Argonne's nuclear energy research moves toward greater reliance on computer simulation

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The U.S. Department of Energy's Argonne National Laboratory is taking its nuclear energy research into new territory – virtual territory that is.

With the recent arrival of the new IBM Blue Gene/P and the lab's development of advanced computer models, Argonne has a critical role in making it possible to burn repeatedly nuclear fuel that now sits as waste, thus closing the nuclear fuel cycle and reducing the risk of nuclear proliferation.

The move toward greater reliance on computer simulation and modeling to conduct nuclear energy research is a progressive trend seen in other areas of scientific research supported by DOE.

"High-speed supercomputers are increasingly tackling difficult problems that could once be addressed only in a laboratory setting," Argonne Director Robert Rosner said.

"The traditional approach to developing nuclear energy technologies is to do a bunch of experiments to demonstrate a process or reaction," said Mark Peters, deputy to the assistant laboratory director of applied science and technology and Argonne's program manager for the Global Nuclear Energy Partnership. "What Argonne is doing is creating a set of integrated models that demonstrate and validate new technologies, using a smaller number of experiments."

Moreover, "advanced simulation can greatly reduce facilities' costs by allowing us to better identify and target the physical experiments which underlie their design," said Andrew Siegel, a computational scientist at Argonne and the lab's nuclear simulation project leader.

Siegel and a team of Argonne computational scientists are in the throes of refining computer codes that will eventually be used to conduct the underlying scientific research that will support the development of next generation nuclear systems such as advanced fast reactors, Siegel said. "We will use advanced simulation to improve and optimize the design and safety of advanced fast reactors," he said.

The Sodium Fast Reactor (SFR) design, which was born at Argonne, is a key part of President Bush's Global Nuclear Energy Partnership, a strategy that will significantly reduce the radioactivity and volume of waste requiring disposal and reduce the risk of nuclear proliferation. SFR designs are safe, capable of reducing the volume and toxicity of nuclear waste, and economically competitive with other electricity sources.

Using internal lab funding initially and GNEP funding more recently, Argonne computational scientists are designing a modern suite of tools called SHARP – Simulation-based High-efficiency Reactor Prototyping, Siegel said. The SHARP toolkit is a collection of individual software components that digitally mimic the physical processes that occur in a nuclear reactor core, including neutron transport, thermal hydraulics and fuel and structure behavior, Siegel explained.

SHARP has been developed to fully leverage Argonne's new Advanced Leadership Computing Facility, which is made up of the Blue Gene/P, an IBM computer that is designed to operate at a sustained rate of 1-petaflop per second and capable of reaching speeds of 3 petaflops.

SHARP will build upon and may eventually replace existing computer codes that are used to conduct safety evaluations of today's portfolio of aging nuclear power reactors. Furthermore, those older codes, while adequate for evaluating the scoping designs of next generation reactors, are not as well-equipped to validate the performance of new reactor concepts now under design, Siegel said. A simulation tool like SHARP, which is being written specifically to test SFR design concepts, have the potential to shave off millions of dollars in reactor design development and construction, he said.

The kind of modeling and simulation work taking place at Argonne in support of the development of advanced nuclear energy systems is not by accident. "We see Argonne as the one place that can pull off the creation of advanced simulation tools that will be able to successfully replace some types of experiments," Siegel said.

The reason: Argonne has the biggest concentration of scientists involved in fast reactor design and fuel reprocessing technologies – expertise that is essential to refining SFR design concepts. "This is the center of brain power for nuclear energy research," Siegel said. Moreover, Argonne's nuclear engineers and chemical engineers have already been collaborating with the lab's computer scientists to develop precise computer simulations of the process of physical changes that would occur in an SFR, as well as other important aspects of the nuclear fuel cycle (e.g., separations and processing technologies).

Source: Argonne National Laboratory