as the site for the National Leadership Computing Facility, which will provide the foundation to propel the U.S. back to the forefront of high-performance computing.

"Our new computers will play a big part in making this project a success," Batchelor said. "Being able to run large-scale numerical simulations that take into account the many coupled processes at work in magnetized plasma taking place on disparate time scales is vital to the development of fusion energy."

Not only do plasma simulations serve to advance science by allowing researchers to evaluate and test basic theory through comparison with experiments, they also maximize the productivity of experimental facilities and support design decisions for new facilities. For a device like the International Thermonuclear Experimental Reactor, which will cost up to $1 million per day, such decisions can have multi-billion dollar consequences, Batchelor said.

ITER is the experimental step between today's studies of plasma physics and tomorrow's electricity-producing fusion power plants. ITER, which will be located in Cadarache, France, represents a collaboration among The European Union, Japan, the Republic of Korea, the Russian Federation, the United States and The People's Republic of China. Completion of ITER is scheduled for 2016.

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