University of Tennessee, ORNL lead national team to study nuclear fusion reactors

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Power from nuclear fusion reactors has the promise to be safe, sustainable and limitless. But science has not been able to bring fusion energy to the commercial energy market. This is partly because the operating limits of the reactor materials are not known.

A team of researchers at the University of Tennessee, Knoxville, and Oak Ridge National Laboratory, in collaboration with seven other institutions, is trying to change that.

Led by Brian Wirth, UT-ORNL Governor's Chair for Computational Nuclear Engineering, the Scientific Discovery through Advanced Computing (SciDAC) project will receive $2.3 million from the Department of Energy for the first year with plans for a total of $11.5 million over five years. ORNL and UT will receive $850,000 for the first year with plans for a total of $4.1 million over five years.

Nuclear fusion promises an almost limitless supply of clean and safe energy. Unlike the nuclear fission reactors used today, it doesn't come with the challenge of managing used nuclear fuel containing very long-lived radioactivity. This is because the process to create the energy is different. In nuclear fission, an atom is split into two smaller atoms which remain radioactive for hundreds to many thousands of years. In fusion, two or more smaller atoms are fused into a larger atom that is not radioactive.

"However, the fusion process currently pursued unleashes a very high-energy neutron that is believed to produce more damage to reactor materials than in fission," Wirth said. "Now is the right time to examine this impact of fusion reactions on materials as we determine whether we can really make fusion work as a practical energy source."

The researchers will examine how the surfaces of materials which comprise the reactor respond when being bombarded by energetic neutrons and ions. Using high-performance computers such as ORNL's Jaguar and UT's Kraken, the researchers will try to accurately predict materials' performance and evaluate materials systems and component design for the fusion reactor environment. The team will then be positioned to use their computational tools to evaluate new materials and component designs to enable fusion energy.

"A fusion reactor works by introducing plasma—a hot, electrically charged gas that serves as the reactor fuel—into a vacuum vessel," Wirth said. "The plasma is then confined using electric and magnetic fields into a central, vacuum region."

The problem, he said, is that ions from the plasma escape and bombard the material surfaces, in addition to the high-energy neutrons. This combination causes significant damage and changes the properties of the reactor materials.

"It's likely materials do not exist today that could be used to build a reactor that would contain the plasma," Wirth said.

The material property changes are driven by many processes that occur in less than a nanosecond. Yet, it is the cumulative interaction of such processes over much longer times that determine the precise value of these changes. Wirth and his team aim to develop models which stretch this interaction over the period of many decades to evaluate their long-term effects.

"We are trying to identify and model numerous microscale defect and impurity interaction processes that occur over rapid time scales which can span less than a nanosecond," Wirth said. "And then we are trying to integrate these into a model that can predict the material response over the years and decades for which a plasma reactor needs to operate."

Wirth notes that making these goals more challenging is the fact that no current experimental facilities exist that accurately represent the environment these materials are expected to face.

"Our research will address one critically important aspect toward getting to fusion energy," Wirth said. "I'm optimistic about the potential for fusion energy, but realistic in understanding how difficult it will be to realize."

Provided by University of Tennessee at Knoxville

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