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Computational Challenges in Coupled Multiphysics Simulations of Nuclear Reactor Cores

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As part of the DOEs Nuclear Energy Advanced Modeling and Simulation (NEAMS) program, SHARP framework is being developed at Argonne National Laboratory to carry out coupled multiphysics reactor core simulations in high fidelity. The goal of this simulation effort is to reduce the uncertainties and biases in reactor design calculations by progressively replacing existing multi-level averaging (homogenization) techniques with more direct solution methods. This talk will discuss the architectural and algorithmic challenges encountered in these simulations on the leadership platforms (such as Blue Gene/P at Argonne and XT5 at ORNL). We will also present detailed, high-resolution simulations of neutron transport in fast reactor cores using our code UNIC. This code implements a scalable solution methodology for the discrete ordinates, even-parity form of the neutron transport equation. For high-fidelity descriptions of complex reactor geometries (respecting spatial heterogeneities and large number of energy groups), the memory requirements are huge. We will discuss an approach (using p-multigrid) to contain the memory requirement in the context of Zero Power Reactor (ZPR) Experiment 6/6a simulations on Blue Gene/P and XT5. This talk will also highlight the importance of developing memory-saving algorithms for multiphysics simulations a crucial requirement for the future petascale (and exascale) machines where the current trends indicate significantly reduced memory per thread of execution.