

NEAMS Microreactor Panel

Panelists:

Multiphysics Applications and Fuels – Yinbin Miao (ANL)

Thermal Fluids – Josh Hansel (INL)

Reactor Physics – Tara Pandya (ORNL)

Structural Materials & Chemistry – Lynn Munday (INL)

Non-NEAMS: John Jackson/Abdalla Abou-Jaoude

Moderator: Jan Vermaak



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Panelists



Jan Vermaak
INL
MR App Driver WPM
Moderator



Yinbin Miao
ANL
ANL MR App Driver WPM
BISON developer



Joshua Hansel
INL
Sockeye Lead
Developer



Tara Pandya
ORNL
ORNL Reactor Physics WPM
Lead Shift developer



Lynn Munday
INL
INL Structural Materials



Abdalla Abou-Jaoude
INL MARVEL
Microreactor Lead
External Panelist



Program Vision
Through cross-cutting research and development and technology demonstration support, the Microreactor Program will enable broad deployment of microreactor technology by:

- Achieving technological breakthroughs for key features of microreactors
- Identifying and addressing technology solutions to improve the economic viability and licensing readiness of microreactors.
- Enabling successful demonstrations of multiple domestic commercial microreactors.

Program Objectives

- Address critical cross-cutting R&D needs that require unique laboratory/university capability or expertise
- Develop R&D infrastructure to support design, demonstration, regulatory issue resolution, and M&S code validation
- Develop advanced technologies that enable improvements in microreactor viability

Technology Readiness Level



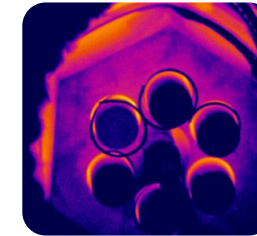
Microreactor Application

- Integrated Nuclear Testing
- Applied R&D



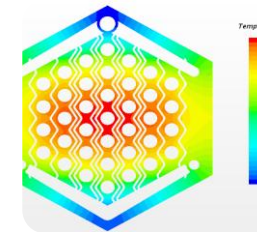
Demonstration Support Capabilities

- Non-nuclear Testing
- Test-beds for developers/regulators



Technology Maturation

- Matures fundamental microreactor enabling technologies and capabilities



System Integration & Analyses

- Identification of technology and regulatory gaps for Microreactors

MARVEL Can Enable a New Class of Nuclear Reactors

(Microreactor Applications Research, Validation & Evaluation)

Project Goals:

Development of a small-scale microreactor that provides a platform to test unique operational aspects and applications of microreactors

Primary Objectives:

- **Operational** microreactor authorized by DOE on INL site
- Produce **combined heat and power (CHP)** to a functional **microgrid**

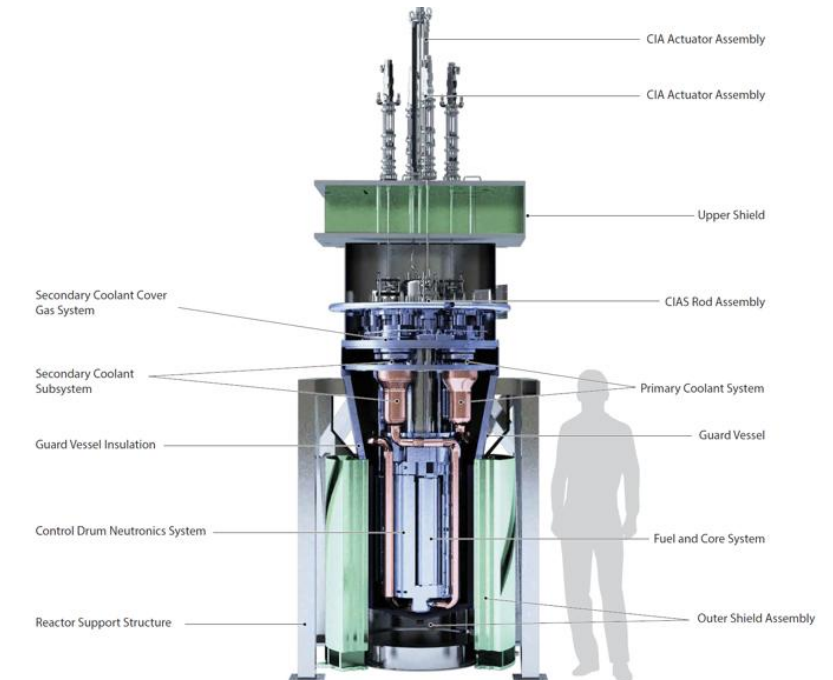
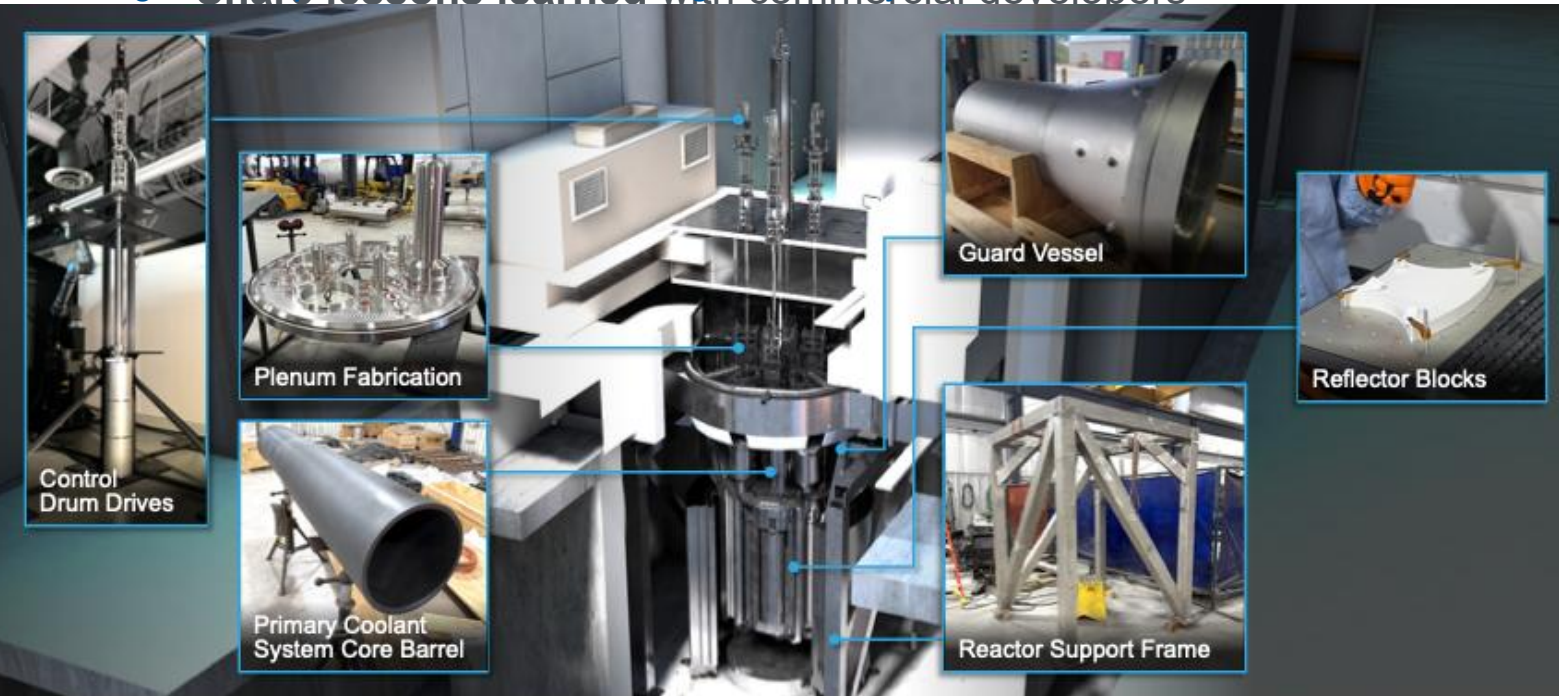


Specs

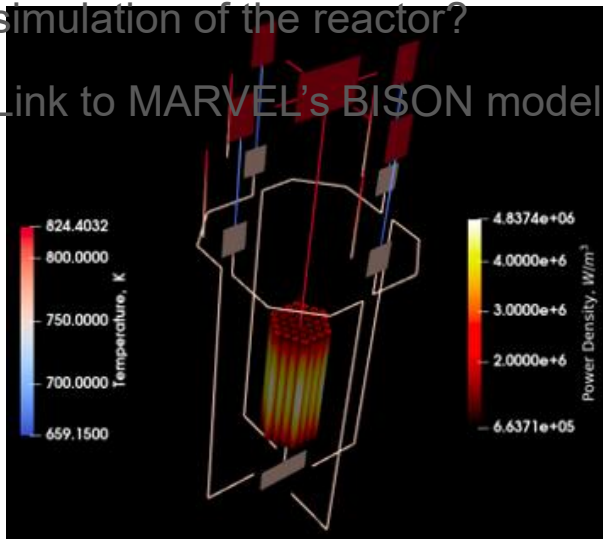
- 80 kW-thermal
- 20 kW-electric
- ~10 feet tall
- < 12 tons
- UZrH TRIGA fuel
- NaK eutectic primary coolant

Moving from Paper to Real Reactor: Target Criticality 2026

Share lessons learned with commercial developers



- Hardware and Software:
 - 2025 PCAT hydraulic data benchmark?
 - NEAMS tools for VIBRANT?
 - 2026 Dry Criticality for Griffin benchmark?
 - 2028 MARVEL ops data for validation?
- Multiphysics MARVEL model
 - End goal: Wholistic Multiphysics 3D simulation of the reactor?
 - Link to MARVEL's BISON model?

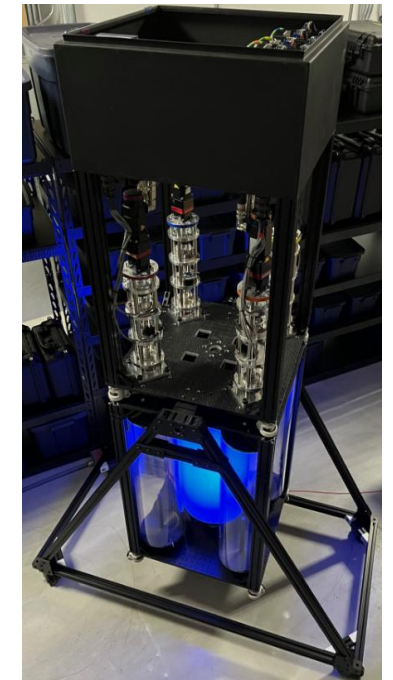


Griffin + RELAP Multiphysics MARVEL Model

PCAT TH Test



MACS/VIBRANT Controls Testing



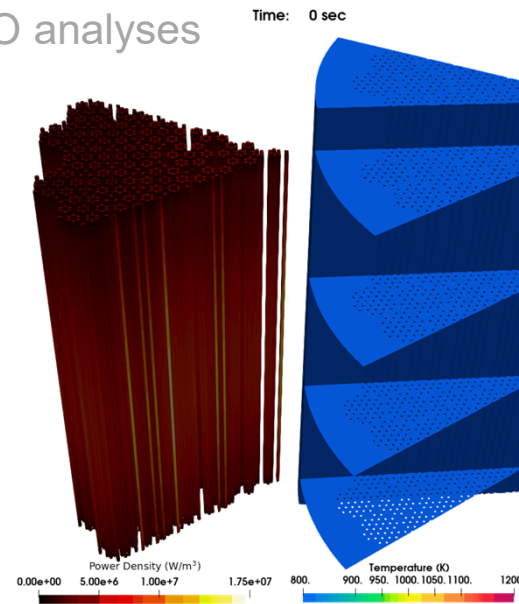
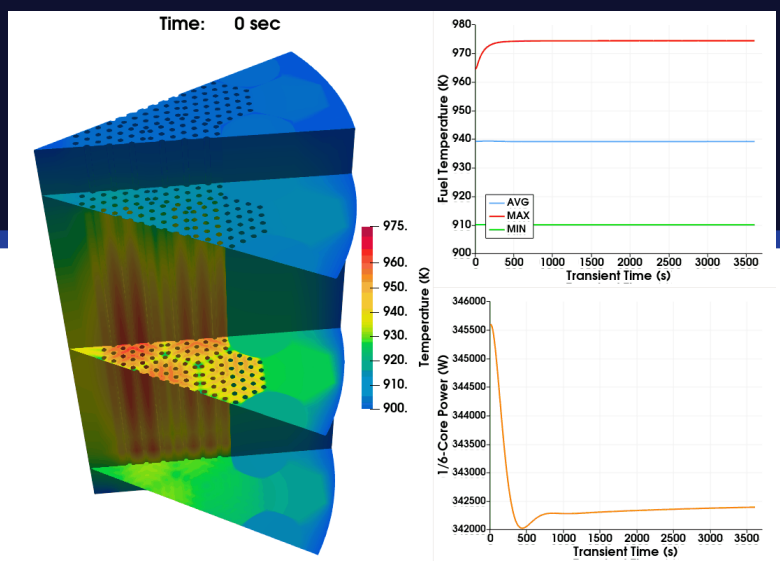
Long-Term: Using Intentional MARVEL Transients for Multiphysics Validation of NEAMS Tools?

Table 5. The two tracks of long-term collaboration between NEAMS and MARVEL.

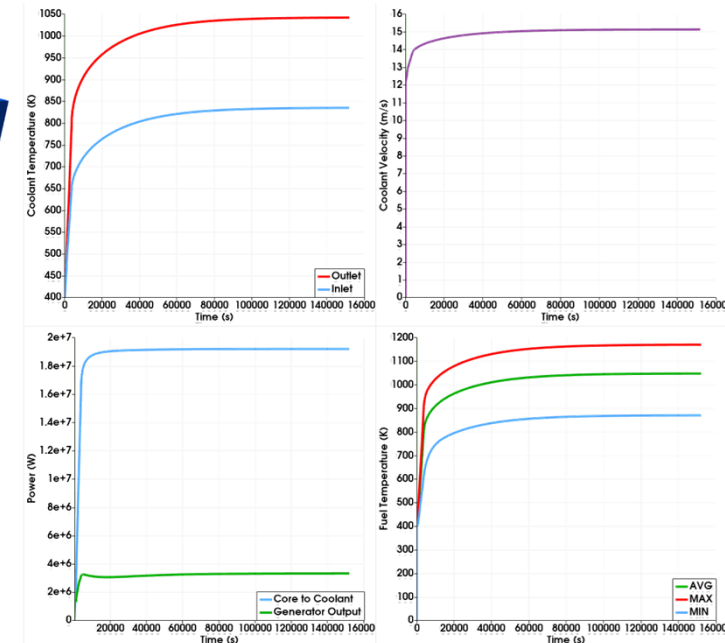
	Reactor Modeling	Material Modeling
FY 2025	Code-to-code benchmark	Coupling fuel performance modeling with reactor physics modeling Leveraging characterization data
FY 2026	Comprehensive, coupled multiphysics model of MARVEL	
FY 2027	Startup validation	—
FY 2028	Full power and transient validation	Model material impact during operations
Beyond	Analysis of hardware modifications	PIE validation

NEAMS Multiphysics Applications

- Heat Pipe Microreactor (HPMR)
 - High-fidelity 3D full-core multiphysics model
 - Na-HPMR variant w/ liquid-conduction vapor-flow (LCVF) model
 - Startup and other transients modeled based on LCVF.
 - Integration of solid mechanics
 - Secondary loop model development
 - Advanced solid mechanics models + improved TRISO analyses
- Gas-Cooled Microreactor (GCMR)
 - High-fidelity 3D full-core multiphysics model
 - Comprehensive transient analyses with hydride
 - Integration with a Balance-of-Plant (BoP) model
 - Implementation of fission products tracking
 - Heterogeneous effects of TRISO particles
 - Evaluation of online cross-section generation
 - Extended transient simulation with BoP-integrated



↑ **Na-HPMR Startup** ↓ **GCMR-BoP Startup**



- **Accomplished**
- **Ongoing**

Contributors
ANL: Yinbin Miao (WPM), Yan Cao, Yiqi Yu, Soon Kyu Lee, Ahmed Abdelhameed, Kevin Sawatzky, Nicolas Stauff, Kun Mo
INL: Jan Vermaak (WPM), Brandon Cox
PSU: Stefano Terlizzi



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NEAMS Multiphysics Applications

- KRUSTY

- High-fidelity 3D full-core multiphysics model

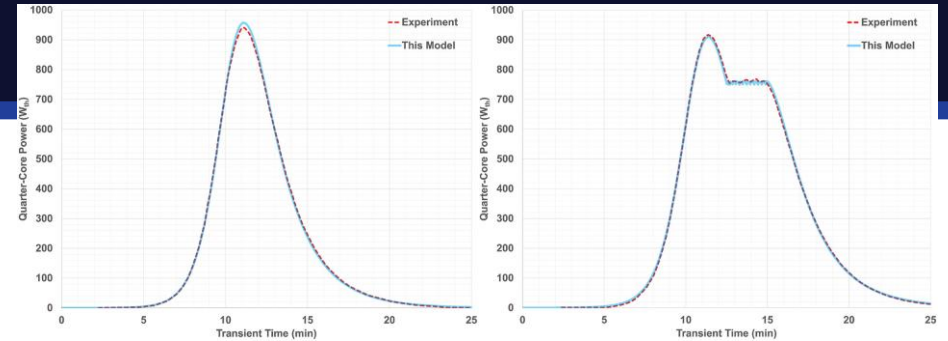
- Code validation based on warm critical tests
 - Published on *Nucl. Sci. Eng.*
(<https://doi.org/10.1080/00295639.2025.2560170>)
- Code validation based on nuclear system tests

- MARVEL

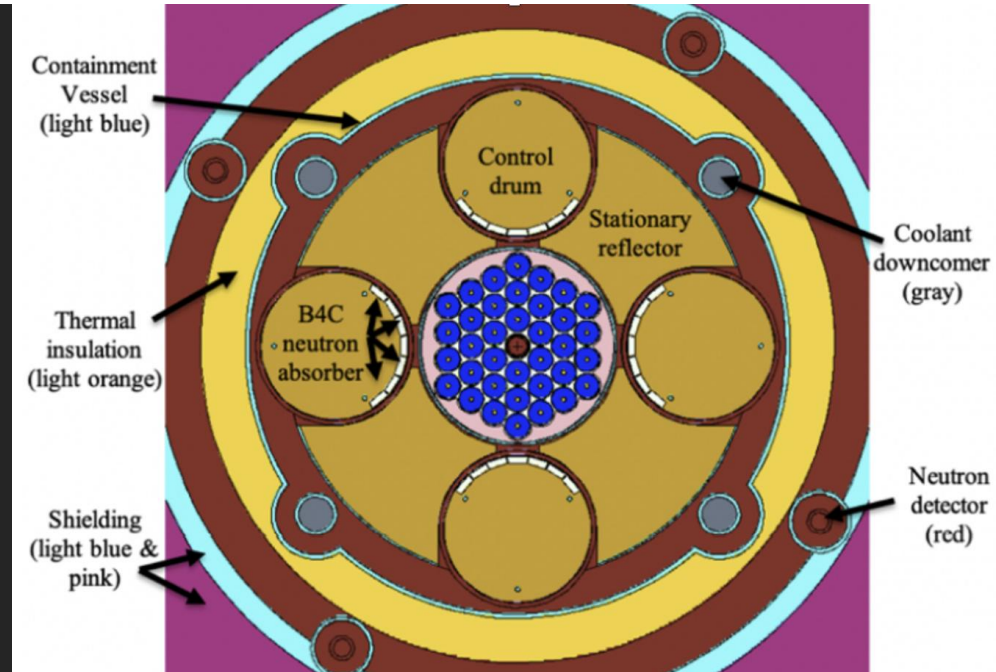
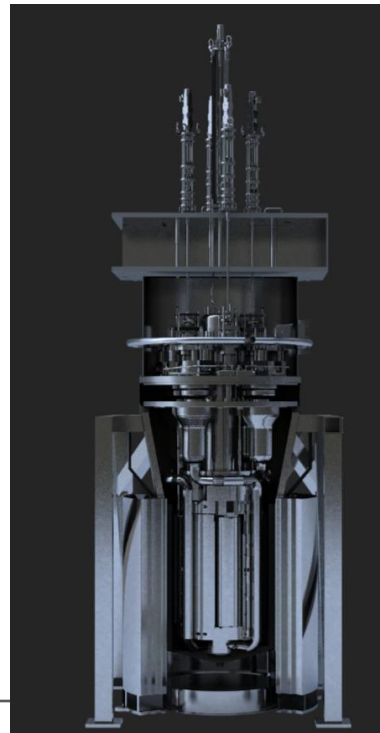
- Multiphysics modeling using Griffin, BISON, SAM and MOOSE SCM
- Recently started efforts on hydrogen migration within the Zirconium-Hydride fuel
- Thermal-Hydraulic data available from cooling apparatus experiment.

- Accomplished

- Ongoing



KRUSTY 15C and 30C Reactivity Insertion Tests



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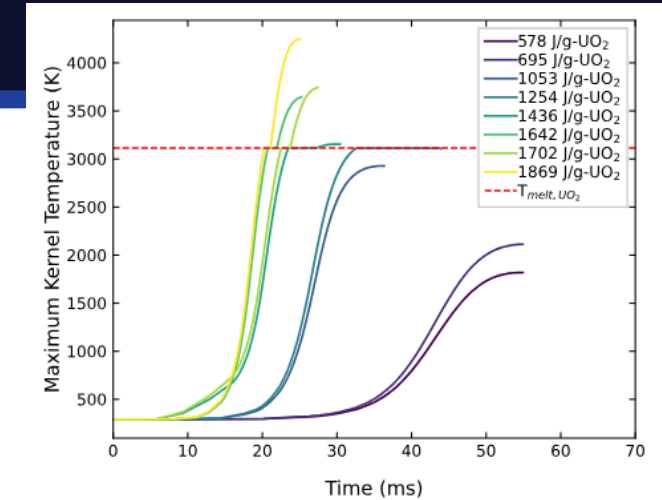


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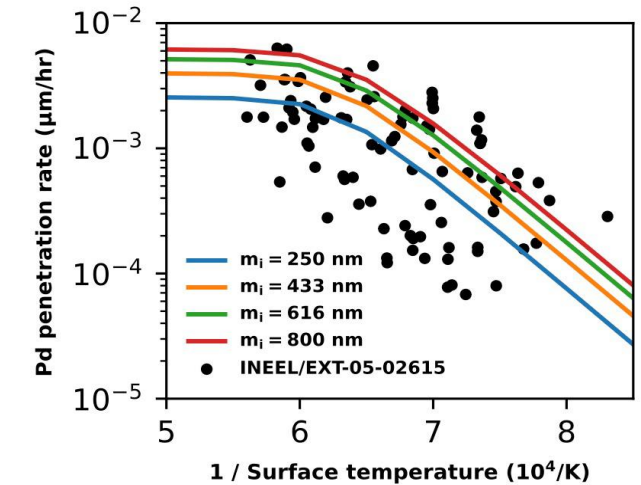
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NEAMS Fuel Performance

- TRISO (UCO)
 - Assessments on TRISO transient experiments & separate effects tests
 - Pd-SiC penetration model high-temperature expansion and validation
 - Informed by lower-length-scale/mesoscale Pd-Ag-SiC models
 - User-friendly Mortar layer debonding model based on AGR properties with UQ
 - Layer cracking model development, demonstration, and effect analyses
 - Pd transport to SiC, accelerated Pd penetration in SiC, and consequent particle failure



Temperature Prediction (NSRR Transient)



Pd Penetration (model vs. legacy data)

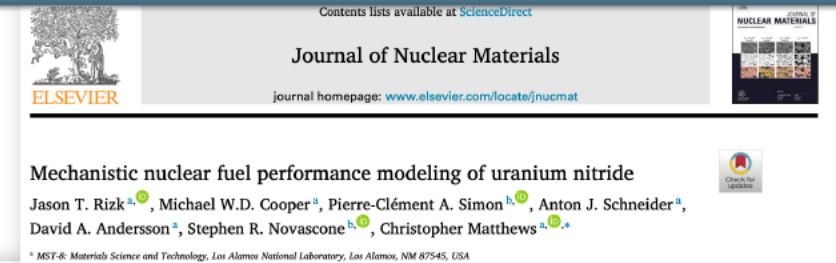
- Accomplished
- Ongoing



NEAMS Fuel Performance

- Uranium Nitride
 - Baseline capability for UN swelling during steady state and transients
 - Informed by lower-length-scale models
 - Completed model set + assessment cases
 - Baseline model and behavioral model refinement to support TRISO applications
 - Preliminary assessment case for modern TRISO particles with UN kernels
 - Mechanistic model for impurity effects in uranium nitride swelling model

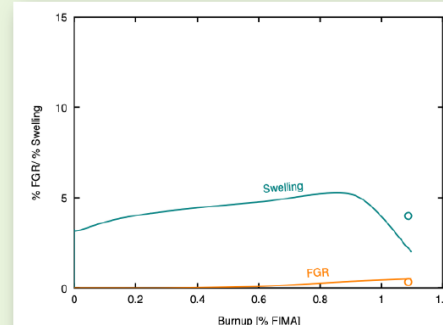
Uranium nitride capable BISON ready for external users



Continuing work focused on 1) chemistry dependence, 2) porosity dependence, and 3) application to TRISO

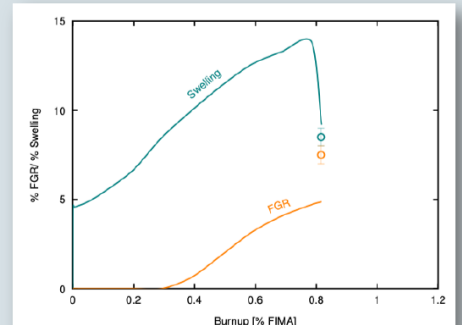
SNAP50-57-672 (MTR)

- Model with best historical data
- Temperatures [K]: 1430, 1500 (avg, max)
- Fsnrates [fsn/m³/s]: 1-1.5x10¹⁹ (avg, max)



SP1 (EBR-II)

- Model with best historical data
- Temperatures [K]: 1800, 2050 (avg, max)
- Fsnrates [fsn/m³/s]: 3-3.3x10¹⁹ (avg, max)



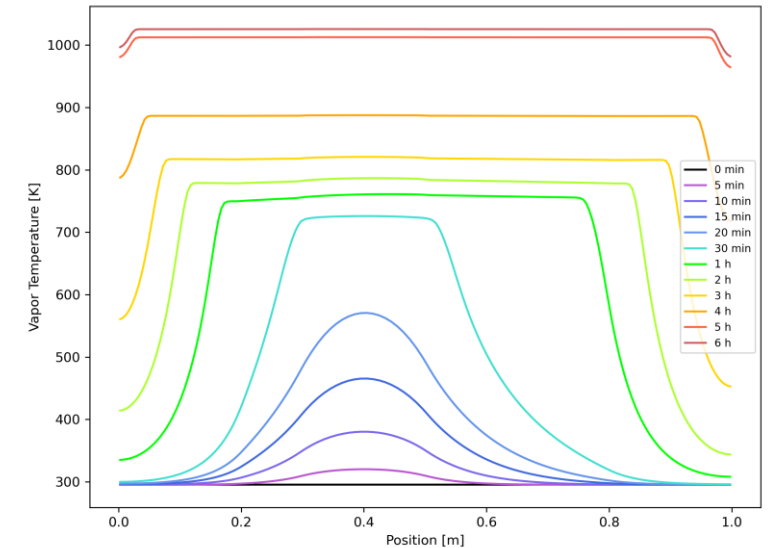
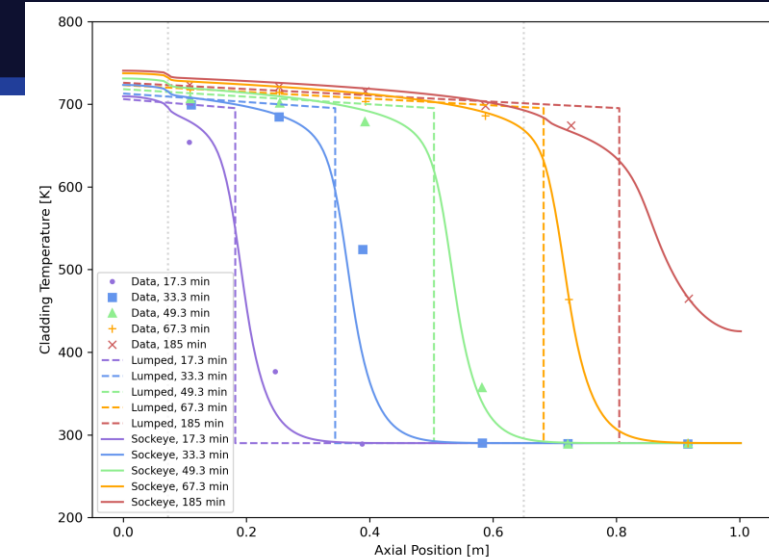
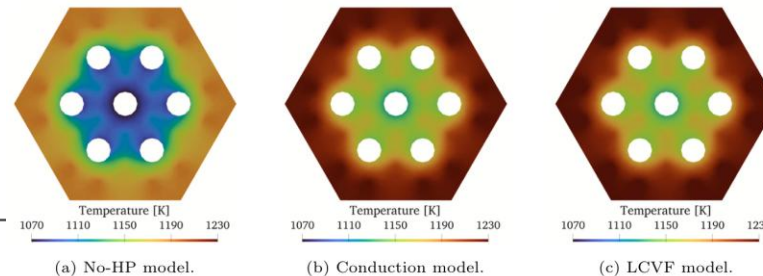
Combined Assessment Cases with Same Parameters

- Accomplished
- Ongoing



NEAMS Thermal Fluids

- Robust and accurate heat pipe frozen startup
- Developed and implemented non-condensable gas capability
- Heat pipe model validation:
 - Ulsan National Institute of Science & Technology
 - University of Wisconsin-Madison
- Publications:
 - J. Hansel, J. Ortensi, M. Jaradat. Studies of the influence of heat pipe model and coupling strategy in heat pipe microreactor simulations using Sockeye (2025). Annals of Nuclear Energy 224. No 111694.
 - J. Hansel et al. Modeling a Sodium Heat Pipe Experiment at SPHERE Using Sockeye (2025). NURETH-21. Busan, South Korea.
 - J. Hansel and L. Charlot. Modeling Heat Pipe Startup and Noncondensable Gases in Sockeye (2025). Idaho National Laboratory. INL/RPT-25-85650.



NEAMS Reactor Physics

Goal: Develop and deploy codes for modeling **neutral particle transport** and **nuclide depletion/decay**

- **MPACT:** Light water reactor (LWR) 2D/1D multigroup (MG) transport solver (ORIGEN depletion)
- **Griffin:** non-LWR MOOSE-based reactor physics code (internal depletion solver)
- **Shift:** LWR and non-LWR Monte Carlo (MC) reactor physics code (ORIGEN depletion)

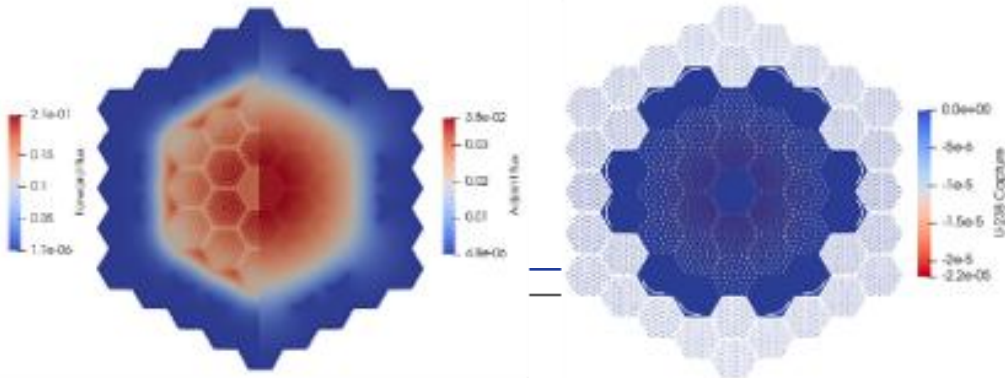
Deployed Capabilities in Shift and Griffin for Microreactors

- *Griffin* diffusion and Sn radiation transport solvers with nuclide depletion and online self-shielding
- Standalone *Shift* MC reference solutions including ex-core shielding
- Two-step neutronics workflow for *Shift-Griffin* calculations

NEAMS Reactor Physics

FY25 accomplishments

1. Started on *Griffin* reactivity and sensitivity evaluations using fast reactor problems, preliminary tests using Empire
2. Deployed transport optimizations in *Griffin* for ex-core shielding calculations using TREAT
3. Deployed improvement of *Shift* calculation of scattering cross sections for trace nuclides



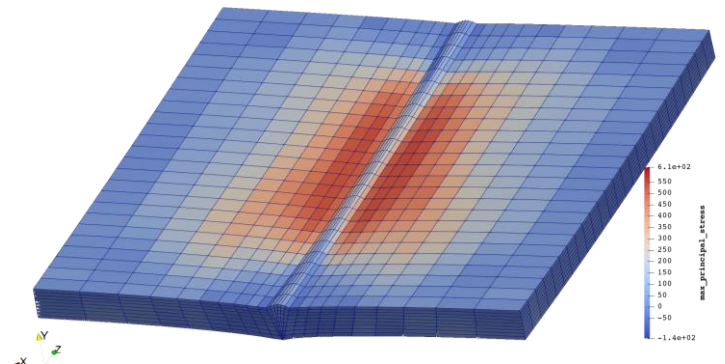
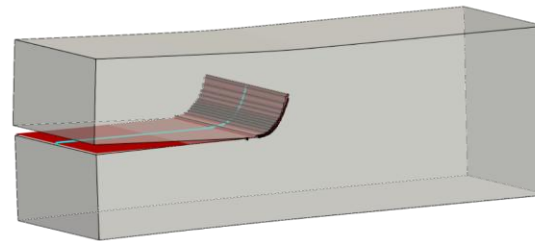
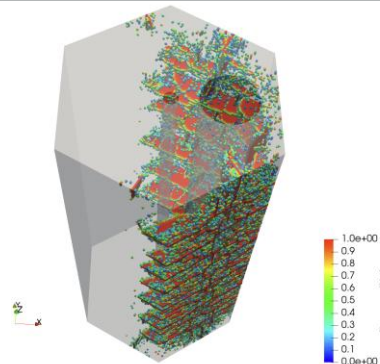
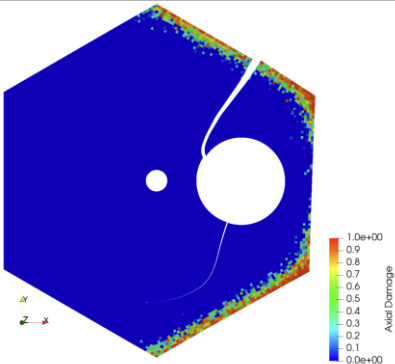
Current and future work

1. Recent memory and speed improvements to *Griffin* Sn solver (both CPU and GPU based) are enabling more common use of heterogeneous models
2. Continue testing *Griffin's* online cross section generation capability for multiphysics transients
3. Start on *Griffin-Shift* workflows for ex-core reference calculations and verification benchmarks specific to micro-reactor shielding analyses
4. Start on automated *MOOSE-to-Shift* reference solutions

NEAMS Structural Materials & Chemistry

FY25 Accomplishments

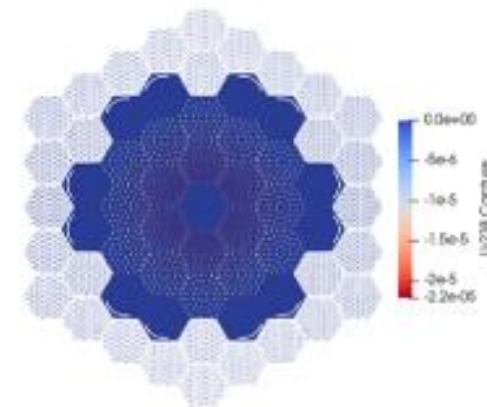
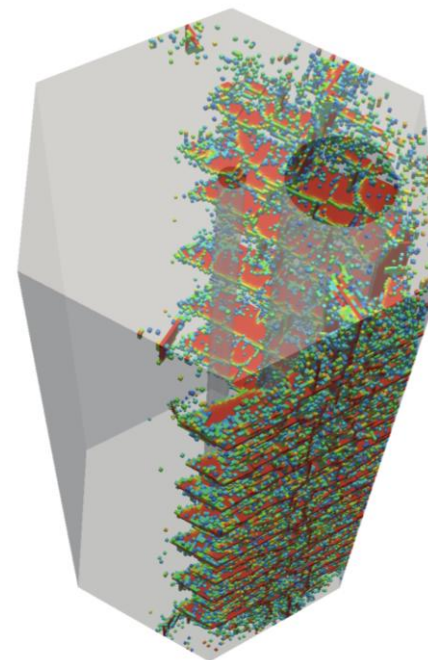
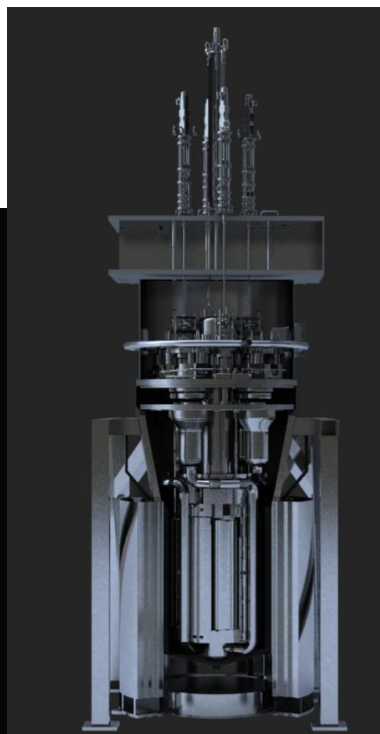
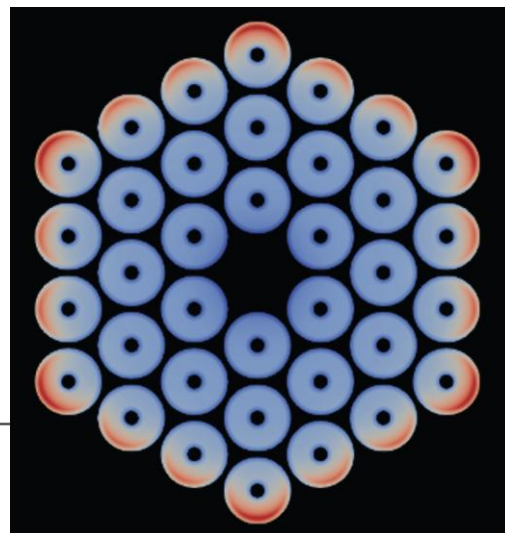
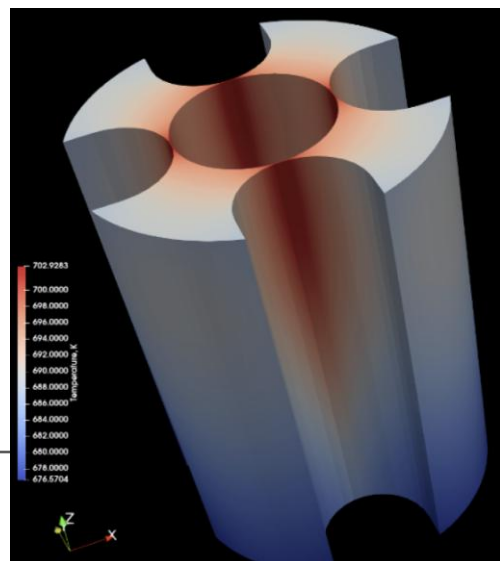
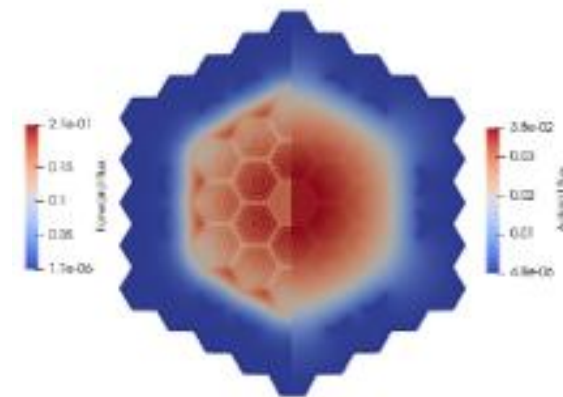
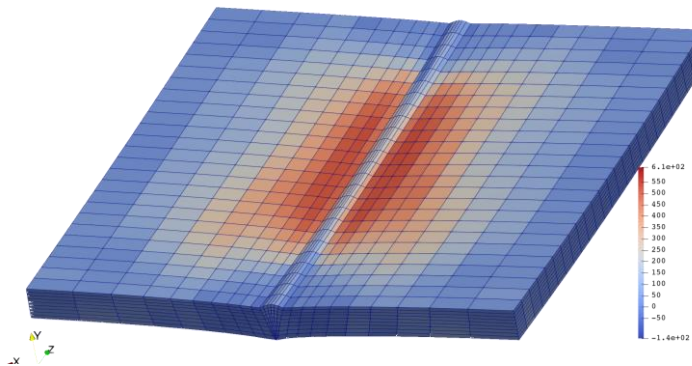
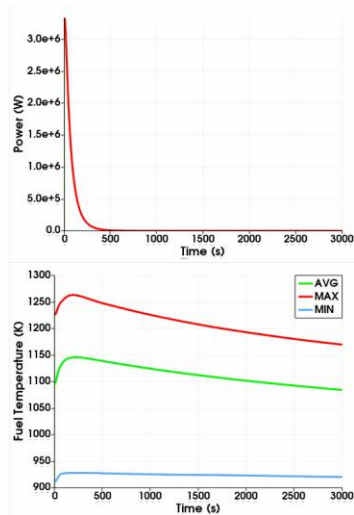
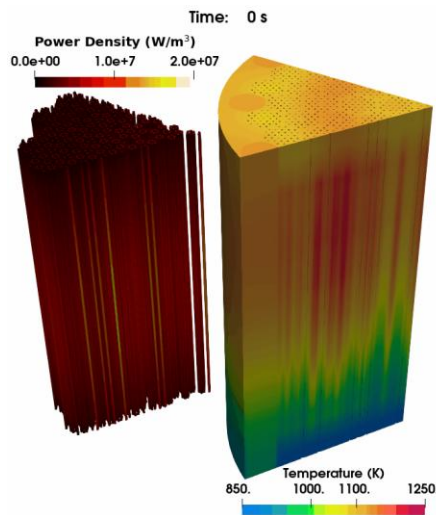
- Bayesian calibration of irradiated graphite models (thermal, mechanical, irradiation) for high temperatures
- NEML2 integration in MOOSE for GPU enabled material modeling: Implementation of updated grade 91 LAROMance model
- Stress Corrosion Cracking XFEM capability
- Alloy 709 creep/thermal aging model development and qualification.



Current and Future work

- Demonstration of stress corrosion cracking XFEM analysis of welded component
- Efficient Cluster Dynamics implementation in MOOSE through stand-alone coupling and MOOSE implementation
- Update Bayesian calibration of Grizzly graphite models and component level demonstration of forward uncertainty quantification
- Expand use of Lagrangian kernels in MOOSE for large deformation simulations







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