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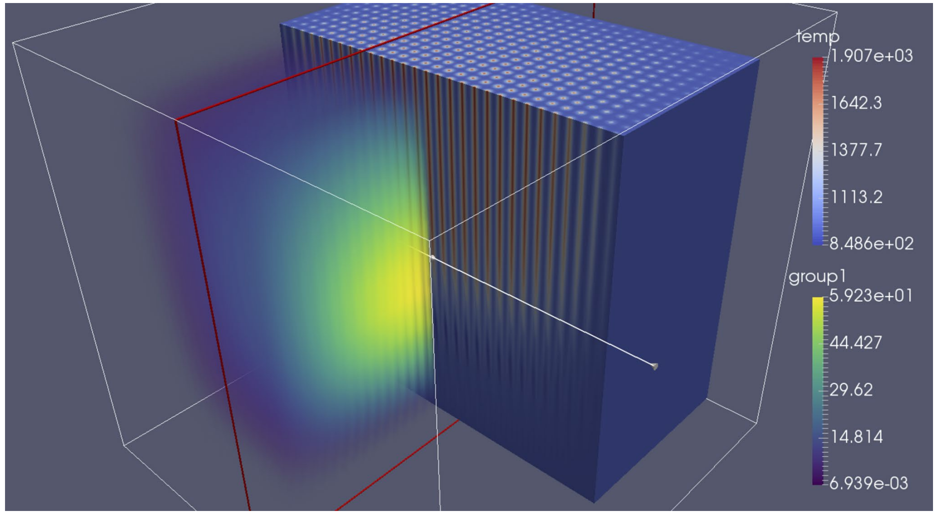
COUPLED MULTIPHYSICS OF ADVANCED MOLTEN-SALT NUCLEAR REACTORS



The coupled fast neutron flux and temperature in a 3D cuboidal model of a molten-salt reactor. Moltres coupled results have been validated against experimental results from the Molten-Salt Reactor Experiment.

Research Challenge

Nuclear power provides 19% of the total electricity generated in the United States and is our largest source of clean energy. Advanced molten-salt reactor (MSR) technology represents numerous distinct advantages over the light-water reactor (LWR) used today. Current state of the art in advanced nuclear reactor simulation focuses primarily on LWR. This work extends the state of the art by enabling modeling and high-fidelity simulation for MSR designs. This requires development of models and tools for representing unique materials, geometries, and physical phenomena.

Methods & Codes

Two new simulation tools were developed to enable advanced reactor and fuel cycle simulations. First, the finite-element-based physics application, Moltres, couples the thermal–hydraulics and neutronics of molten-salt flow in high-temperature liquid-fueled reactor designs. Second, a Python package for modeling fuel-salt reprocessing, Saltproc. It relies on full-core high-fidelity Monte Carlo simulations to perform depletion computations that require significant computational time and memory.

Results & Impact

Developed in the open, this effort enables both transparency and distributed collaboration on promising nuclear reactor concepts. It can improve designs, help characterize performance, inform reactor safety margins, and enable validation of numerical modeling techniques for unique physics.

MSR technology is exciting and well worth advancing. MSRs are a compelling next-generation nuclear reactor technology as many MSR designs promise improved passive safety, fissile material utilization, recycling flexibility, and power generation responsiveness appropriate for an electric grid involving variable renewable electricity generation.

Why Blue Waters

Accurate simulations at realistic spatial and temporal resolution are only possible with the aid of high-performance computing resources. To assess nuclear reactor performance under a variety of conditions and dynamic transients, myriad 2D and 3D finite element simulations must be conducted. Transient and multiscale simulations, which require greater capability per simulation, are on the horizon for our work. These may occupy up to 100,000 CPU cores at a time.