



**UNITED STATES
NUCLEAR REGULATORY COMMISSION**
WASHINGTON, D.C. 20555-0001

Grant # 31310021M0045

Grantee: Virginia Polytechnic Institute

Title of Grant: Development of a Novel Multi-Modal In-Situ Detection System Supporting Human-Machine Collaboration in Core Monitoring and Control of Advanced Reactors

Period of Performance: 9/27/2021-9/26/2024 (FY2021 Notice of Funding Opportunity NOFO)

Executive Summary

We propose to develop an in-situ detection and monitoring system with a physics-based Machine Learning (ML) algorithm to infer nuclear reactor core physics data with high fidelity and facilitate human-machine interaction for next generation nuclear reactors. This in-situ monitoring system, with its ML algorithm, will significantly contribute to improved safety and efficacy by making system adjustments in response to the data generated by the proposed in-situ detection system. For this project we will develop a software interface to couple the CHANDLER multi-modal detection system and the VRS-RAPID (Virtual Reality System for Real-time Analysis for Particle transport and In-situ Detection) neutronics code system and expand on the exiting ML algorithm and virtual reality visualization framework to provide an effective means for the human-machine collaboration. The proposed software will be validated using the Jozef Stefan Institute's research reactor in Slovenia and the Dominion Energy's North Anna Power Station in Virginia. This proposal addresses several areas of interest, identified by the NRC, including: 'advanced sensors and controls'; 'human reliability analysis for advanced nuclear applications'; 'Analyses, data and evaluations'; and 'advanced technology approaches that enhance regulatory decision making'.

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Presentations and Publications

The list of publications was submitted with the final report after grant expiration.

- 1) Mascolino V., A. Haghighat, and L. Snoj, "On the Novel 3-D Neutron Transport Kinetic tRAPID Algorithm and its Validation," *proceedings of the International Conference on Physics of Reactors (PHYSOR 2022)*, May 15-20, 2022.
- 2) Pungercic, V. Mascolino, A. Haghighat, and L. Snoj, "Application of the bRapid Fission Matrix Burnup Methodology to the JSI TRIGA Mark II Research Reactor," *proceedings of International Conference on Physics of Reactors (PHYSOR 2022)*, May 15-20, 2022.

- 3) Mascolino, V. and A. Haghighat, "A novel hybrid deterministic and Monte Carlo neutron transport formulation and algorithm (tRAPID) for accurate and fast 3-D reactor kinetics," accepted for publication in *Nuclear Science and Engineering*, March 2023.
- 4) Pungercic, V. Mascolino, A. Haghighat, and L. Snoj, "Verification of a novel fuel burnup algorithm in the RAPID code system based on Serpent-2 simulation of the TRIGA Mark II research," *Nuclear Engineering and Technology*, Volume 55, Issue 10, October 2023.
- 5) Pungercic, A. Haghighat, and L. Snoj, "Depletion Algorithm for On-the-Fly Nuclide Inventory Determination for Research Reactors in the RAPID Code System," *International Conference on Research Reactors: Achievements, Experience and the Way to a Sustainable Future*, 27 November – 1 December 2023, Dead Sea, Jordan.
- 6) Pungercic, A. Haghighat, and L. Snoj, "Experimental and Computational Validation of Novel Depletion Algorithm in the RAPID Code System using JSI TRIGA reactor," *Proceedings of the NENE 2023*, Sept 2023. (Received the best poster award).
- 7) Pungercic, A., A. Haghighat, and L. Snoj, "JSI TRIGA fuel rod reactivity worth experiments for validation of Serpent-2 and RAPID fuel burnup calculations," *Nuclear Engineering and Technology*, accepted March 28, 2024 (DOI: <https://doi.org/10.1016/j.net.2024.03.041>).
- 8) Stroh, B., W. Al Hajj, and A. Haghighat, "High Fidelity Whole Core Reactor Eigenvalue Calculation using the Hybrid Monte Carlo and Deterministic RAPID Code System," *EPJ Web of Conferences*, Volume 302 (2024).

Patents

N/A