NEUP Nuclear Energy University Program
U.S. Department of Energy

# Inference of flow conditions from in-core detector measurements for accelerating SMR licensing

**PI**: Benoit Forget – Massachusetts Institute of Technology

**Collaborators**: Emilio Baglietto - MIT
Majdi Radaideh – U Michigan
Kent Welter - NuScale
Jason Christensen – INL

**Program**: Licensing, Safety and Security

**ABSTRACT:**

Reactor modelling relies on the detailed description of reactor systems but often lacks the true as-built characteristics of a system and cannot realistically model impactful details a priori. This lack of knowledge can lead to large discrepancies between the observables and modelling and simulation predictions, and in real production system there is often insufficient instrumentation and access to correct this lack of information. This proposal aims to use all the information available between measurements and simulations to infer key knowledge gaps. A demonstration of this insufficiency is often seen as part of the licensing basis where low power physics tests must demonstrate a sufficiently low radial tilt in the power profiles in order to continue to full power. While the core is designed and built to be symmetric, a tilt often occurs that cannot readily be explained. These tests demonstrate to the regulator good predictive capabilities of the analysis tools (e.g., modeling and simulation) and that core loading was performed as expected. As a demonstration case, the BEAVRS (Benchmark for Evaluation And Validation of Reactor Simulations) benchmark will be used for validation of the approach. It is a full core PWR model of a real operating plant with 2 full cycles of in-core detector measurements. The first core is of the first cycle of the plant life and thus contains only fresh fuel. During the low power physics tests, the core map demonstrated a large tilt that met the NRC requirements but still remains troubling from a modelling perspective that a fresh and fully symmetrical core leads to "unexplained" large spatial variations. For fresh fuel, the largest contribution to fuel bowing comes from hydraulic forces caused by the inlet flow. Many studies have demonstrated that core inlet flow is often non-uniform during the unfortunate symmetrical design of the cold and hot leg nozzles, which induces a non-symmetrical flow distribution which is impacted by the pumps start up sequence and can further lead to unstable flow switching referred to as "lower plenum flow anomaly" (LPFA). First identified at several Westinghouse plants in the 1980's, LPFA still negatively impacts operating PWR plants with additional DNBR penalties. The goal of this proposal is to develop a framework that can learn from all of the reactor information available (like detector signals) and apply it to our demonstration problem to identify fuel bowing distribution and flow disparities in the as-built conditions. Such tilts are not unique to the BEAVRS benchmark and are often limiting to the predictive capabilities of our modelling and simulation tools used during licensing. In the case of the NuScale SMR, the tilt is not a major concern due to the small size of the core, but the ability to infer accurate inlet flow conditions can be very important in defining margins to critical heat flux.