A Consortium for Strategic Revitalization of Cyber-Physical Nuclear Infrastructure for Advanced Small Modular Reactors

PI: Dr. Seungjin Kim, Purdue
Co-PIs: Purdue, MIT, NCSU, Ivy Tech, TCRDF

Program: Infrastructure Revitalization

National Lab Collaborators: ANL, INL

Industry Collaborators: BWXT, Constellation, Curtiss-Wright, Duke Energy Indiana, GE-Hitachi, ORAU, Sargent & Lundy, and Westinghouse

ABSTRACT:

This project represents a collaborative effort to revitalize and enhance nuclear research infrastructure, leveraging a holistic consortia model that includes a blend of universities, national laboratories, community colleges, Historically Black Colleges and Universities (HBCUs), and industry partners. With a total budget of $6 million, the initiative aims to upgrade and establish cutting-edge cyber-physical capabilities for Small Modular Reactor (SMR) and Advanced Reactor (AR) technologies across participating institutions of Purdue, MIT, and North Carolina State University. These upgrades are supported by expertise from Argonne National Lab (ANL), Idaho National Lab (INL), and are complemented by workforce development efforts led by Oak Ridge Associated Universities (ORAU) and Ivy Tech Community College of Indiana, with a focus on career awareness and optimizing recruitment strategies. Tougaloo College Research and Development Foundation (TCRDF) will serve as a liaison between Purdue and HBCUs for student engagement and summer internships.

The project's technical thrust focuses on replacing outdated equipment and integrating new, advanced digital instrumentation and controls, including the development of high-fidelity digital twins and reactor simulators on four university facilities. PUMA, the only existing scaled integral test facility for advanced light water reactor designs, featuring up to 300 kWth simulated nuclear heating, reactor control logic and more than 500 instruments has been employed in the past to simulate both steady-state and transient thermal-hydraulic phenomena for light water-based advanced reactors. This project will allow these components to not only be refurbished to full operational condition, but will also provide a new balance of plant, thermal energy storage system, digital control room, instrumentation upgrades, and a high-fidelity digital twin with a full-scale control room simulator. PUR-1, the first university reactor with a fully digital control system, will be enhanced with a high-fidelity dynamic real-time digital twin. MIT and NCSU simulators will be enhanced with high-fidelity simulators for full scale SMR simulations that will include cloud-based capabilities through OPC servers to receive real-time sensor and control data from PUR-1 and PUMA to serve as a real-time digital twin.

With a new nuclear infrastructure as our foundation, we will create: (1) a regional center of excellence for **S**mall **M**odular & **A**dvanced **R**eactor **T**echnology digital **T**win (SMART^2) comprised of four inter-connected cyber-physical facilities equipped with state-of-the-art digital instrumentation and with full scale control room upgrades that would enable sharing and use of equipment and instrumentation by universities, national labs, industry and other institutions for multi-disciplinary research related to safety assessments, cyber-physical protection, and advanced control technologies of SMRs, (2) a pipeline of nuclear professionals with education and skills to bring advances in AI/ML, cyber-physical protection and digital twinning to accelerate SMR development, and (3) a long-term educational program with a series of workshops, internships, and summer camps to attract students and to ensure sustainability of nuclear engineering and related disciplines' educational programs.