

# NEAMS: The Nuclear Energy Advanced Modeling and Simulation Program

**VISION:** *Enhance the value of the Office of Nuclear Energy's (NE) research and development portfolio through the use of advanced computational methods.*

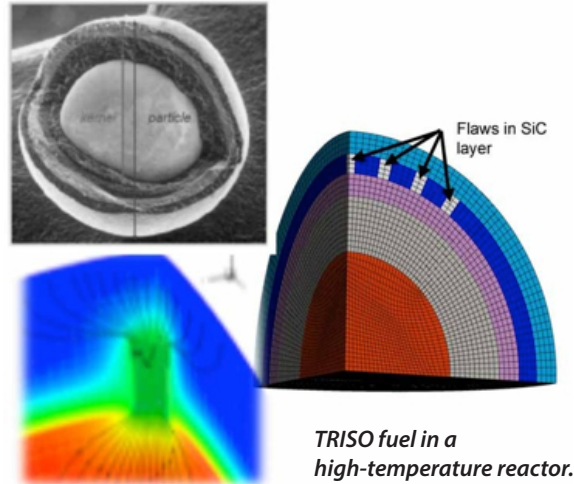
The Nuclear Energy Advanced Modeling and Simulation (NEAMS) Program is developing a simulation tool kit using leading-edge computational methods that will accelerate the development and deployment of nuclear power technologies that employ enhanced safety and security features, produce power more cost-effectively, and utilize natural resources more efficiently. The NEAMS ToolKit will generate insights by simulating advanced reactor system behaviors that are impossible to observe in a laboratory setting.

**OBJECTIVE:** *Develop and validate predictive analytic computer methods for the analysis and design of advanced reactor and fuel cycle systems.*

The NEAMS objective is to develop a “pellet-to-plant” simulation capability that will predict the performance and safety of a broad class of nuclear reactor systems. Initial development and validation will focus on sodium-cooled fast reactor (SFR) technologies, for which an abundance of high-quality data exists for validation. Other reactor technologies will be modeled as resources permit.

NEAMS is organized along two modular product lines: Fuels Product Line (FPL) and Reactors Product Line (RPL). Each physics module will simulate a key phenomenon (e.g., neutronics; structural, thermal, and fluid mechanics) and employ mechanistic descriptions to replace empiricism and engineering correlations, such as “burnup,” wherever possible. The NEAMS ToolKit will integrate these modules to predict behaviors dominated by the competition between phenomena, as in fast transient conditions.

The FPL uses a multiscale approach to the implementation of mechanistic descriptions. Simulations with the BISON code at the engineering (continuum) scale are informed by



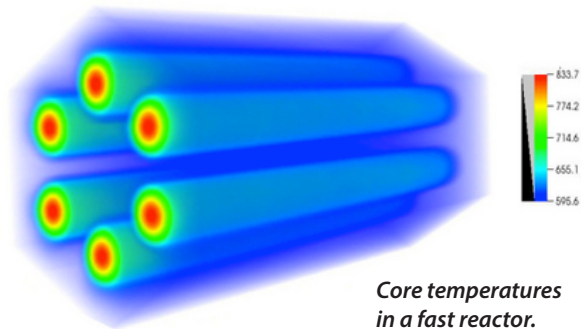
*TRISO fuel in a high-temperature reactor.*

mesoscale (grain-scale) simulations with MARMOT of microstructure evolution under irradiation. The mesoscale simulations are, in turn, informed by fundamental materials parameters obtained from atomistic simulations. An unprecedented degree of predictability can be achieved in this way.

The RPL has also adopted a multiscale approach to ensure its tools are predictive. Multiphysics integration connects separate phenomena, while multiscale integration connects different scales of each phenomenon. This hierarchical coupling allows the coarse one-dimensional plant-level model to be informed by high-fidelity, three-dimensional fluid dynamics simulations. Use of high-performance computing methods and increased modularity means that the plant model will run faster than currently accepted simulation tools.

The primary customers of the NEAMS ToolKit are DOE-NE R&D programs. The NEAMS leadership wants academia, industry, and the nuclear regulator to also embrace its use. Therefore, an important goal is to design the ToolKit for easy use by someone without simulation expertise. For

example, for the plant-level module, the Electric Power Research Institute provides requirements development, early-user support, and code validation through DOE-NE's Light Water Reactor Sustainability program.



To accommodate a diverse user base, the NEAMS ToolKit will be developed to operate on the spectrum of computer platforms available to the users, from desktop or cluster computers (industrial and regulatory communities) to leadership supercomputers (laboratory and university communities). Portability will be provided by built-in options for resolution and scale, by either lower-fidelity physics models or ToolKit-managed functionality for multiple platforms.

Assessments and validation studies using experimental benchmarks will be included with each release of the ToolKit or its components to build confidence in their reliability. These studies will help users who need additional validation for their simulation parameters and assumptions.

## Program Scope, Schedule, and Cost

The NEAMS ToolKit will be rolled out in three major installments:

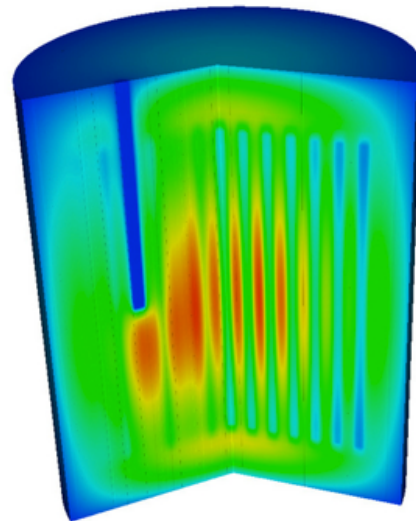
- In FY2014, the project will release tools for modeling oxide fuels.
- In FY2015, an early version of the reactors tools will allow expert users to model a limited set of problems in an SFR.
- In FY2018, the project will release the full NEAMS ToolKit 1.0, which will integrate both product lines for full-plant modeling of conditions ranging from steady-state operation to accident scenarios.

Development of integration components will be coordinated to support the major releases of the NEAMS ToolKit listed above. Throughout the project, the modeling approaches and their implementation will be assessed and validated to both provide confidence in the ToolKit's reliability and inform subsequent development.

NEAMS ToolKit 1.0 will have the following features:

- The FPL will predict the irradiation performance of oxide and metallic fuels in three dimensions for both thermal and fast-spectrum reactors.
- The RPL integrate models of physics phenomena to predict steady-state and transient behavior of a pin-resolved, three-dimensional SFR core.
- Both product lines will model a range of normal and off-normal operating scenarios.
- The NEAMS Integrated Computing Environment (NiCE) will provide a graphical user interface for problem definition, job launch and control, and data analysis and visualization.
- A full integration of the FPL and RPL will be demonstrated on a single scenario.
- The ToolKit will be rigorously validated and uncertainties will be qualified for research applications.

The program needs an annual project-usable budget of at least \$20 million (FY2012 dollars) to accomplish the work scope and retain the experts who carry out the work. The rate of progress in any given year will depend on the available funding.



*Neutron flux in a heavy water reactor.*

The schedule assumes that NEAMS:

- Teams up with participating NE R&D programs to obtain functional requirements, relevant experiments and validation, and in some cases additional funding to accelerate model development and validation.
- Continues to benefit from computational technology improvements and modeling work funded by non-NE programs, such as the Office of Science and NNSA, e.g., in the areas of fluid behavior and materials modeling.
- Enjoys continued access to high-performance computing resources, including leadership-class computers.
- Keeps its long-term perspective, since the objective is a long-term effort; consistent program direction maintains momentum and accelerates progress.

## Development Team and Collaborations

### DOE National Laboratories

Most of the advanced modeling and simulation expertise and technical leadership needed for NEAMS reside at the National Laboratories. The Labs also provide a bridge to stakeholders in DOE-NE R&D programs and the nuclear industry. NEAMS leverages DOE and NNSA investments in expertise and leadership-class computing facilities.

### Universities

NEAMS has access to academic expertise through the Nuclear Energy University Program. Their contributions include cost-effective acceleration of capability development and access to high-quality validation data. Collaborations were established with six universities in FY2012, and more will be engaged in the future.

### Industry

Although the DOE-NE R&D programs are the primary stakeholders in the near term, the NEAMS leadership has reached out to the nuclear industry and its primary regulator. This community will be invited to participate

in the enhancement of the NEAMS ToolKit by suggesting program requirements to address their specific needs.

### International Collaborations

NEAMS participates in several international collaborations to accelerate development of specific modules and obtain relevant validation data. Benchmarking and validation collaborations have been established with four countries and the Euratom community. Additional collaborations are being discussed with the United Kingdom and Norway.

Current collaborations are:

- U.S. – Russian Federation Working Group on Nuclear Energy and Nuclear Security, which is focused initially on validation of high-fidelity CFD codes. Future directions will expand into radiation transport and structural mechanics.
- U.S. – Republic of Korea International Nuclear Energy Research Initiative, which is focused on advanced radiation transport, thermal hydraulics, and multiphysics codes for high-temperature, gas-cooled reactors.
- U.S. – France – Japan Tri-lateral Agreement, which is focused on advanced SFRs.
- U.S. – Euratom International Nuclear Energy Research Initiative for CFD simulations of SFR fuel assembly coolant flows.

## Program Management

The senior leadership team comprises the Office of Advanced Modeling and Simulation (AMSO), a National Technical Director from Argonne, and two product line leaders (from Idaho and Oak Ridge). Integration, validation, and other program-wide efforts are overseen by the NTD or shared by the product leaders.



NEAMS Website

<http://energy.gov/ne/advanced-modeling-simulation>

