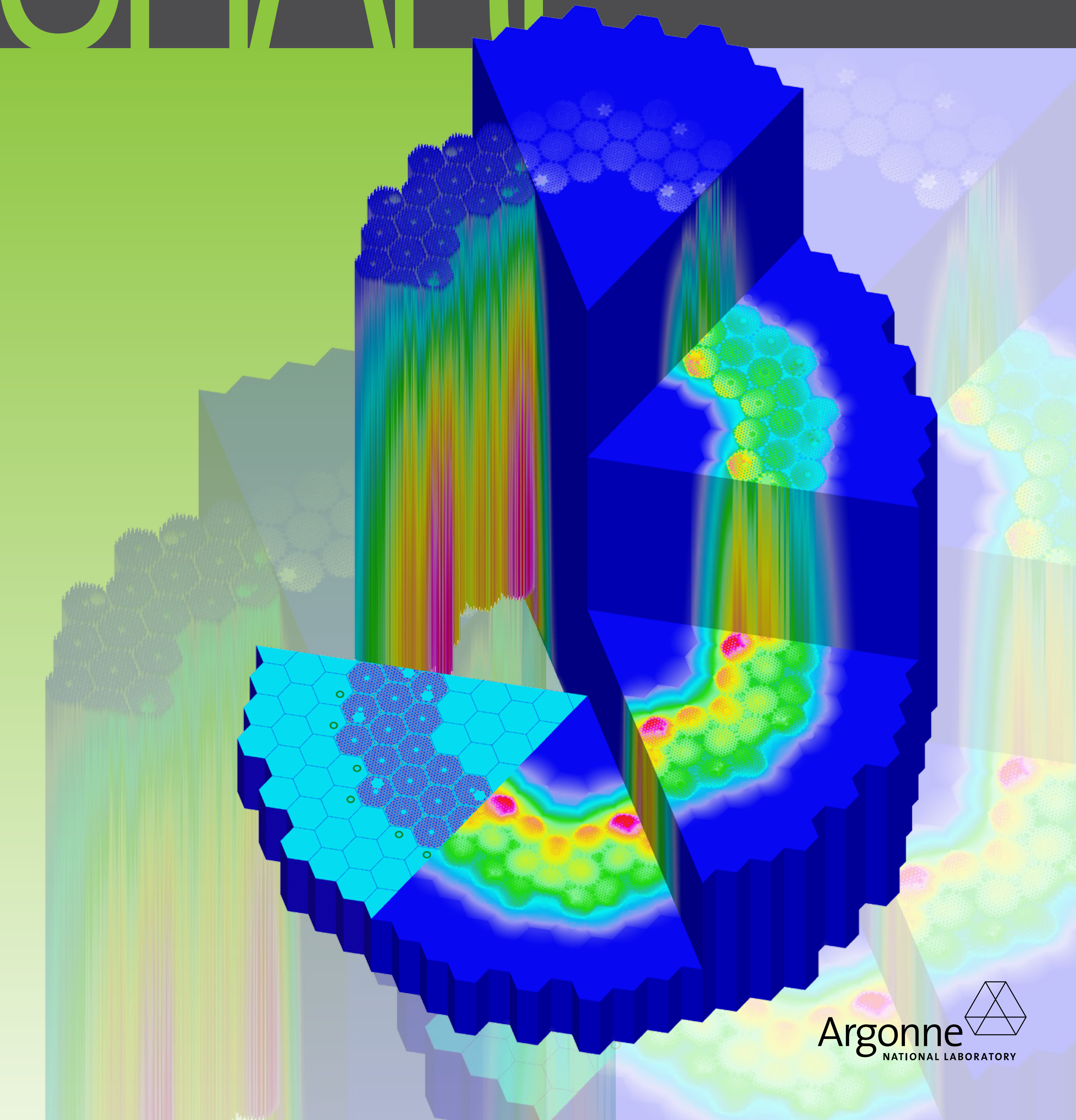
SHARP

Argonne National Laboratory's

Reactor Performance and Safety Simulation Suite



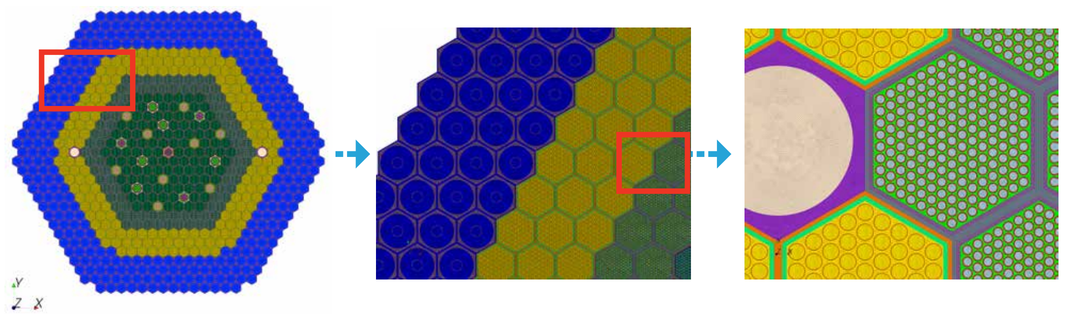
Argonne
NATIONAL LABORATORY

SHARP could save millions in nuclear reactor design and development. . .

The Simulation-based High-efficiency Advanced Reactor Prototyping (SHARP) suite of codes enables virtual design and engineering of nuclear plant behavior that would be impractical from a traditional experimental approach.

. . .by leveraging the computational power of one of the world's most powerful supercomputers.

Exploiting the power of Argonne Leadership Computing Facility's near-petascale computers, researchers have developed a set of simulation tools that provide a highly detailed description of the reactor core and the nuclear plant behavior. This enables the efficient and precise design of tomorrow's safe and clean nuclear energy sources.



◀ A significant challenge in reactor performance and safety simulation is creating a computational mesh that accurately describes the complex reactor geometry. SHARP's MeshKit module can generate reactor core geometries nearly automatically. This mesh, which uses 101 million volume elements to describe the reactor core, was generated by SHARP simulation tools in as little as seven minutes.

Introducing the SHARP Suite

Argonne's high-fidelity computer modeling and simulation work in support of advanced nuclear energy systems is a natural outgrowth of the cumulative years of Argonne's expertise in nuclear energy.

SHARP is a suite of physics simulation software modules and computational framework components that enables the user to evaluate the impact of design decisions on performance and safety of nuclear reactors or their components. SHARP digitally mimics and allows researchers to "see" the physical processes that occur in a nuclear reactor core, including neutron transport, thermal hydraulics and fuel and structure behavior.

SHARP builds on experience gained in the application and maintenance of existing computer codes that are used to conduct safety evaluations of today's portfolio of aging nuclear power reactors. Those older codes, while well calibrated for evaluating the safety of next-generation reactor designs, provide little opportunity to optimize designs for efficiency or cost. SHARP was written specifically to support the integrated assessment of safety and performance of advanced design concepts. SHARP allows users to attach the new simulation modules to the older legacy codes, thereby avoiding costly rewriting of codes.

Creating Virtual Models

With the SHARP suite, users construct complex virtual reactor models that accurately integrate the governing physics to evaluate the performance of the reactor in a wide variety of operational or accident scenarios. Alternatively, SHARP users may construct highly detailed component models using high-fidelity methods, which rely on few or no engineering models or approximations.

SHARP harnesses the power of commercial-scale computing platforms of today and provides transitional tools to aid industry's migration to future commercially viable petascale computing platforms. SHARP provides heterogeneous neutron and gamma transport in exact geometries, three-dimensional thermal fluid analysis and finite element structural mechanics analysis capabilities.

A Technology-Neutral Toolset

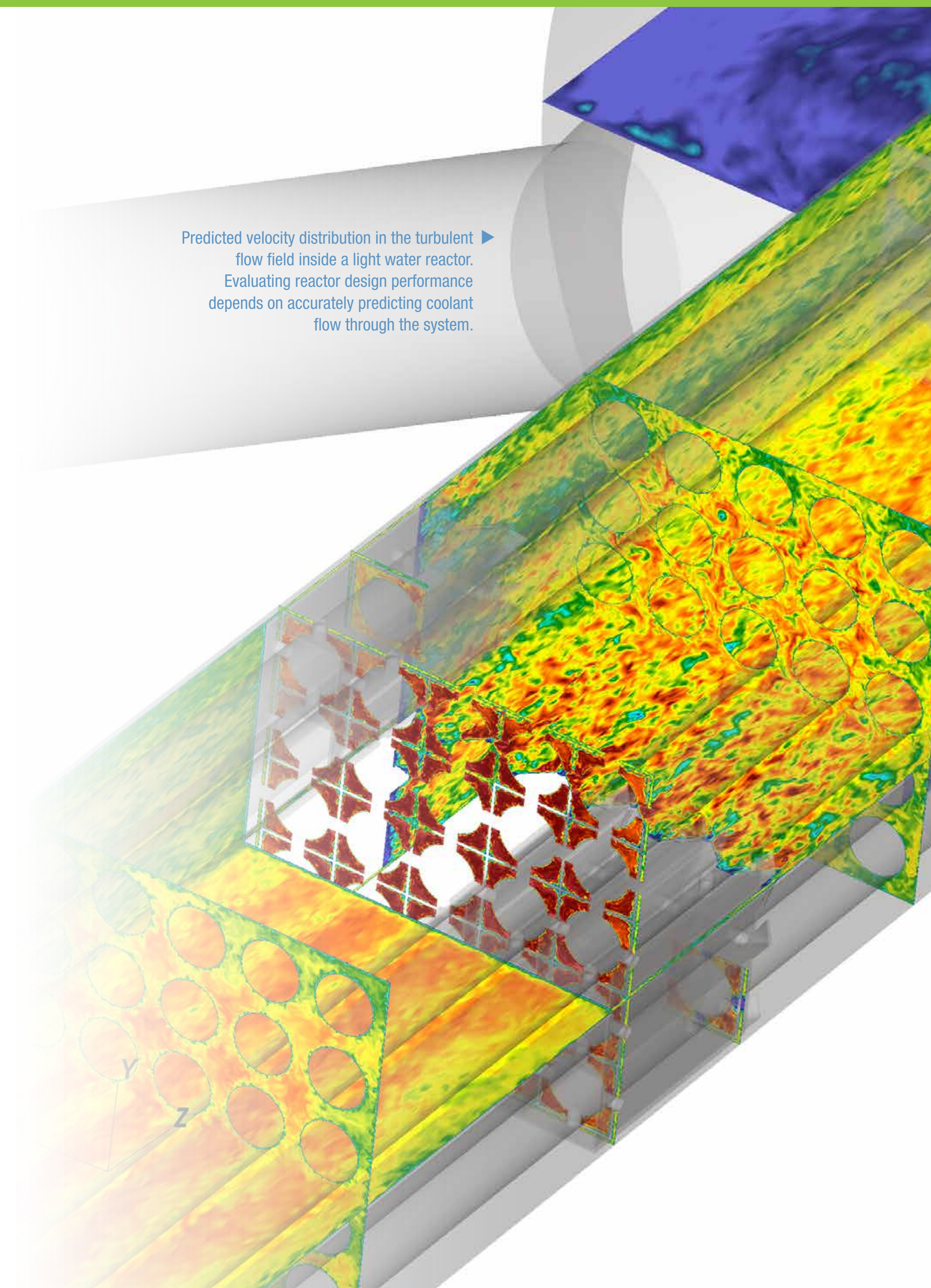
SHARP relies on high-fidelity science-based methods that do not require calibration tied to a specific reactor application. As a result, SHARP is largely technology neutral and can be applied to virtually any type of reactor.

The SHARP development team has initially focused on two driver problems supported by industrial collaborators and related Department of Energy research programs.

1. Analysis of stability of reactor vessel coolant flows, especially in advanced light water reactors. The capabilities that target this problem address both forced and natural convection flow regimes and provide detailed conditions in fuel assemblies of interest.

2. Analysis of bypass flow effects on performance of advanced core designs, especially in prismatic very high temperature reactors (VHTR).

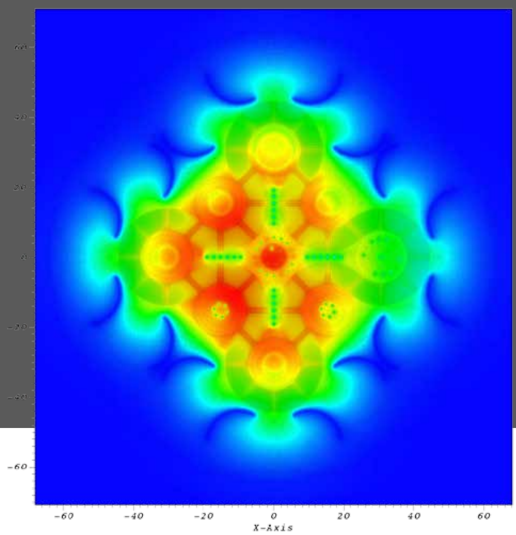
The capabilities developed to address these two problems provide foundations for analyzing many multiphysics reactor design and performance features in many other reactor types. Investments to extend the toolset to additional reactor types primarily focus on developing material property libraries and implementing transient scenarios.

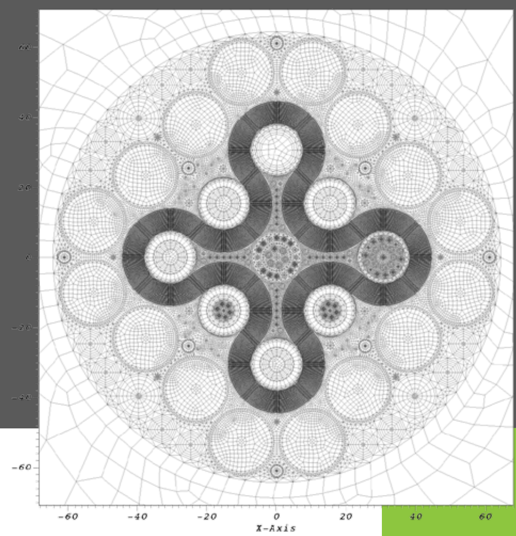


Predicted velocity distribution in the turbulent flow field inside a light water reactor. Evaluating reactor design performance depends on accurately predicting coolant flow through the system. ▶

World-Class EXPERTISE

Argonne has one of the world's largest concentrations of scientists and engineers involved in advanced reactor design—expertise essential to the formation of new analysis capabilities that will enable future design concepts. Argonne's nuclear and chemical scientists and engineers actively collaborate with the lab's computational scientists to develop precise computer simulations of the physical changes that would occur in a reactor over the lifetime of the power plant.





◀ Predicted distribution of neutrons of a certain energy range in the complex geometry of an advanced test reactor. Evaluating reactor design performance depends on accurately predicting the interactions between neutrons moving through the reactor core and the materials located there.

How SHARP Adds Value

- Permits modeling that integrates reactor performance across varied scenarios
- Harnesses the power of today's petascale computing platforms
- Enables users to evaluate the impact of design decisions on performance and safety of nuclear reactors or their components
- Constructs highly detailed component models using science-based high-fidelity methods—which rely on few or no engineering approximations—to optimize designs for safety and performance
- Provides heterogeneous neutron and gamma transport in exact geometries, three-dimensional thermal fluid analysis and finite element structural mechanics analysis capabilities
- Includes transitional tools that aid migration to commercially viable petascale computing platforms
- Promises millions of dollars in cost savings on reactor design, development and construction

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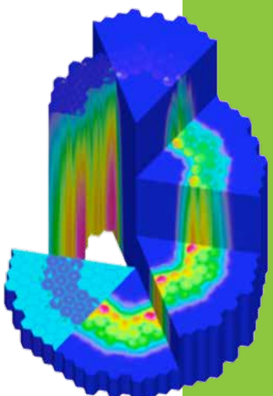
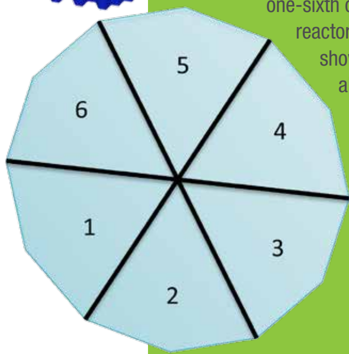
The SHARP simulation suite development team, led by Argonne National Laboratory, includes other leading national laboratories and research universities. SHARP is developed under the auspices of the U.S. Department of Energy, Office of Nuclear Energy, Nuclear Energy Advanced Modeling and Simulation Program (NEAMS).

Seventy years of leadership in nuclear science and technology

Argonne developed and/or built experiments, research reactors or prototypes of nearly every kind of commercial nuclear reactor in the world today, as well as many research and training reactors. An overview of this history can be found at

www.ne.anl.gov/About/ANL-Reactors.shtml





On the cover

The SHARP toolset accurately predicts temperature distributions of a very high temperature reactor from a simulation of one-sixth of a VHTR core. Wedge 1 shows the reactor core geometry. Wedges 2 through 5 show temperature distributions across all core materials at different axial heights. Wedge 6 shows temperature distributions in the cylindrical fuel compacts.

U.S. DEPARTMENT OF ENERGY

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