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Demonstrating Autonomous Control, Remote Operation, and Human Factors for Microreactors Under Prototypic Conditions in PUR-1

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ABSTRACT:

The United States is on the precipice of a surge in the deployment of nuclear technology, the likes of which have not been seen since the 1960s. The passive advanced nuclear systems currently under development, e.g., microreactors, are designed to be much smaller—both in size and power output—than the medium and large commercial nuclear plants in operation today and will enable remote operation and control in remote areas. There are numerous remote mining operations and communities with limited access to a grid that could benefit from a microreactor power source. At present, the cost to generate their electricity becomes exorbitant, not only from the price of the diesel fuel or the variability of renewables, but also from the transportation costs associated with moving the fuel over long distances on often unpaved roads and lack of access many months per year.

While remote operation and control capabilities offer numerous advantages, a big challenge to the deployment and future licensing of microreactors is the lack of applicable technology, real-world data, and a knowledge base of nominal and transient autonomous operation and control for these systems. For example, a microreactor may not have a conventional control room. In some instances, human operators (ideally no more than one or two) may not be located onsite and may instead be operating or monitoring the microreactor (or fleet of microreactors) from a remote location using just a workstation.

To fill this critical gap, we propose to use Purdue University's Research Reactor (PUR-1) as an autonomous control testbed. PUR-1 is the first research reactor in the U.S. with fully digital instrumentation and control (I&C) and unique digital capabilities including remote monitoring. The proposed research will experimentally demonstrate autonomous control and remote operation, and use the findings to explore issues related to human factors for microreactors while providing a set of unique real-world data. Access to, and deep knowledge of, PUR-1 will provide a unique opportunity to develop readily deployable control technologies and regimes that enable unattended and reliable operations.

In this project, we will develop a modular autonomous control platform with various levels of automation using a remote workstation with Machine and Deep Learning algorithms. The algorithms will be trained using data from existing physics-based high-fidelity microreactor models and real-time digital operation data collected from PUR-1. Then, we will demonstrate remote operation and control be performing thorough testing and validation under an actual nuclear environment in PUR-1 using real data from reactor sensors and digital controllers. Finally, we will evaluate performance for various levels of automation and identify inputs needed for a human to safely monitor and operate a microreactor from a remote location.