U.S. Department of Energy

Center of Excellence for Thermal-Fluids Applications in Nuclear Energy: Establishing the knowledgebase for thermal-hydraulic multiscale simulation to accelerate the deployment of advanced reactors

IRP-NEAMS-1.1: Thermal-Fluids Applications in Nuclear Energy

PI: Dr. Elia Merzari, Penn State University

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Collaborators: Emilio Baglietto – Massachusetts Institute of Technology, Igor Boltnov, Truc Nam Dinh – North Carolina State University, Yassin Hassan – Texas A&M University, Annalisa Manera – University of Michican, Wayne Strasser – Liberty University, Ling Zou, Rui Hu, – Argonne National Laboratory, Richard Martineau, Sebastian Schunert – Idaho National Laboratory, Hangbok Choi – General Atomics, Milorad Dzodzo – Westinghouse, Mathieu Martin – TerraPower LLC, Brian Jackson – Kairos Power

ABSTRACT:

The recently established Center of Excellence (COE) for Thermal Fluids Applications in Nuclear Energy at Idaho National Laboratory (INL) and Argonne National Laboratory (ANL) provides leadership, best practices, research, support and/or training for computational thermal-fluids applications in nuclear energy. **This proposal seeks to establish a university component to the COE that fully integrates with the current efforts of the Center while strengthening the relationship with key stakeholders (industry and NRC). The proposed university consortium will expand the capabilities of the center with a focus on fundamental research aimed at accelerating the deployment of advanced reactors.** The university consortium will leverage the resources of partners from academia, industry, and National Laboratories and seamlessly coordinate joint development efforts with the leadership of the COE. In support of the proposed work we have assembled an interdisciplinary team comprising the world leading experts in advanced thermal-hydraulic modeling and simulation and the experimental validation of the state-of-the-art tools.

The unique design of advanced nuclear reactors presents many fluid-flow problems that hinder safety and performance. Currently, solving these problems is approached in an *ad-hoc* manner at varying scales. Such approaches are time-consuming and costly. This proposal seeks to conduct modeling and experiments focused on a set of four industry-defined Challenge Problems (Fig. 1) to develop a knowledgebase for solving issues associated with the thermal hydraulic performance of advanced reactors quickly, accurately, and at lower cost.

Through the four Challenge Problems, the consortium will deliver improved, fast-running models for complex physical phenomena involving turbulent mixing, thermal stratification and thermal striping in complex geometries relevant to these reactors. This will in turn lead to improved economics by achieving higher operating temperatures and/or a reduction in capital costs.

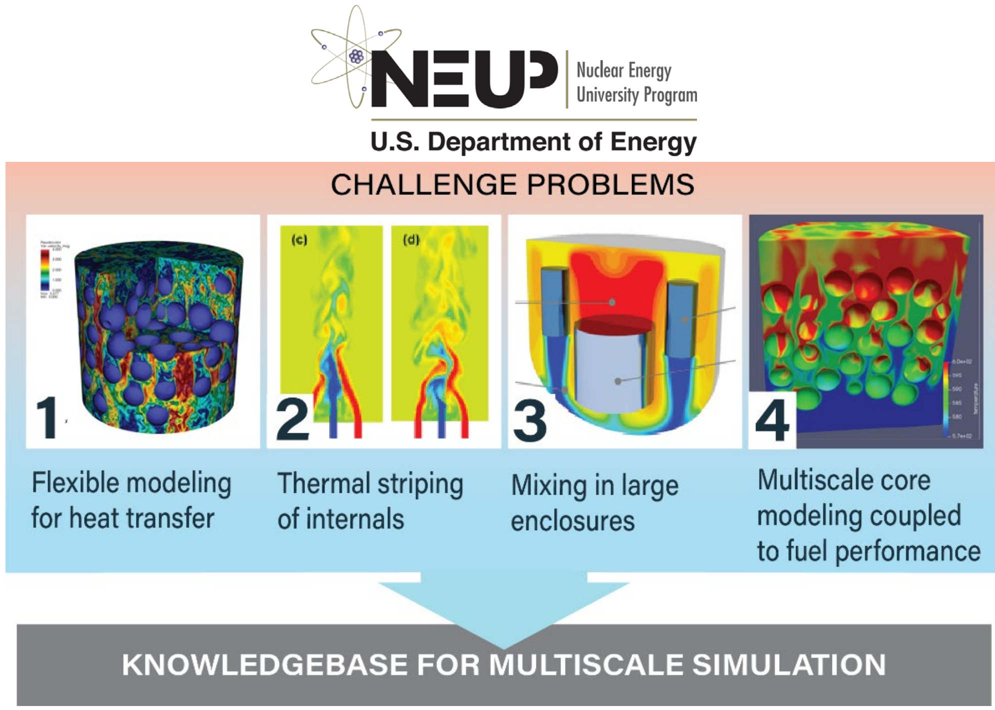

Figure 1. *Challenge Problems identified in consultation with industry partners.*

We note that these Challenge Problems have broad applicability to advanced reactor concepts, cover most technologies proposed in the United States (Molten Salt Reactors, Fluoride Cooled High Temperature Reactors, Sodium Fast Reactors, Lead Fast Reactors and Gas Reactors) and go well beyond the specific interests of the participating industry partners. Results from the university consortium efforts will be integrated into the ongoing programmatic efforts and industry engagement of the COE to ensure maximum impact of the proposed research.

This proposal goes beyond simply addressing a series of separate tasks aimed at solving highly relevant advanced reactors problems. We propose to tackle each Challenge Problem using the multiscale code infrastructure of the COE, while leveraging the synergy in the work performed in each task. This will allow to address two outstanding issues in current thermal-hydraulic modeling of advanced reactors. Primarily, there is a severe deficit of direct thermal-hydraulic data that is applicable to new, innovative nuclear system designs due to a lack of integral-effect test facilities for the wide range of scenarios and conditions necessary to produce a risk-informed analysis of such systems. Secondly, the "big data" currently obtained in advanced instrumented, small-scale, separate-effect experiments and high-fidelity numerical simulations is inefficiently used. These conditions highlight the **pressing needs for bridging this scale gap, enabling the use of high-fidelity simulation data to deliver improved fast running models. The outcome will be the establishment of the knowledgebase for multiscale simulation.** We use the word "knowledgebase" (one word to be consistent with DOE practice) to signify the ensemble of models, data, methods and tools needed for multiscale analysis.

We seek to build the knowledgebase for multi-scale methods, models and data to support the goals of DOE and the code infrastructure of the center. We focus on developing novel methodologies that will allow a seamless transfer between scales, in contrast with current ad-hoc efforts. We envision that this effort will increase the understanding and modeling of turbulent thermal mixing in complex geometries and the interaction of the flow with fuels and structures and enable a paradigm shift in the way multiscale simulations are performed.