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GCR Methods Area Overview & International Collaborations

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ART-GCR Methods lead

GCR Methods Area Overview & International Collaborations

Experimental Validation, Reactor analysis, International Collaborations

ART Advanced Reactor Technologies
GAS-COOLED REACTORS

Contributors

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- **ANL**
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- **Universities**
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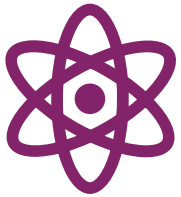
Content

Methods Experimental Validation - New-generation tools (e.g., BISON, Griffin, Pronghorn) have advanced capabilities that requires high-quality/high-fidelity experimental data (including uncertainty information) for validation purposes: HTTF benchmark activities. NSTF data generation for validation. HTGRs related NEUPs



Reactor analysis - Development of integrated methodologies to test new tools capabilities for HTGRs specific needs: Develop and integrate start-up, running-in and equilibrium core calculation methodologies.

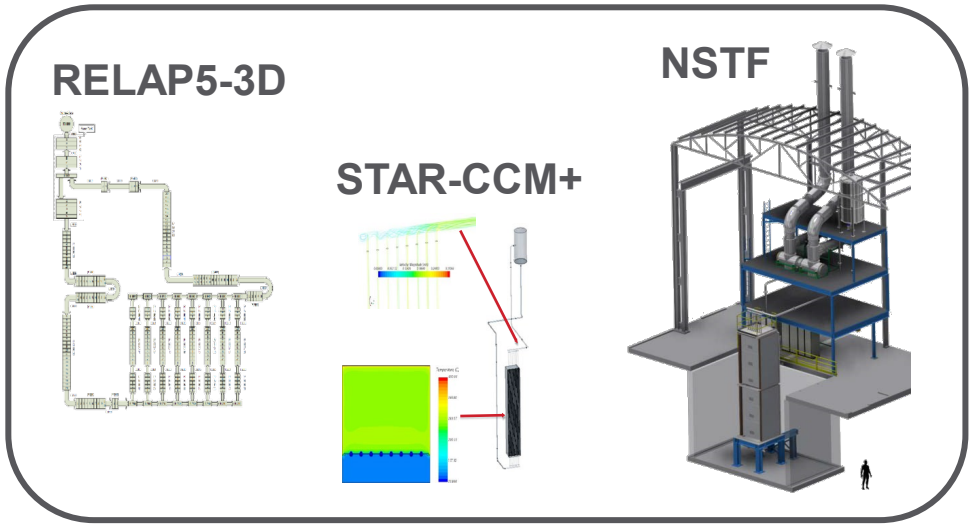
Reduced order models generation for optimization and UQ

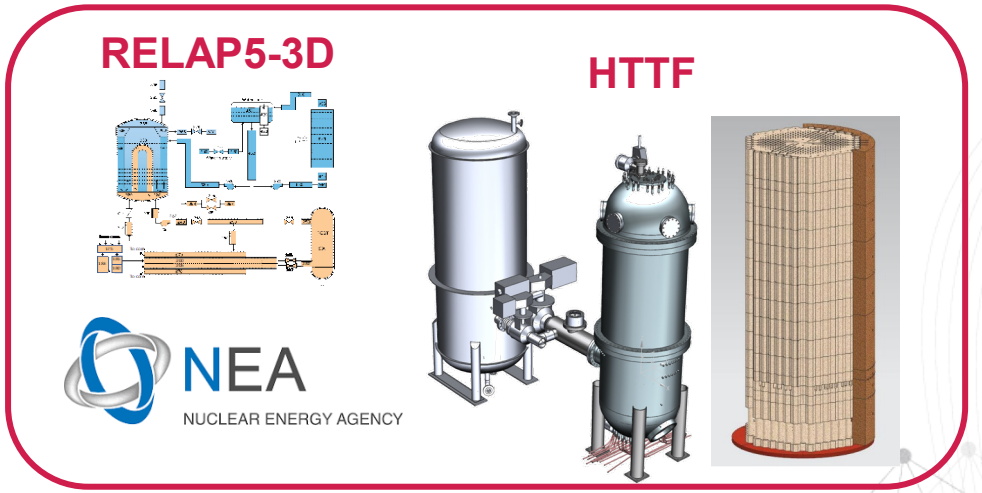
International collaborations - Leveraging international collaboration to obtain data for validation: 5 WPs part of the GIFIV Forum agreement.

New data from the FY22 experiments will be available trough the Civil Nuclear Energy Working Group Collaboration with Japan. The new data will be used to continue the HTTR model validation effort using NEAMS tools.

Methods Experimental Validation

- **Natural Convection Shutdown Heat Removal Test Facility (NSTF) experiments:**
  - **1/2 scale axial height** of a typical full sized gas cooled reactor → **Framatome 625 MWt** Steam Cycle High-Temperature Gas-Cooled Reactor SC-HTGR
  - **Top level objectives** of NSTF program: Confirm the performance of the next generation nuclear plant reactor cavity cooling systems (RCCS) based on passive safety; Generate NQA-1 qualified licensing data for industry; Provide benchmark data for code V&V.
  - **Parallel modeling and simulation activities** using CFD and System codes to support validation, design modifications and experimental activities preparation**.**
  - With successful conclusion of **air-based** (**completed**, FY13 - FY16) testing, program has shifted to a **water-based** operation (**on-going**, FY18 to present) of the existing test facility.
  - The experimental campaign will run for the **next years** investigating normal and off-normal RCCS conditions in support of gas cooled reactor vendor V&V efforts.
- **High Temperature Test Facility (HTTF) Benchmark:**
  - ¼ scale of General Atomics' modular high-temperature gas-cooled reactor Helium cooled, electrically heated, prismatic blocks made of Alumina, Over 500 instruments, designed primarily to investigate phenomena occurring during depressurized (DCC) and pressurized (PCC) conduction cooldown transients
  - The benchmark will include PG-26 and PG-27 (respectively symmetric PCC and DCC) data for validation of System code and CFD tools - 3 exercises.
  - The experimental campaign is concluded, the benchmark specifications draft will be finalized FY22/beginning of FY23, the benchmark will run for at least for the next 3y.
  - Benchmark has interest from industry, academia, and labs around the world
  - RELAP5-3D validation activities based on HTTF have shown an ability to reproduce trends in the HTTF data, but reproducing specific HTTF values is a challenge
    - This is consistent with other HTTF validation analyses in the literature
  - This work will accelerate the deployment of prismatic HTGR microreactors by providing an opportunity for designers to assess their codes against experimental data and solutions from other codes





Task	FY23		FY24		FY25		FY26	
NSTF Experiments								
HTTF Benchmark								

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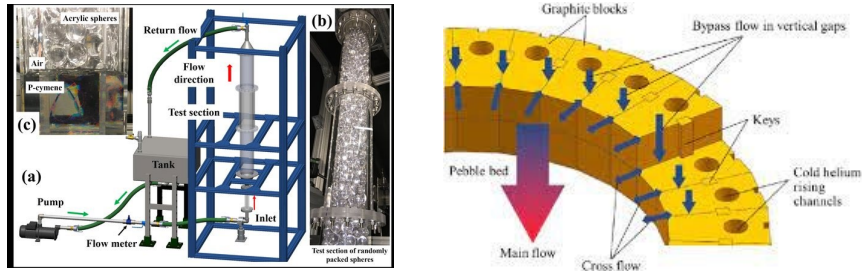
Methods Experimental Validation

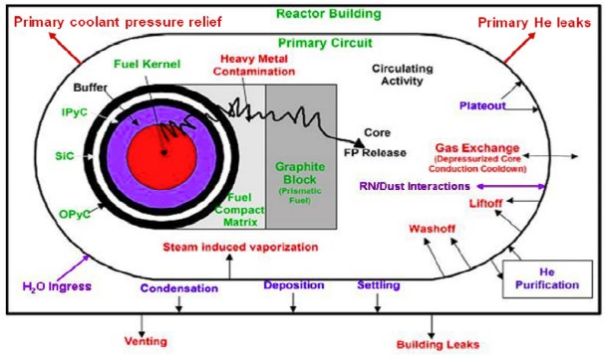
- NEUP - Experimental Investigations and Numerical Modeling of Near-wall and Core Bypass Flows in Pebble Bed Reactors

- NEUP - Experimental Investigations of HTGR Fission Product Transport in Separate-effect Test Facilities Under Prototypical Conditions for Depressurization and Water-ingress Accidents

Facility **Modeling**

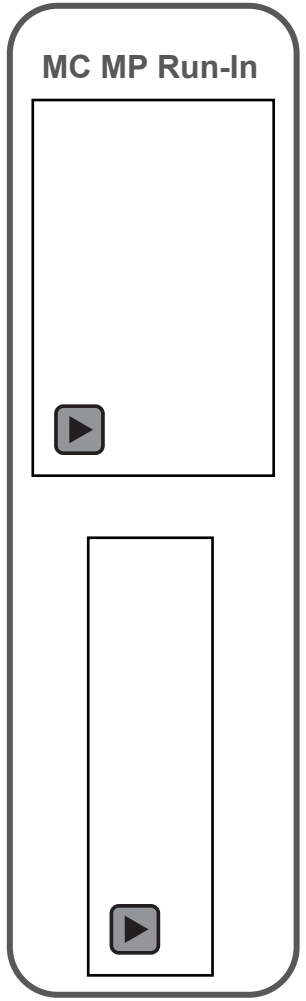


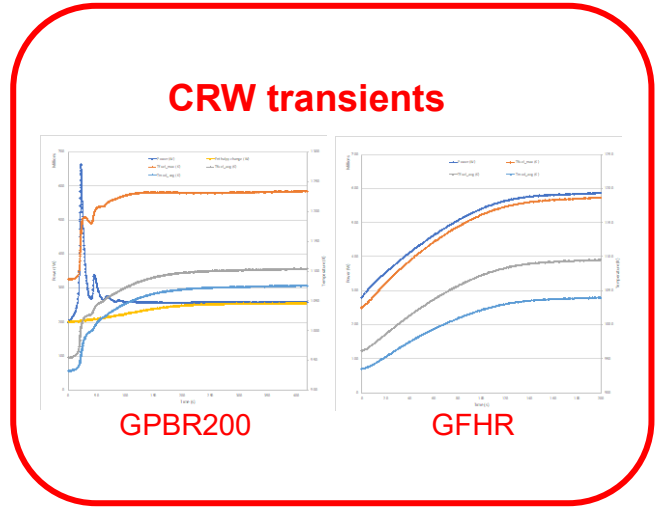
Facility **Modeling**

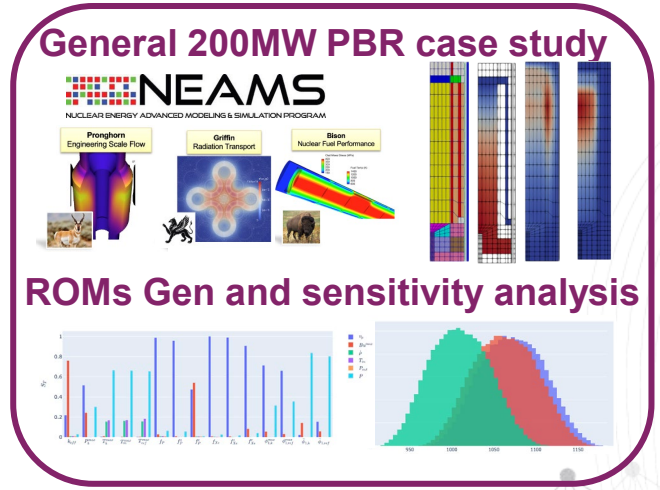


Methods Reactor Analysis

- **Monte Carlo based running in methodology integration:**
  - This approach use **existing Monte Carlo codes** and **remove completely the difficult cross-section generation** stage for pebble bed reactor running in calculations.
  - The pebbles can be modeled explicitly defining and random distribution with **real local packing fractions**
  - FY22 prototype has been developed assuming simplified temperature profiles and criticality search procedures; FY23 the methodology will inform simplified multiphysics models developed using NEAMS tools to get appropriate control rod position and temperature feedback. FY24 possibly will be dedicated to improve and standardize the procedure for external users.
- **Reduced order model development for optimization studies and uncertainty propagation:**
  - **Optimizing** Equilibrium core design and running in procedures is currently **challenging** using **conventional tools**.
  - Training **Reduced Order Models** (e.g. Neural Networks, Polynomials) selected based on the results behavior will provide a **fast running and accurate** tool for optimization studies and uncertainty quantifications.
  - During FY22 the methodology to generate ROMs has been applied to equilibrium core calculations, studying economics and performance of the reactor, during FY23 safety related parameters will be considered simulating DBAs after reaching the equilibrium core, during FY24 ROMs for running in scenarios will be generated FY25-26 uncertainty propagation analysis will be performed using the generated ROMs.
- **TRISO fuel performance study during Control Rod Withdrawal accidents:**
  - Two reactor models using TRISO fuel: GPBR200 and GFHR. Generic Models developed by NEAMS and ART.
  - Equilibrium core conditions calculated using Griffin Pronghorn new features.
  - Realistic withdrawal from critical position at full power for both the reactors.





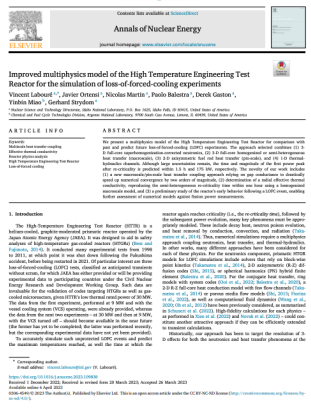


Task	FY23		FY24		FY25		FY26	
Running in, Equilibrium core capabilities								
ROMs generation for Optimization studies								
Modelling assumption verification trough high fidelity simulations								

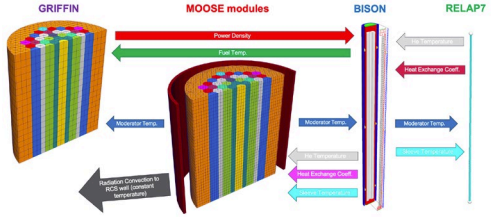
International collaborations

- **High Temperature Test Reactor (HTTR) Loss of Forced Cooling (LOFC) Benchmark:**
  - **30MW Gas cooled prismatic reactor** capable of reaching **950℃ (Max.)** of helium outlet temperature at 4.0MPa.
  - The experimental campaign was **interrupted in the 2011**, the only test performed so far was a **9MW LOFC** scenario with the Vessel Cooling System (VCS) activated.
  - The data have been collected in an **NEA international benchmark** HTTR LOFC benchmark.
  - The reactor **restarted operation in the FY22** and a **new test** has been performed **30MW LOFC** scenario with the Vessel Cooling System (VCS) activated.
  - The LOFC Test#3 data have just been shared, Test#2 (LOFC full power VCS on) planned for the end of CY23.
- **Civil Nuclear Energy Research and Development Working Group (CNWG) US and Japan bilateral agreement:**
  - From January 5 to March 21, 2010, JAEA operated the HTTR ramping the reactor power from zero to full power and back to zero in 1800h.
  - Although the focus of the experiment was tritium measurement other reactor parameters such as fluid temperatures and Control Rod (CR)s positions were recorded.
  - The model developed using NEAMS tools for the LOFC experiment will be modified adding CR explicit modelling and used to simulate the power ramps
  - A MELCOR model of HTTR will be developed to simulate production and transport of TRITIUM within the reactor.
  - #1 Extension of the multiphysics NEAMS model validation range to startup and shutdown conditions.
  - #2 Validation of TRITIUM production and transport modelling in MELCOR for high temperature reactors.

Task	FY23		FY24		FY25		FY26	
HTTR LOFC Benchmark								
US/Japan - CNWG								?

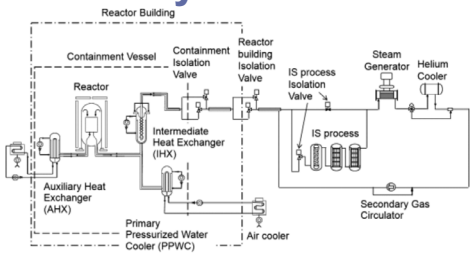

Annals of Nuclear Energy

Improved multiphysics model of the High Temperature Engineering Test Reactor for the simulation of loss-of-forced-cooling experiments

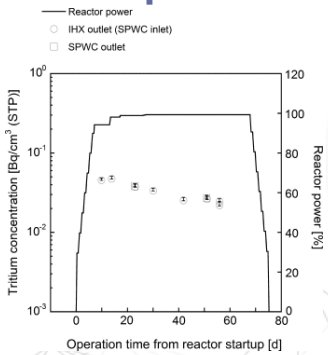


NEAMS tools (GRIFFIN, BISON, RELAP7) Model

HTTR systems



Power ramp transient



MELCOR NEAMS NUCLEAR ENERGY ADVANCED MODELING & SIMULATION PROGRAM

Dipu, Arnoldus Lambertus, et al. "Assessment of amount and concentration of tritium in HTTR-IS system based on tritium behavior during high-temperature continuous operation of HTTR." Annals of Nuclear Energy 88 (2016): 126-134.

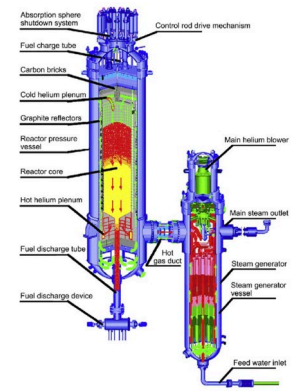
International collaborations

- **GIF Very High Temperature Reactor – Computation Methods Validation and Benchmark (VHTR-CMVB):**
  - **Several participants** including the following signatories: Korea Atomic Energy Research Institute (KAERI) for the Republic of Korea, Institute of Nuclear and New Energy Technology of Tsinghua University (INET) for China, U.S. Department of Energy (DOE) for the United States (U.S.), Joint Research Centre (JRC) for EURATOM, Japan Atomic Energy Agency (JAEA) for Japan.
  - **U.S. is leading 3 out of the 5 WPs** and oversees subtask in all the WPs.
  - U.S. will likely sign the agreement within the FY22 (all the other members signed between 2020 and 2021) so that activities will **start on FY23**
  - The agreement involve 5 WP that in total require 7y of work after all the members signatory accordingly to the schedule suggested on the project specifications.

GEN IV International Forum
Expertise | Collaboration | Excellence

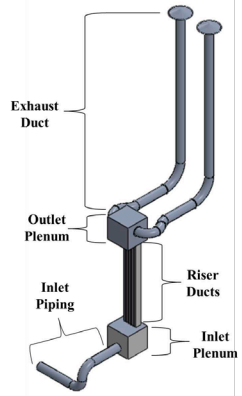
VHTR
C-PIRT

HTR-PM

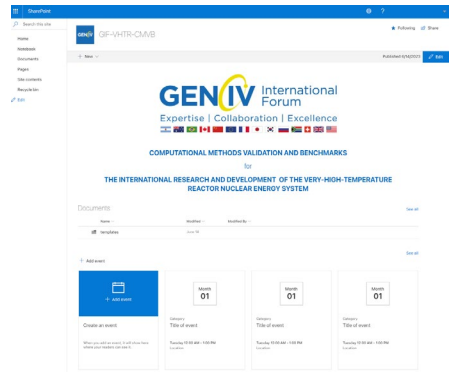


HTR-PM

Air-Cooled RCCS University of Wisconsin and NSTF



SharePoint



Task	FY23		FY24		FY25		FY26	
GIF VHTR-CMVB								

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FY23 External Collaborations and Editorial Production

NEUPs

- TAMU - High-fidelity, data science-informed pebble-bed reactor simulator - **ongoing**
- OSU - Progression of High-Resolution SET and IET Benchmarks on PCC and DCC events in HTGRs - **ongoing**

ARDPs, iFOA, Other Programs

- iFoa X-energy Neutronics Support Analyses for the Xe-100. Licensing Baseline – **finalized FY22**
- ARDP X-energy for NQA1 Xe-100 model generation, and new ACE data file cross sections – **starting end of FY22**
- NEAMS HTGRs Multiphysics.
- NRIC VTBs
- ASME – **VVUQ** for nuclear engineering applications recommendations.

LDRDs

- **New approach** for code **validation** demonstration using HTGRs experimental data FY23-24
- Long term **pebble storage** studies using NEAMS tools FY23-25

PhDs and Articles

- **Three** Ph.D. students currently working in the Methods area.
- **>Nine** Conference papers on different areas (NURETH19, PHYSOR2022, ANS Annual & Winter meeting,…)
- **>Four** Journal papers on the way by the end of the FY.

Thanks for your attention…
Questions?