INL/CON-24-76839-Revision-0

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Prepared for the
U.S. Department of Energy
Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517

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[Placeholder for Digital Object Identifier (DOI) to be added by ANS]

Abstract.

The National Reactor Innovation Center (NRIC) was established to accelerate the deployment of novel reactor concepts by providing physical and virtual spaces for building and testing reactor experiments. The Virtual Test Bed (VTB) represents the virtual counterpart to physical test beds. The VTB is a collaboration with the Department of Energy's (DOE) Nuclear Energy Advanced Modeling and Simulation (NEAMS) program. Its mission is to accelerate the deployment of advanced reactors by facilitating the adoption of advanced modeling and simulation (M&S) tools developed by DOE. This mission has been carried out by the VTB since 2020 by hosting and featuring dozens of advanced fission nuclear reactor models developed by national laboratories and academia. The definition of advanced reactors in the charter of the NRIC also includes fusion nuclear reactors. The tools developed by the NEAMS program are increasingly used for modeling fusion energy devices, and there is an increasing need to host fusion reactor models on the VTB repository. The VTB will therefore be extended in 2024 to support fusion energy M&S.

The VTB consists of a large open-source repository available on GitHub at https://github.com/idaholab/virtual_test_bed where the models are hosted, including the meshes, inputs files, and relevant data, and an accompanying documentation website detailing the models at https://mooseframework.inl.gov/virtual_test_bed. Extensive documentation provides new users of the model with context on the simulated system, a step-by-step guide through the content of the input files, and finally, an overview of the results. The objective of the VTB is to disseminate access to cutting-edge modeling examples. This is already being used within academia to build on capabilities stemming from DOE and by regulators to accelerate the review timeline of proposed demonstration (e.g., by downloading an open-source benchmark problem from the VTB and modifying the geometry to an applicant's proprietary design). While many of the advanced fission reactor modeling tools are not open-source, about a third of the models hosted are, in fact, using solely open-source tools. For fusion device modeling, the intent is to keep an even larger majority of the models exclusively reliant on open-source tools, following the fusion community best practices.

The first model to be released on the VTB for fusion energy modeling is a multiphysics simulation of a breeder blanket. The modeled system is an innovative solid ceramic breeder helium-cooled blanket designed for use in the Fusion Nuclear Science Facility, an intermediate reactor concept that attempts to fill the gap between the International Thermonuclear Experimental Reactor and a sustainable commercial fusion reactor. The model leverages the Multiphysics Object-Oriented Simulation Environment (MOOSE) and OpenMC codes (both open source). MOOSE is a massively parallel finite-element/volume multiphysics simulation platform that has been widely adopted within the nuclear fission community. OpenMC is an open-source neutral particle transport code which can be used for shielding calculations. This model integrates neutronics analysis, system thermal-hydraulics simulation, and full 3D heat transfer calculations. It couples the various physics on separate nonconforming meshes using a variety of field variable transfers in MOOSE. The model may be extended in the future to include multidimensional tritium breeding calculations using TMAP8, a state-of-the-art tritium inventory code developed as a MOOSE application.

The VTB is a collaborative effort and is deliberately available freely online to all. Contributions from institutions, academia, industry, and other governmental organizations, even internationally, are encouraged. The guidelines for contribution are published on the documentation website.

Keywords: Fusion, repository, modeling & simulation, MOOSE