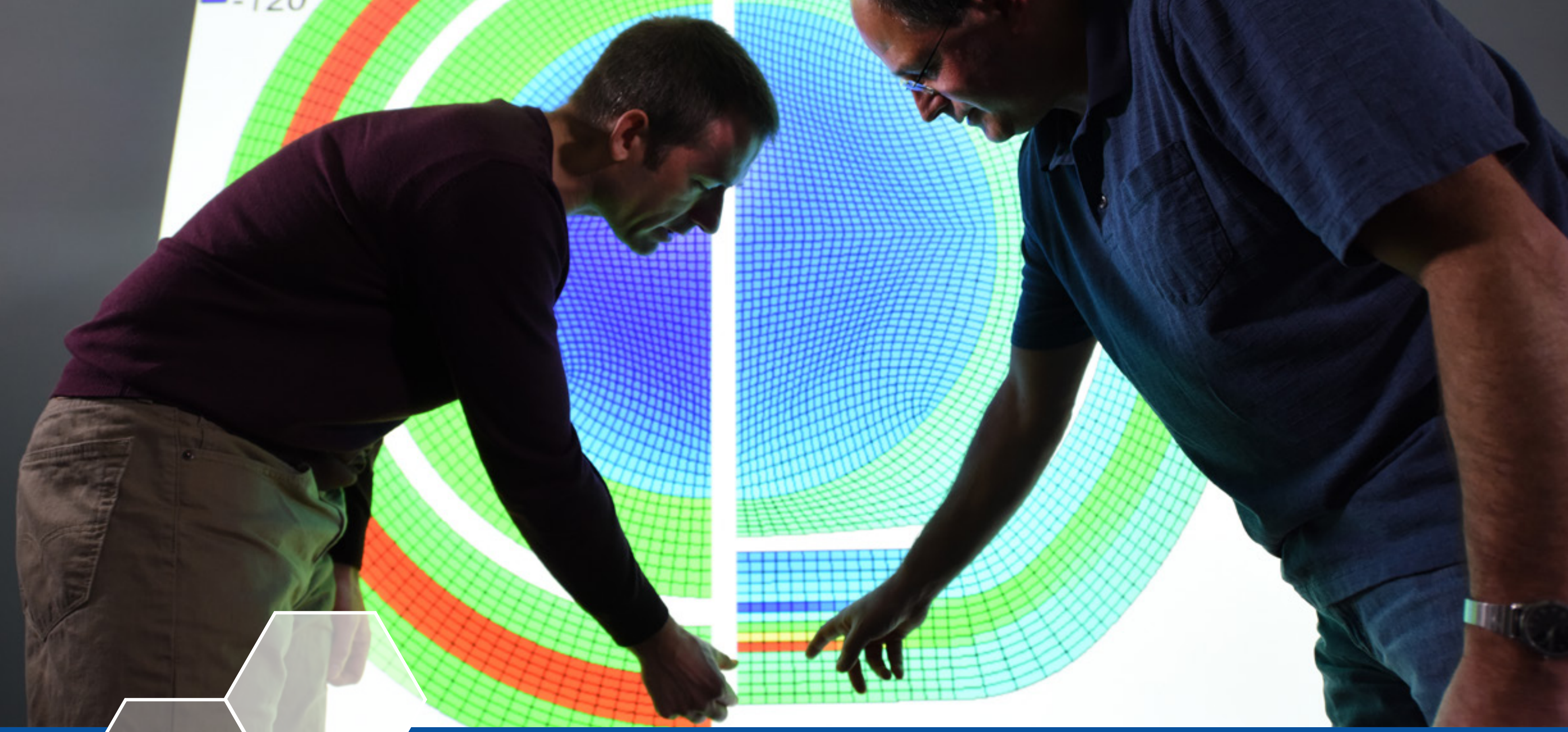


MOOSE Simulation Environment

Fostering a herd of modeling applications

MOOSE enables tools like Bison to show the inside of a fuel pellet.

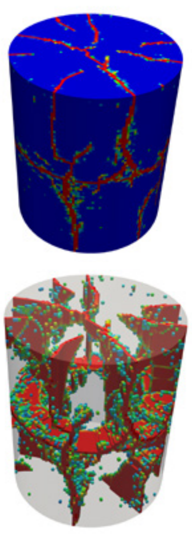
Modeling and simulation has become standard practice in nearly every branch of science. Building useful simulation capability has traditionally been a daunting task because it required a team of software developers working for years with scientists to describe a given phenomenon.

Developed at Idaho National Laboratory (INL), Multiphysics Object Oriented Simulation Environment, better known as MOOSE, makes modeling and simulation more accessible to a broad array of scientists. MOOSE enables simulation tools to be developed in a fraction of the time previously required. The tool has revolutionized predictive modeling, especially in the field of nuclear engineering where it allows nuclear fuels and materials scientists to develop numerous applications that predict the behavior of fuels and materials under operating and accident conditions.

Scientists lacking in-depth knowledge of computer science can now develop an application that they can "plug and play" into the MOOSE simulation platform. In essence, MOOSE solves the mathematical equations embodied by the model.

Such a tool means scientists seeking a new simulation capability don't need to recruit a team of computational experts versed in, for example, parallel code development. Researchers can focus their efforts on the mathematical models for their field, and MOOSE does the rest.

The simplicity has bred a herd of modeling applications describing phenomena in nuclear engineering, geosciences, earthquakes and material sciences.



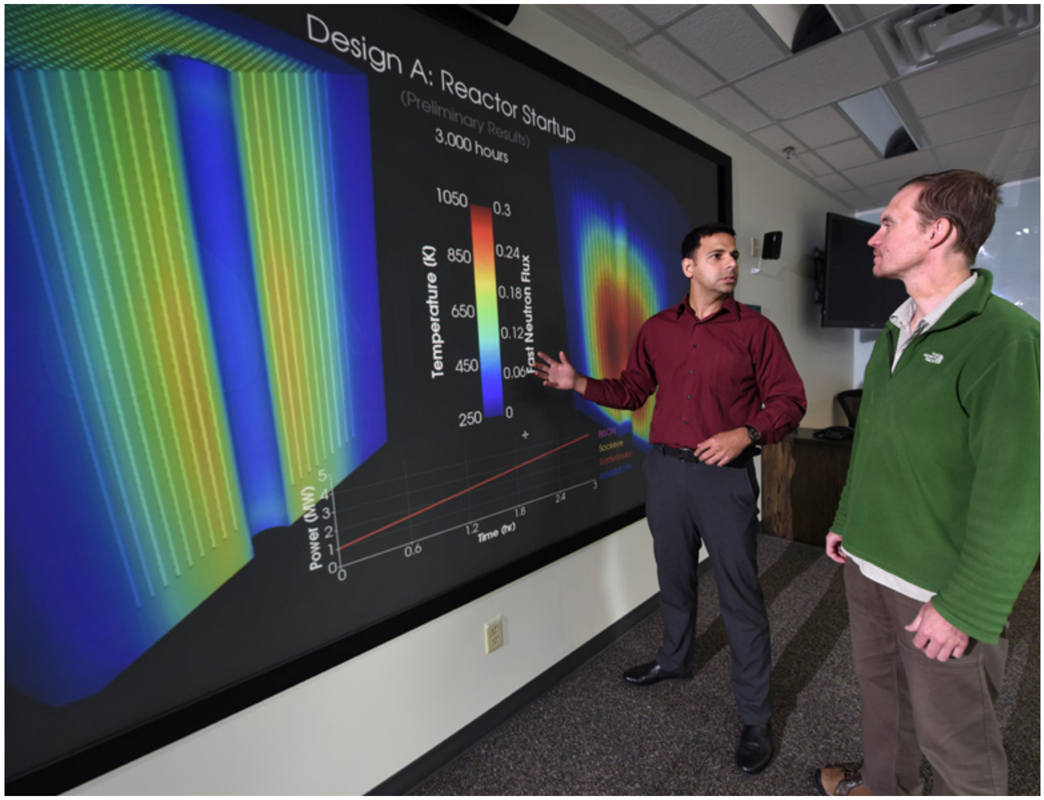
Bison has been used to show cracking in a Transient Reactor Test (TREAT) facility-irradiated fuel pellet both from the exterior (top) and the interior (bottom) with the undamaged material shown as translucent to identify cracks.

Idaho National Laboratory

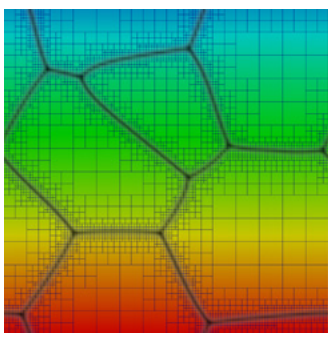
INL-MANAGED MOOSE CODES

Name	Description	Availability
Bison	Bison is a nuclear fuel performance code that can model light water reactor fuel rods, TRISO particle fuel, metallic rod and plate fuel, and other fuel forms. Bison solves thermomechanics and species diffusion equations for 1D, 2D and 3D geometries, with fuel models that describe temperature properties, fission product swelling and other material aspects.	License
BlackBear	BlackBear models degradation in concrete, steel, and other structural materials over time and under specified environmental conditions. It also models the response of those materials to loading conditions that they are safely expected to withstand, with these simulations done accounting for the modeled degradation.	Open Source
BlueCRAB	BlueCRAB is a generic reactor simulator that can be used to analyze proposed advanced reactor designs like molten salt reactors, fluoride salt-cooled high-temperature reactors, and microreactors. Additionally, BlueCRAB can be used to model light-water reactors and links to current U.S. Nuclear Regulatory Commission tools.	License
DireWolf	DireWolf is a code suite developed to analyze heat-pipe-cooled nuclear microreactors. It pulls together several applications for this purpose including Griffin, Bison and Sockeye to study nuclear microreactor physics, reactor physics, radiation transport, nuclear fuel performance, heat pipe thermal hydraulics, power generation, and structural mechanics.	License
FALCON	Falcon models fluid flow, heat transfer, rock mechanics and chemical reactions in geological porous material. It is primarily used to study geothermal reservoirs, thermal energy storage, carbon sequestration, and groundwater flow and transport.	Open Source
Grizzly	Grizzly models the degradation of nuclear power plant systems, structures and components. The code also simulates the ability of degraded components to safely perform under a variety of conditions. It can be applied to a variety of components with development initially focused on the embrittlement of reactor pressure vessels and concrete structures.	License
Griffin	Griffin is a reactor multiphysics application. It is suitable for steady state and time-dependent coupled neutronics calculations leveraging the multiple MOOSE-based thermal-fluids applications (Pronghorn, RELAP-7, Sockeye, etc.) and fuel performance application (Bison). Griffin has been used to analyze pebble bed reactors, prismatic reactors, molten-salt reactors, fast sodium-cooled reactors, microreactors, nuclear thermal propulsion and several experimental facilities.	License

Name	Description	Availability
Magpie	Magpie links various atomistic codes that analyze distinct, separable and independent elementary components to MOOSE applications. Magpie currently provides coupling modules for SPPARKS (a kinetic Monte Carlo solver from Sandia National Laboratories that simulates particle motion) and MyTRIM (a binary collision Monte Carlo solver for ion transport in materials).	Open Source
Marmot	Marmot is a mesoscale fuel performance code. As such, it can predict the evolution of the microstructure and material properties of fuels and claddings due to stress, temperature, and irradiation damage. MARMOT can supply microstructure-based materials models to other codes that work on a larger scale, e.g., Bison. MARMOT solves equations involving solid mechanics and heat conduction using the finite element method.	License
Mastodon	Mastodon is used for seismic analysis and risk assessment. It can simulate source-to-site wave propagation and analyze risk over time during a simulated event for 1D, 2D and 3D soil structures. Mastodon's risk assessment is probabilistic meaning it can estimate the likelihood of an outcome as well as provide a deterministic analysis of risk.	Open Source
Pronghorn	Pronghorn is a multi-dimensional, coarse-mesh, thermal-hydraulics code for advanced reactors and is particularly well-suited to model gas-cooled pebble bed and prismatic reactors. It serves the intermediate fidelity realm situated between detailed computational fluid dynamics analysis and lumped system models.	License
RELAP-7	A next generation nuclear systems safety code, RELAP-7 takes advantage of advances in computer architecture, software design, numerical methods, and physical models for use in the Risk Informed Safety Margin Characterization methodology and in nuclear power plant safety analysis.	License
Sockeye	Sockeye is a heat pipe simulator and analysis tool. It accurately predicts heat transfer for heat-pipe-cooled microreactors and other heat pipe applications. Importantly, Sockeye models heat conduction transients in 1D and 2D as well as offering tools to analyze the operating envelope of heat pipes. It provides insight into operational limits in transient conditions, something not readily possible with steady-state analysis. Using Sockeye, users can spot operational limits and adjust designs accordingly.	License



INL researchers modeled a microreactor core during reactor startup using INL's DireWolf tool to build an integrated, microreactor simulation.



Marmot can help predict the evolution of microstructure and material changes in fuel and claddings.

A COLLABORATIVE TOOL

Although MOOSE was developed at INL, several other national laboratories have contributed to the platform and to INL-managed codes like Pronghorn. Some national laboratories have also developed their own MOOSE-based codes like Argonne National Laboratory's System Analysis Module (SAM), Oak Ridge National Laboratory's Mole and Los Alamos National Laboratory's Centipede.

Additionally, the Nuclear Energy Advanced Modeling and Simulation (NEAMS) program provides significant support to MOOSE and to the development of several codes, like Griffin and Bison. NEAMS, a U.S. Department of Energy Office of Nuclear Energy program, is focused on developing advanced modeling and simulation tools and capabilities to accelerate the deployment of advanced nuclear energy technologies.

HOW TO GET ACCESS TO THE CODES

The MOOSE environment is available to users as an open-source tool. MOOSE, along with other open-source tools are available on INL's GitHub page (github.com/idaholab).

If you are interested in accessing one of INL's licensed codes, visit the Nuclear Computational Resource Center's website (inl.gov/ncrc) to request access.

FOR MORE INFORMATION

Technical contact
Cody Permann
208-526-8444
cody.permann@inl.gov

Tiffany Adams
208-520-9509
tiffany.adams@inl.gov

www.inl.gov

A U.S. Department of Energy National Laboratory

Battelle Energy Alliance manages INL for the U.S. Department of Energy's Office of Nuclear Energy. INL is the nation's center for nuclear energy research and development, and also performs research in each of DOE's strategic goal areas: energy, national security, science and the environment.