U.S. Department of Energy

# Development of a Benchmark Model for the Near Real-Time Radionuclide Composition Measurement System using Microcalorimetry for Advanced Reactors


**PI**: Braden Goddard, Virginia Commonwealth University (VCU)

**Collaborators**: Kyle Hartig, University of Florida; Zeyun Wu, VCU; Mark Croce, Los Alamos National Laboratory; Shayan Shahbazi, Argonne National Laboratory


**Program**: CT-4


**ABSTRACT:**

Pebble bed reactors (PBRs) and molten salt reactors (MSRs) that use liquid fuel are particularly challenging from a regulatory, safety, security, and safeguards (3S) perspective due to the non-traditional feature that their fuel continuously "flows" through the reactor core. This movement of the fuel creates challenges with current used fuel accountancy techniques to ensure that all used fuel is accounted for and the composition of the used fuel is well characterized. However, the fact that fuel continuously flows through these cores can be an asset for near real-time fuel characterization. By measuring gamma rays from short-lived fission products and other nuclides in the fuel, they can be used as an indicator of the concentration of fissionable nuclides currently in the fuel. Since short-lived fission products emit a wide range of gamma ray energies, an advanced gamma ray detector with unprecedented energy resolutions is therefore needed to extract the desired photo peak information from the complex gamma spectra. The current state of the art in gamma ray energy resolution is microcalorimetry, which has an energy resolution of approximately 10 times better than that of high purity germanium (HPGe) detectors.

The primary objective of this proposed project is to develop high-fidelity Monte Carlo radiation transport models of a microcalorimetry detector informed by fuel depletion models of an MSR and a PBR to quantify the current and future capabilities of this detector technology to characterize and assay used fuel from these reactors in near real-time. Advanced machine learning approaches will be applied to exploit these novel ultra-high energy resolution measurements to extract features and signatures (e.g., X-ray spectra) related to salt composition, degradation, and contamination arising from excitation of non-radioactive species in these materials. Engineering implementation challenges of using microcalorimetry in commercial facilities, such as photon attenuation and high background radiation, will be explored and included into the simulation models. This will inform and facilitate future development of this technology leading to the eventual implementation in an industrial facility. Performing simulations (that have been validated with measured data) is the most efficient method to explore the capabilities of this new technology and is ideally suited for an initial study of the measurement of short-lived fission products due to the challenges and complexities of performing physical measurements of recently fissioned MSR or PBR fuel. The deliverables for this project include reports and publications of the research described above, development of human capital though trained graduate and undergraduate students, and publicly available Monte Carlo radiation transport models of a microcalorimetry detector.