



Virtual Test Bed (VTB): NRIC FY24 Program Review

March 2024

Changing the World's Energy Future

Lise Cecile Madeleine Charlot, Abdalla Abou Jaoude, Emily Shemon



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NRIC

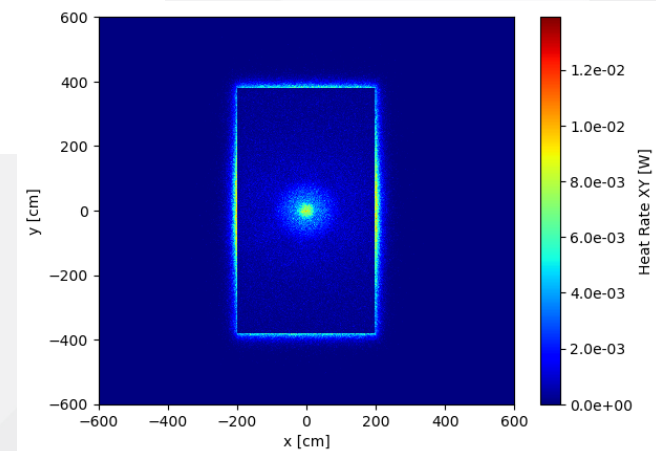
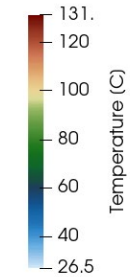
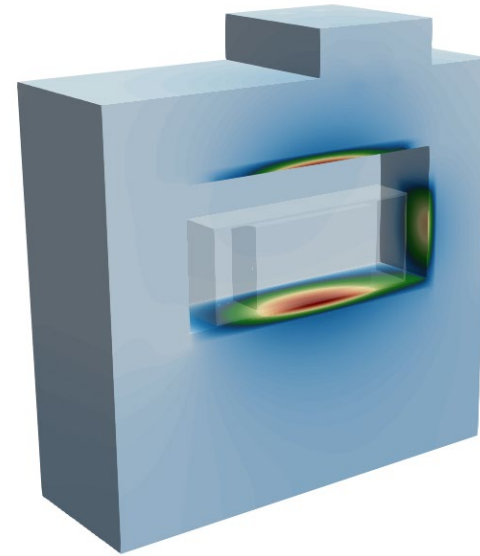
National Reactor
Innovation Center

NRIC Virtual Test Bed (VTB)

NRIC FY24 Program Review

Lise Charlot (INL), Abdalla Abou-Jaoude (INL), Emily Shemon (ANL)

5/21/2024



Mission Statement

NRIC: Deliver successful demonstration and deployment of advanced nuclear energy

- **EBR-II Test Bed (DOME)**
- **ZPPR Test Bed (LOTUS)**
- **Virtual Test Bed (VTB):** Accelerate deployment of advanced reactors by leveraging state-of-the-art ModSim tools to evaluate performance and safety

Ok, but what is it?

- **Library of Reference Model:** database of advanced multiphysics advanced reactor models that users can download, edit, and re-run
- **Continuous Software QA:** linking repository to software development to avoid legacy issues while enabling rapid code development
- **Virtual models of the test bed:** developing demonstration-relevant models (e.g., candidates for DOME/LOTUS) to accelerate safety evaluations

Reactor Demonstrations

Accelerate
Licensing
Evaluation
(NRC)

Accelerate
Authoriza-
tion
Evaluation
(DOE)

Accelerate
Design
Maturation
(industry)

Targeted
Model
Generation

Library of
Reference
Models

Testing for
Agile
Software
QA

NRIC Mission

VTB Mission

VTB Scope





VTB Team

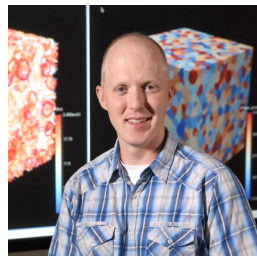
INL Team



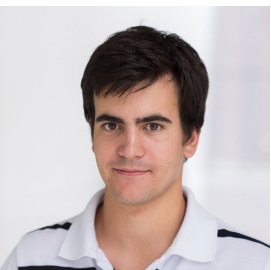
Abdalla Abou-Jaoude
Former VTB Workpackage Manager; PI salt irradiation LDRD; SA&I Techno-economics Lead



Lise Charlot
New VTB Work Package Manager; Computational scientist



Cody Permann
VTB department support; Computational Framework Dep. Manager



Guillaume Giudicelli
VTB Infrastructure Lead; MOOSE Developer



Mustafa Jaradat
VTB DOME model developer; Computational scientist

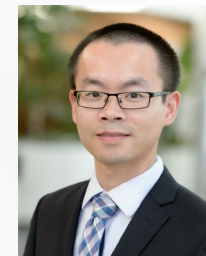


Samuel Walker
VTB External Model Lead; Pronghorn Developer

ANL Team



Emily Shemon
VTB Work Package Manager; NEAMS Multiphysics Applications Technical Area Lead



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Griffin developer

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OpenMC Developer

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The VTB Repository

https://mooseframework.inl.gov/virtual_test_bed

1. Documentation

Detailed explanation of models

The screenshot shows the 'Virtual Test Bed' documentation page. It includes a welcome message, a description of the repository's purpose (facilitating the use of advanced modeling & simulation tools), and a list of information about the VTB. The 'Models documentation' section lists 'Models automated indexing' and 'Models manual indexing'. A 'NOTE' section at the bottom provides a link to the GitHub repository.

Virtual Test Bed

Welcome to the Virtual Test Bed (VTB) repository!

This repository is a National Reactor Innovation Center (NRIC) initiative aiming to facilitate the use of advanced modeling & simulation (M&S) tools developed by the Department of Energy NEAMS program. Following the passage of the Nuclear Energy Innovation Capabilities Act, NRIC was created for accelerating the deployment of these novel reactor concepts. This will be achieved by providing both physical and virtual spaces for building and testing various components, systems, and complete pilot plants. The VTB represents the virtual arm in collaboration with DOE's NEAMS program.

The VTB repository hosts a wide variety of example challenge problems based on advanced reactor designs. This website contains the background and documentation for each use case. Click on a reactor type below to find out more. To access the corresponding inputs and supporting file, refer to the [repository](#).

Users will need to request access to the controlled NEAMS software from the [Nuclear Computational Resource Center](#). For additional information on the VTB, please reach out to Dr. Abou-Jaoude at abdalla.aboujaoude@inl.gov.

Information about the Virtual Test Bed

- [How to use the Virtual Test Bed](#)
- [How to run a Virtual Test Bed example with the NEAMS Workbench on Sawtooth](#)
- [How to cite a model on the Virtual Test Bed](#)
- [How to contribute to the Virtual Test Bed](#)
- [Multiphysics reactor modeling using the MultiApps system](#)
- [Frequently Asked Questions and Discussion Forum](#) \

Models documentation

- [Models automated indexing](#)
- [Models manual indexing](#)

NOTE

[Link to the GitHub repository](#)

2. GitHub Repo

Ability to clone and contribute to models

The screenshot shows the GitHub repository page for 'virtual_test_bed'. It displays the repository's name, public status, and statistics (11 watches, 62 forks, 44 stars). The 'About' section describes it as 'The National Reactor Innovation Center's (NRIC) Virtual Test Bed Repository'. The 'Releases' and 'Packages' sections show no published items. The 'Contributors' section lists 38 contributors. The 'Languages' section shows the repository is primarily in Python.

virtual_test_bed Public

8 Branches 0 Tags

Go to file

About

The National Reactor Innovation Center's (NRIC) Virtual Test Bed Repository

Readme

CC-BY-4.0 license

Activity

44 stars

11 watching

62 forks

Report repository

Releases

No releases published

Packages

No packages published

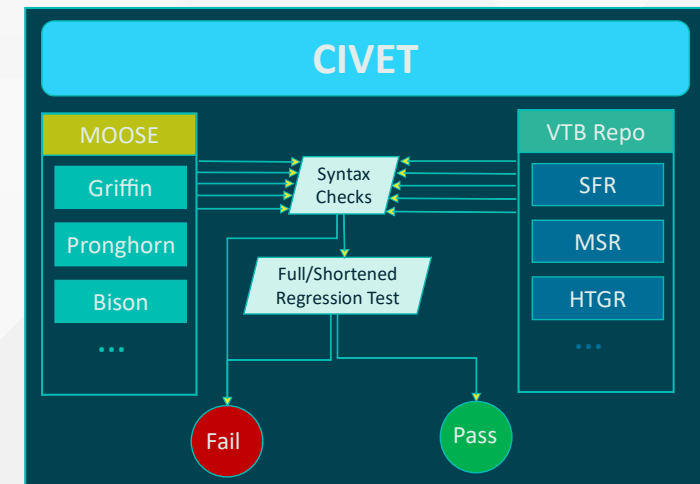
Contributors 38

+ 24 contributors

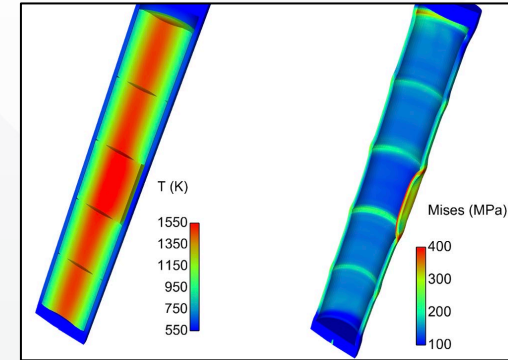
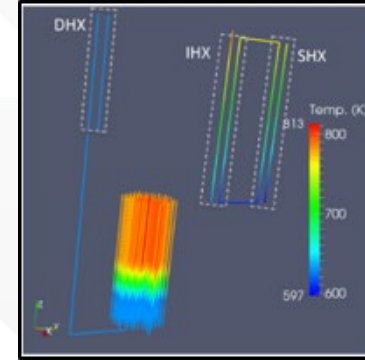
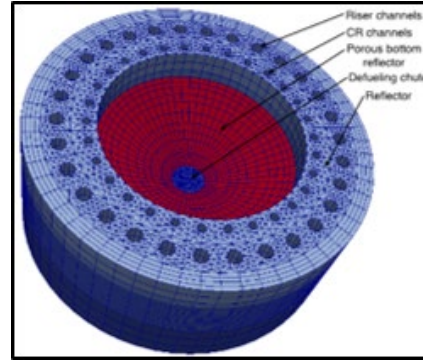
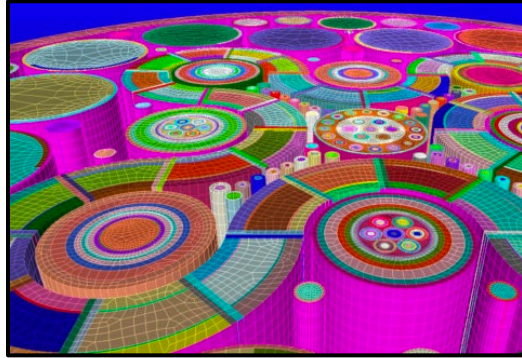
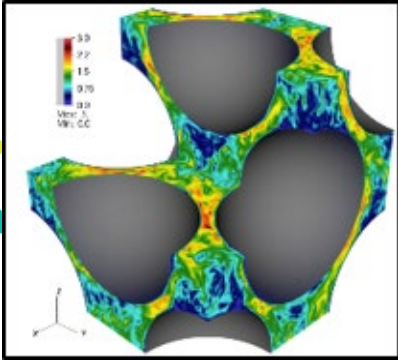
Languages

3. Integration with Code Development

Continuous testing of models against codes using CIVET



Advanced Reactor ModSim Suite



NEK-5000



GRIFFIN



PRONGHORN



SAM



Bison/
Yellowjacket

High Fidelity

2D/3D Multiphysics Transients

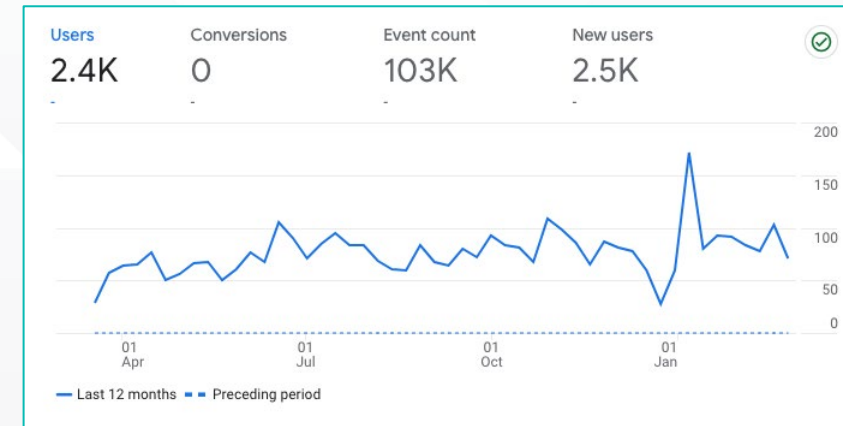
System-level Simulation

Depletion & Fuel Performance

Fuel Performance/
Thermochemistry

VTB Benefits to Stakeholder

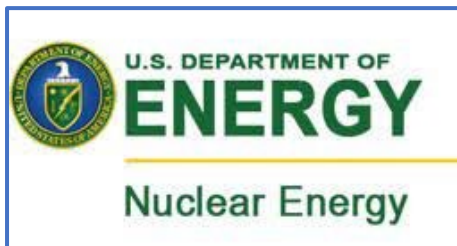
- VTB models can downloaded and repurposed model for specific need/designs
- Hosting open benchmark problems
- Showcasing challenge problems
- Coordination of teams working on similar reactor type
- Direct sharing of models and new capabilities developed through DOE programs
- Industry relevant through active collaborations
- Model used for student training



2400+ distinct users with 100,000+ counts over a year

Success stories

- The MCRE ARD team is using VTB models by building on them for the final proprietary design analysis.
- VTB models are being referenced in an upcoming NRC report on verification and validation of NEAMS tools



VTB Repository Maintenance

While most of the process is automated there are some manual interventions required

- Reviews of input file modifications tied to code updates: 14 in FY23
- Maintenance operations through pull requests to the repository: 40 in FY23
- Documentation improvements operations on existing models: 15 in FY23
- Google Analytics user tracking added March 23
- Search engine created and expanded to replace manual sorting of models (reactor type/physics solved/laptop vs HPC..)

Planned Improvements

- Deployment of VTB Continuous Integration to INL High Performance Computing for expensive model testing (CFD calculations, large transients etc)
- Continuous improvement of the search engine feature

Current status

virtual_test_bed

- dev
- main

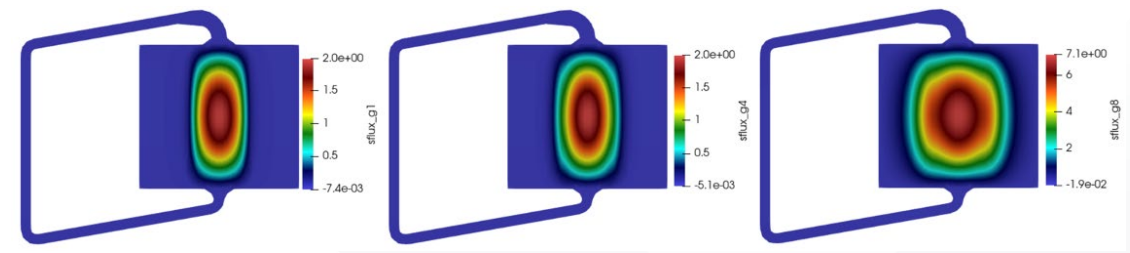
- #67 Add weekly compressible version of MSFR pronghorn by GludGud
- #285 Replace flux transfer in HPMR by aprinovak
- #316 Spatially Resolved Thermochemical analysis of Molten Salt Fast Reactor by mtmwalker
- #335 Add TRISO 2D and 3D examples by jiangwenli
- #360 Adding Cardinal model of a 7-Pin LFR demonstration case by hapfang

Latest 30 events

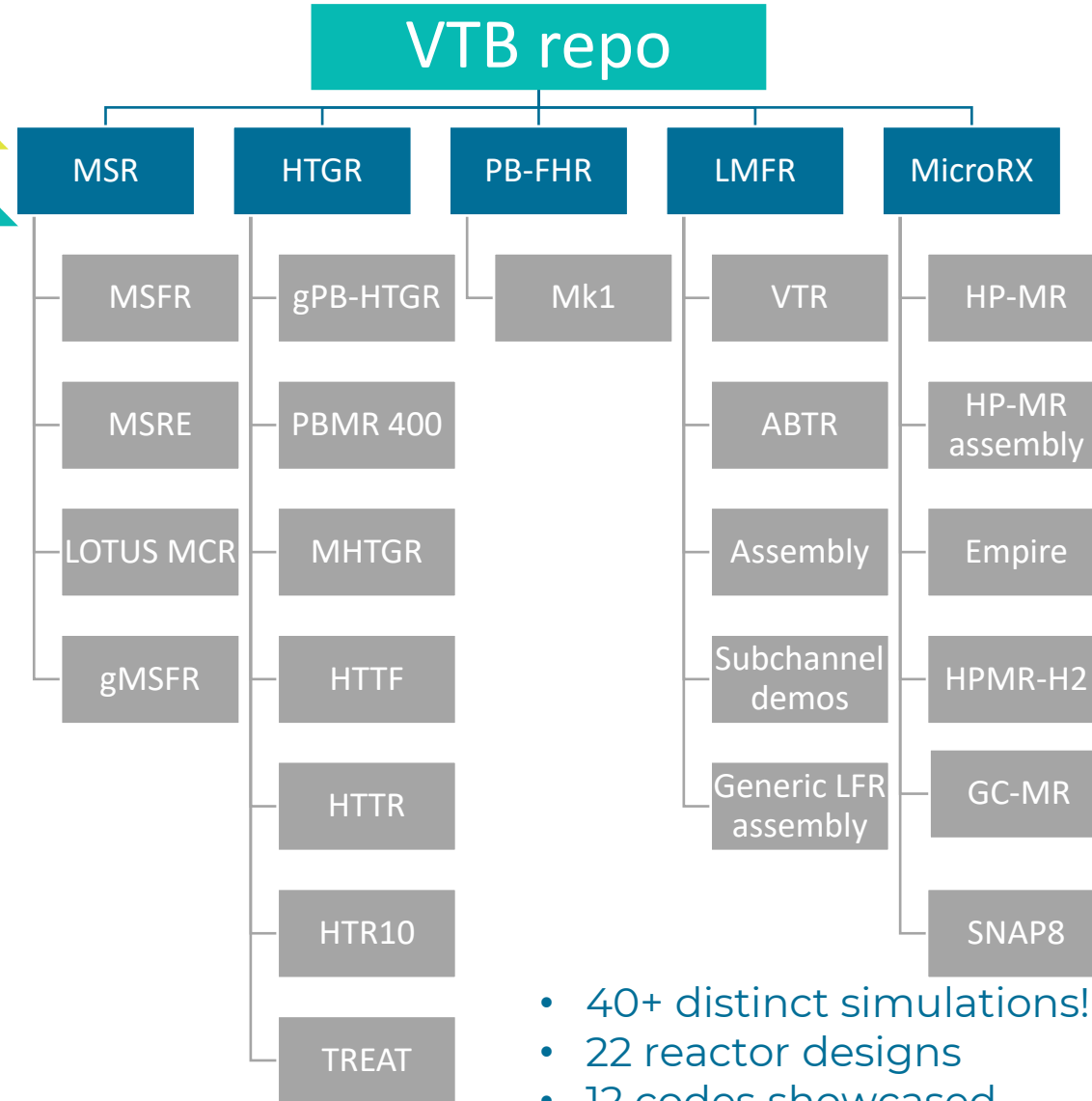
virtual_test_bed #360 : Adding Cardinal model of a 7-Pin LFR demonstration case	Precheck 0:01:57	→	MOOSE 0:29:30 Test modules combined opt	Test Cardinal 0:20:26 Test RELAP-7 Cardinal VTB	Test RELAP-7 0:19:26 Test RELAP-7 VTB opt	Test SAM 0:10:39 Test SAM VTB opt	Test bison 0:21:45 Test bison VTB opt	Test blue_crab 1:12:52 Test blue_crab VTB opt	Test dire_wolf 0:40:22 Test dire_wolf VTB opt	Test griffin 0:49:38 Test griffin VTB opt	Test pronghorn 0:16:34 Test pronghorn VTB opt
	Test sockeye 0:07:47 Test sockeye VTB opt	VTB Documentation 0:09:34									
virtual_test_bed main : Merge commit a916dd	Documentation 0:00:58 (invalidated)										
virtual_test_bed devel : Merge pull request #362 from idaholab/submodule...	Precheck 0:02:26	→	MOOSE 0:42:44	Test Cardinal 0:20:08	Test RELAP-7 0:57:26	Test SAM 0:24:18	Test bison 0:34:06	Test blue_crab 1:40:15	Test dire_wolf 1:03:56	Test griffin 1:05:28	Test pronghorn 0:41:27
	Test sockeye 0:17:35	VTB Documentation 0:08:54	→	Merge 0:01:32							
virtual_test_bed main : Merge commit 995907	Documentation 0:05:50										
virtual_test_bed #362 : General Submodule update	Precheck 0:01:47	→	MOOSE 0:43:11	Test Cardinal 0:20:25	Test RELAP-7 0:37:07	Test SAM 0:24:01	Test bison 0:30:45	Test blue_crab 1:40:28	Test dire_wolf 0:58:09	Test griffin 1:16:04	Test pronghorn 0:35:41
	Test sockeye 0:19:07	VTB Documentation 0:10:24									
virtual_test_bed #362 : General Submodule update	Precheck 0:01:57	→	MOOSE 0:43:23	Test Cardinal 0:17:06 Test RELAP-7 Cardinal VTB	Test RELAP-7 0:40:16	Test SAM 0:23:43	Test bison 0:34:26	Test blue_crab 0:57:14	Test dire_wolf 0:56:44	Test griffin 0:56:53	Test pronghorn 0:36:31
	Test sockeye 0:20:00	VTB Documentation 0:08:48									

Snapshot of the VTB testing dashboard on 03/01/2024 (Red is an external pull request, current status on 3rd line)

VTB Model Tree

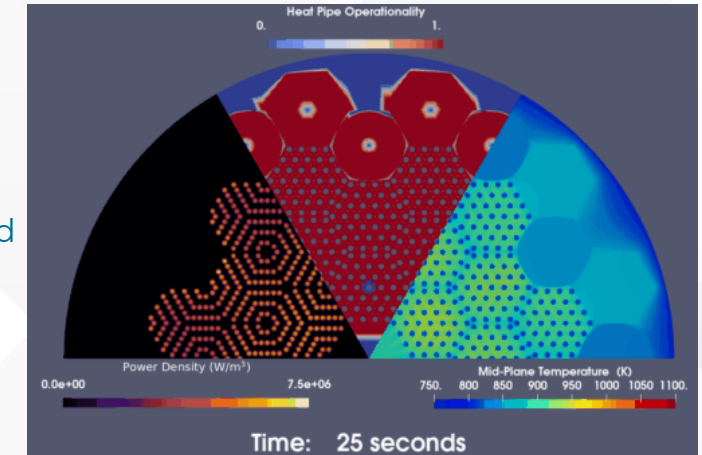


Normalized steady-state neutron fluxes for 3 selected groups in the LOTUS Molten Chloride reactor

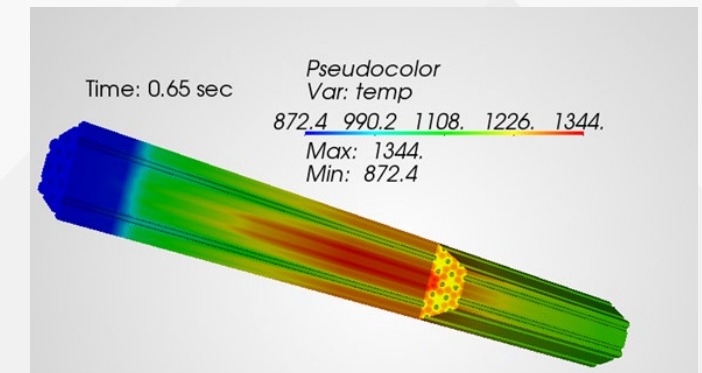


- 40+ distinct simulations!
- 22 reactor designs
- 12 codes showcased

Cascading heat pipe failure in an overpowered heat pipe micro reactor

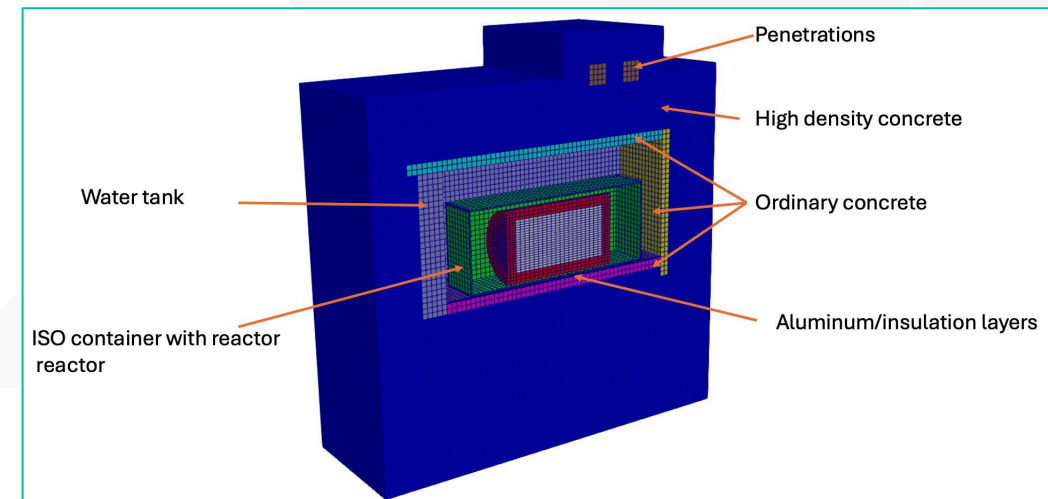
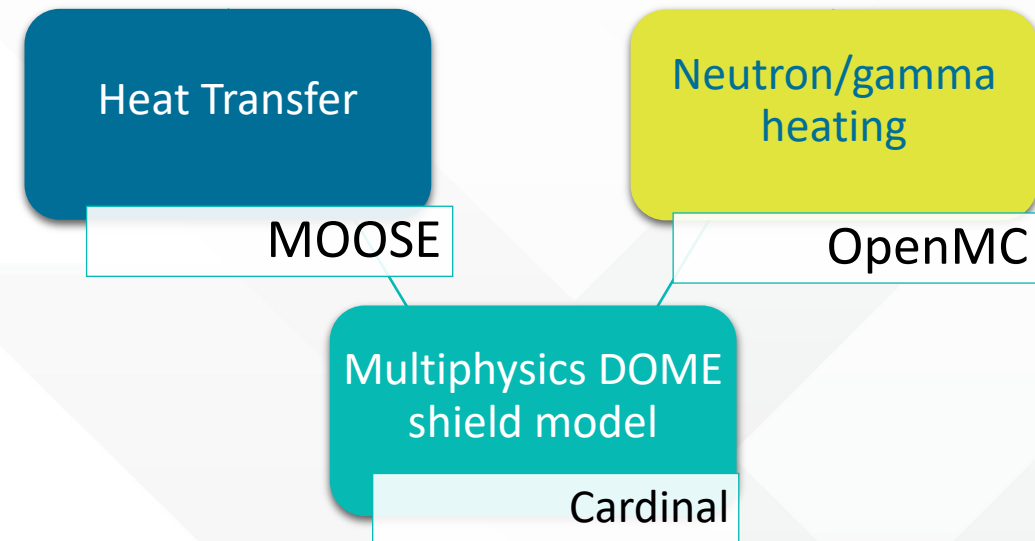


3-D temperature distribution during RIA in a gas-cooled microrx assembly



DOME shield virtual Model

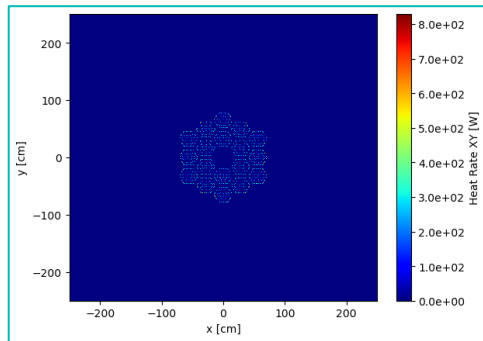
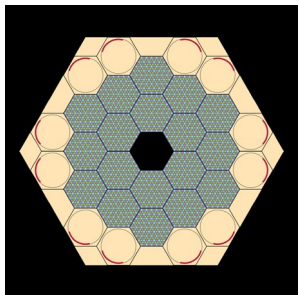
- Add a virtual model of the DOME shield to the VTB repo
- Goal: Accelerate confirmatory analysis by providing a model of the DOME shield that can interface with a DOME user reactor model
- Model requirements:
 - Coupling with any reactor design
 - Evaluation of the maximum concrete temperature in the shield for both steady state operation and transient scenarios.
 - Use open-source codes
 - Model should be easy to modify to accommodate shield configuration changes



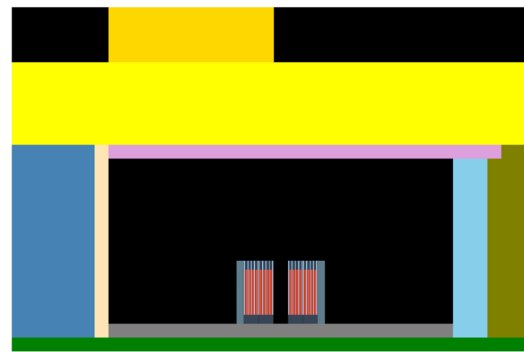
DOME shield model (Conceptual design)

DOME shield model- accomplishments

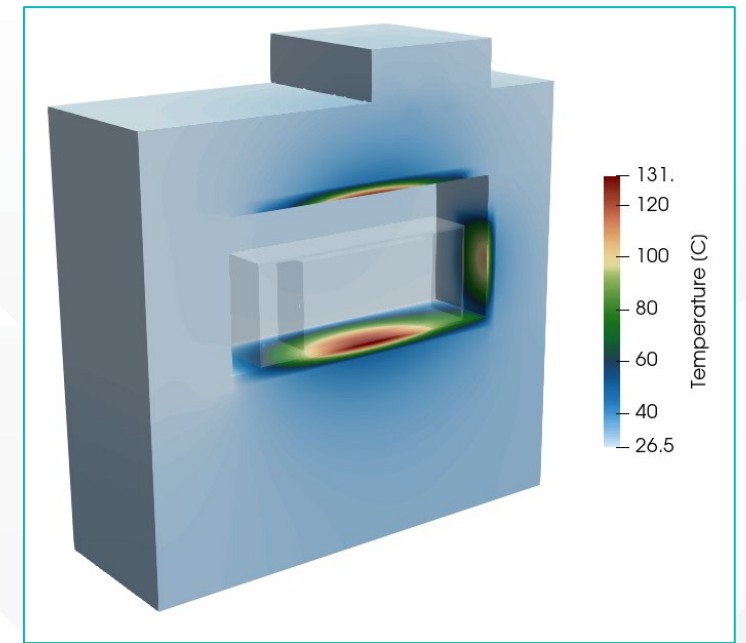
- MOOSE thermal analysis of the DOME shield using FY23 design.
- OpenMC model of a heat pipe reactor to obtain a physical source term
- Model of the shield with a fixed source
- DOME shield models will be released on the VTB repo when the design is finalized



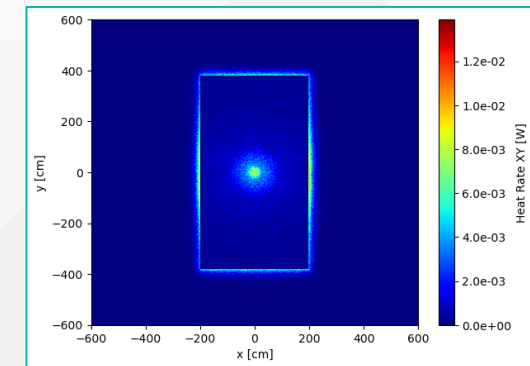
OpenMC model of a heat pipe reactor



Preliminary OpenMC setup of a reactor inside the shield structure



Temperature distribution in the shield concrete (FY23 design)



Predicted heat rate in the shield structure using a fixed source

Funding Timeline & FY24 Tasks

- FY24 Tasks:
 1. Repo improvements: Search, HPC testing
 2. External models: NRC, NEAMS, ART-GC/MSR, etc.
 3. Model development: DOME Shield Virtual model
- Proposed Additional scopes:
 - See Nov M4RC-24IN0206022
 - Cost range: historical + [\$0.6M - \$1.5M]
 - Priorities:
 - Expand DOME shield virtual model
 - Link VTB with Digital Engineering
 - Involve ORNL as key partner
 - Improved cross-section workflows
 - Simplified reduced order models
 - Can start in FY24 or push to FY25

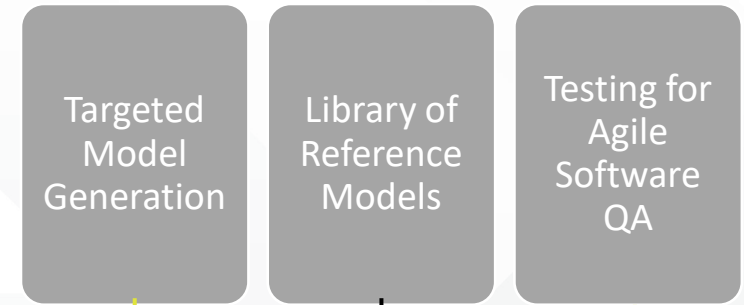
Funding:

	FY21	FY22	FY23	FY24
INL	\$400k	\$350k	\$400k	\$430k
ANL	\$200k	\$200k	\$200k	\$275k

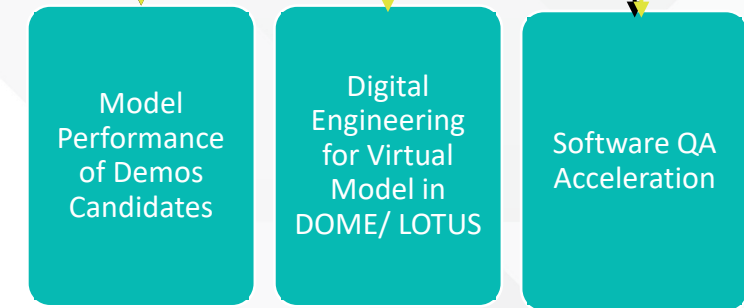
Future Vision of VTB

- Continue existing efforts with a focus on acceleration of licensing (NRC), authorization evaluation (DOE), and industry design maturation
- Support DOE Authorization at DOME:
 - Virtual model of DOME on the VTB repo
 - Leveraging Digital Engineering for automated safety evaluation
- Accelerate Software QA Process:
 - Prioritize V&V problems on VTB
 - Feedback from industry (Westinghouse, USNC, etc.) and NRC
 - Work towards Commercial Grade Dedication of tools
- Once Demos are built: VTB can act as vessel for validation benchmark exercises
- Expand VTB scope to include Fusion ModSim Engagement with ORNL

Current Priorities:



Next Priorities:



End Goal:





Summary

- **VTB Goal:** Support deployment of advanced reactor by building a database of models & simulations integrated with software QA
- **VTB Benefits:** Accelerate timeline for NRC/DOE review of candidate demos, support maturation of industry designs
- **VTB Stakeholder engagements:** Government (DOE, NRC), Industry (Terrapower, Radiant, Natrium, etc.), Academia (MIT, TAMU, UCB, U of Idaho, etc.)
- **FY24 Tasks:** (1) repo improvements, (2) hosting external models, (3) generating models for DOME Shield
- **Future Scopes:** Expand DOME models, Linking with Digital Engineering, Support Commercial Grade Dedication



Questions?

https://mooseframework.inl.gov/virtual_test_bed



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