**Foundations for a Fission Battery Digital Twin**

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The nuclear industry is moving toward the construction of microreactors and next generation reactors. These efforts pose new challenges. A digital twin tool will enable reduced costs and risk through integration of the disparate systems used in the design, construction, and operation of these reactors. Recent investments at Idaho National Laboratory (INL) in open-source digital engineering and Multiphysics framework development provide a foundation from which to create and evaluate a digital twin for nuclear reactors. This digital twin tool will use the Microreactor AGile Non-nuclear Experimental Testbed (MAGNET)1 as a case study to develop a digital twin with both a single heat pipe test article and 37 heat pipe test article. The digital twin will provide the capabilities of remote monitoring and unattended operation (autonomous control) of these systems.

A digital twin is a digital replica of an operating asset that can display data received from live sensors, update a physics model for the asset with the received data, compute predictive results of operational status with artificial intelligence (AI) to aid in optimizing asset use, and apply asset control accordingly. This twin will be developed through integration of the open-source technologies Deep Lynx2 (a data warehouse technology) and the Multiphysics Object-Oriented Simulation Environment (MOOSE)3, physical asset sensors, and physical asset controls. The team hypothesizes that the general AI will successfully predict the events described as MAGNET heat pipe article test cases (such as heat pipe failure) using the integrated data from the MAGNET sensors and physics-based models including the developed meta model(s). A second hypothesis is that the integration of open-source INL software and AI assets with sensor data from a test bed will lead to a repeatable framework and guide for the creation of future digital twins. The team will also perform AI model training and experimentation to determine what models and features are most important for enabling intelligent autonomous control as well as evaluate and determine best practices for digital twin cyber security.

Thus far, the research team has completed several of the preliminary steps towards the full integration, operation, and validation of the digital twin. This includes creation of an initial single heat pipe Multiphysics model in MOOSE. The team has also completed development of the MOOSE Adapter, software that connects the Deep Lynx data warehouse with the Multiphysics model. Machine learning algorithms to aid in identifying relationships between the heat pipe sensor data have also been created and are undergoing validation and improvement. Improvements have also been made to MOOSE and Deep Lynx, providing new and essential features for both this effort and other users of these technologies. With a Multiphysics model in place of the heat pipe and connections between this data and the data warehouse, the attention of the team has been turning to the development and connection of machine learning results with the greater digital twin and design and development of a user interface (UI) to allow for viewing and interacting with the digital twin data.

References

1. Functional and Operating Requirements for the Microreactor Agile Non-Nuclear Experimental Test Bed (MAGNET), internal report, Idaho National Laboratory, Idaho Falls, US, 2020.
2. DARRINGTON, J., BROWNING, J., RITTER, C., Deep Lynx Open-Source Data Warehouse (2021),

https://github.com/idaholab/Deep-Lynx

1. PERMANN, C., GASTON, D., ANDRS, D., CARLSEN, R., KONG, F., SLAUGHTER, A., Multiphysics Object-Oriented Simulation Environment (2021),

https://mooseframework.inl.gov/