INL/MIS-22-66535-Revision-0

# US NIC MFC Tour Posters

April 2022

Changing the World's Energy Future

Stephen R Grabinski, Gregory M Core, Christopher S Ritter, Abdalla Abou Jaoude, Samuel Matthew Reiss, Toni Y Karlsson, Stephanie G Weir, Trina M Davis

Idaho National Laboratory

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**April 2022**

**Idaho National Laboratory**
**Idaho Falls, Idaho 83415**

**http://www.inl.gov**

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

# NRIC Applications of Digital Engineering

Accelerating Nuclear Capability Development through Digital Engineering

**Guiding Principles**
Minimal impact
Ease of use/access
Cost savings
Time savings

**Capabilities of Interest**
Digital threads
Digital twins
Automation
Collaboration

**Domains**
Regulatory compliance
Model-based system engineering
Engineering change management
Computer-aided design documents
Requirements management
Verification and validation

**Digital Architecture**
Datalake (Deep Lynx)
Ontology (DIAMOND, AMBER)
User Interface
Microservice-based
Open source


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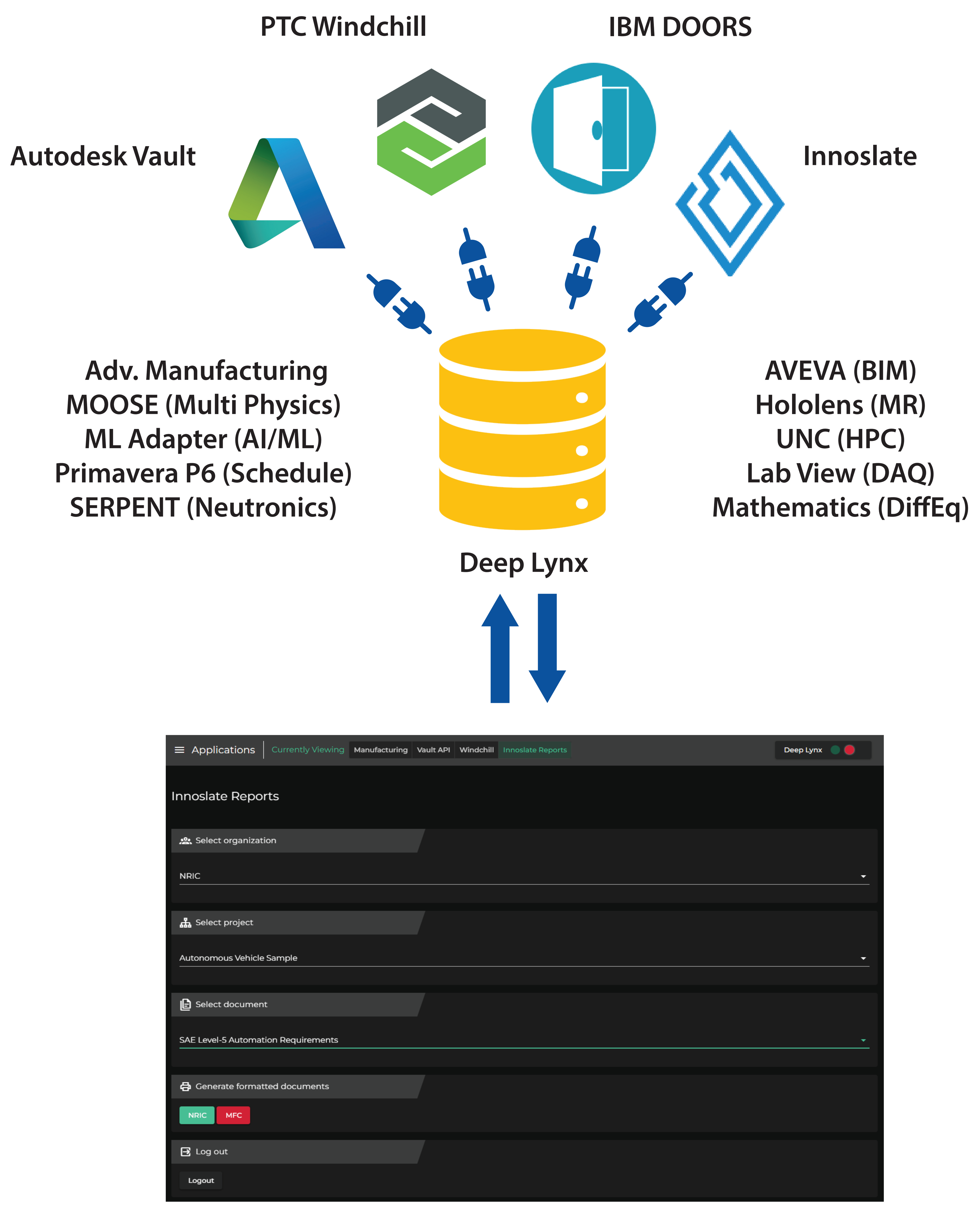



User Interface

**Autodesk Vault Adapter**
Exposes Windows SOAP services to a traditional HTTP REST API. CAD & metadata read access

**PTC Windchill Adapter**
Allows read and write functions for documents and metadata to a Windchill instance

**IBM DOORS Adapter**
One-way ingress of requirements to Deep Lynx

**Innoslate Adapter**
Allows Deep Lynx to both read and write requirements to/from Innoslate

**Reports Generator Application**
Structured data can be exported into formatted, org-compliant Word documents

**File Tracing Application**
Reference creation between CAD drawing elements to MBSE data in Deep Lynx

**Windchill Automation Application**
Creating an automation suite to upload engineering documents into the lab's engineering change management software. Compiles a bulk upload, checks for required EC properties, prompts the user to supplement missing data

# NRIC Advanced Construction Technology (ACT) Initiative

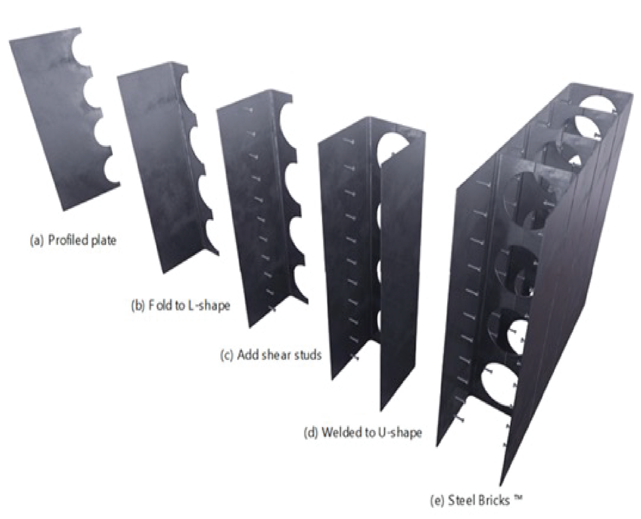
## ACT Goal: Significantly Reduce Costs and Schedule for Nuclear Power Builds

**First Project: Multiyear Cost-Shared Public Private Partnership**
Goal is to Demonstrate 3 high impact technologies in nuclear context

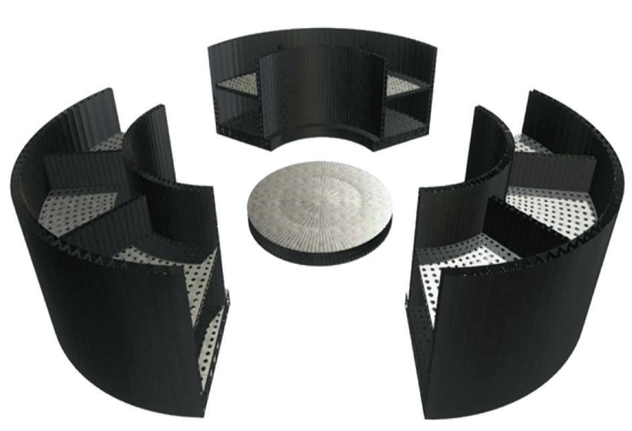
- Vertical Shaft Excavation – reduces excavation and back fill
- Steel Brick™- Steel-Concrete Composite (steel forms fabricated off-site)
- Digital Twin – Sensor and Modeling integration for long-term monitoring

### Phase 1 – 12 months for design, planning, and site selection (70% NRIC 30% GEH - $8.35M)
### Phase 2 – 2.5 to 3 year: demonstrate scaled structure and digital twin

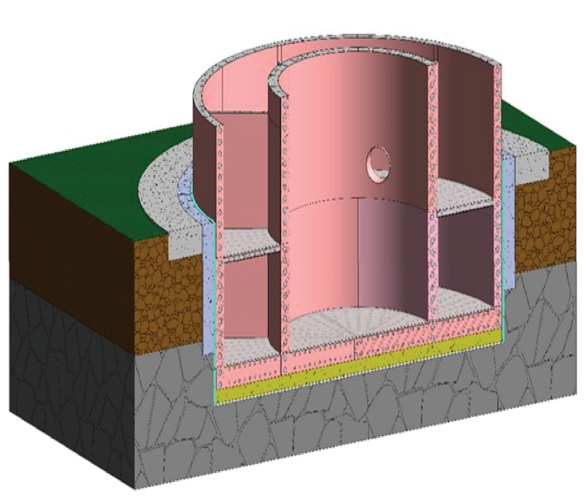
Leverages best practices from the construction industry




Modular Walling Systems Holdings Limited – Steel Brick ™

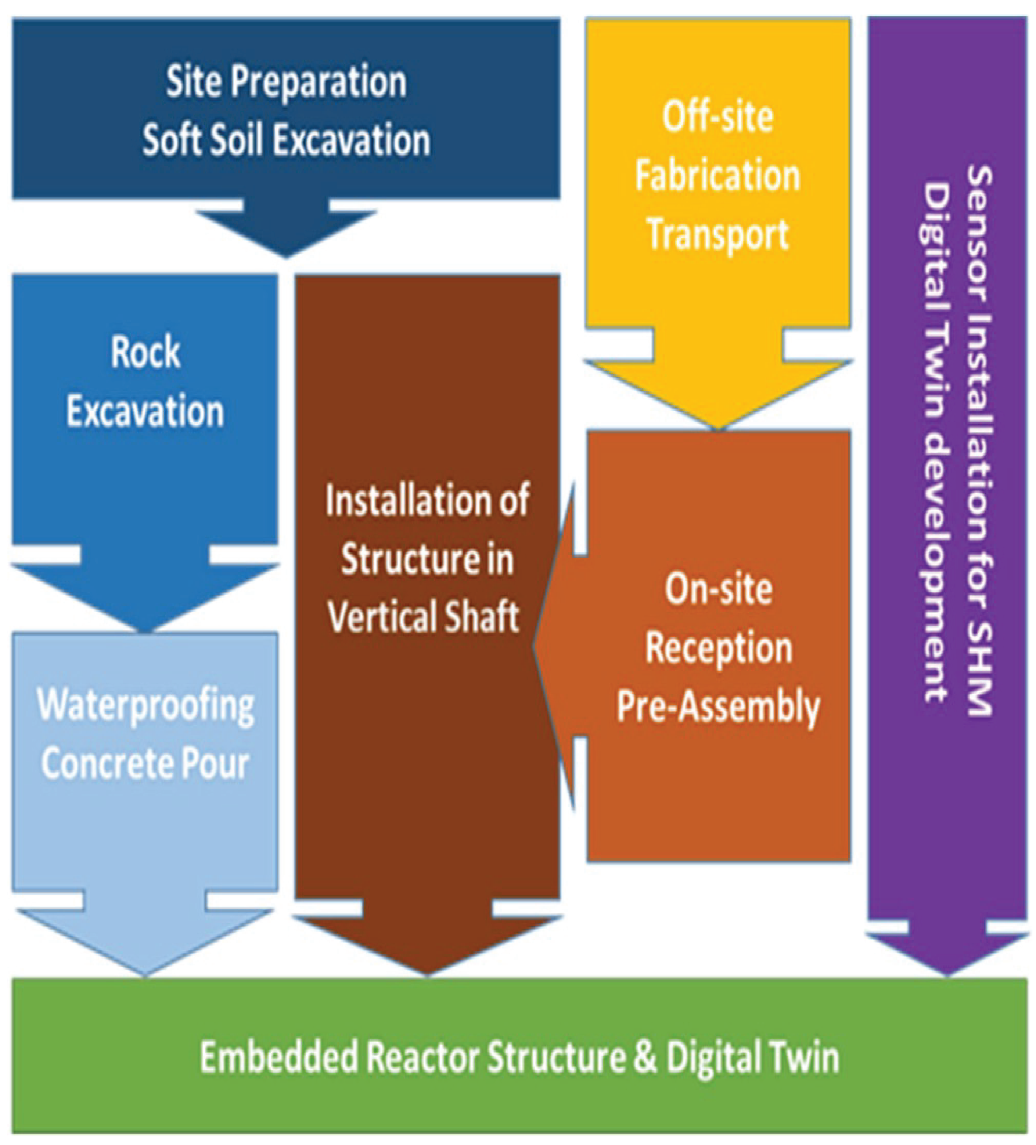


Factory Built Wedge-Shaped Steel Forms Used in Nuclear Energy Construction



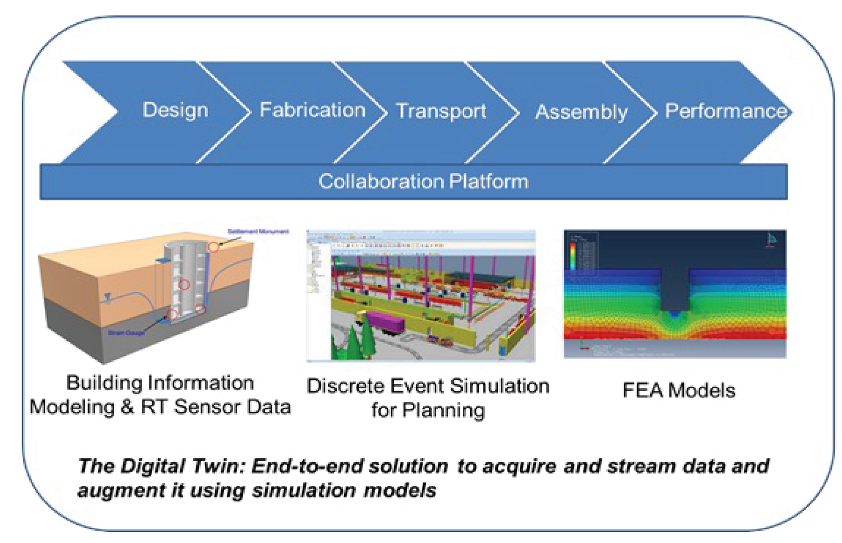
Conceptual design for scaled structure for demonstration

- Shaft diameter: 16 meters; depth: 5 meters
- Height above grade: 2 meters
- Commercial roof will keep structure weather-tight

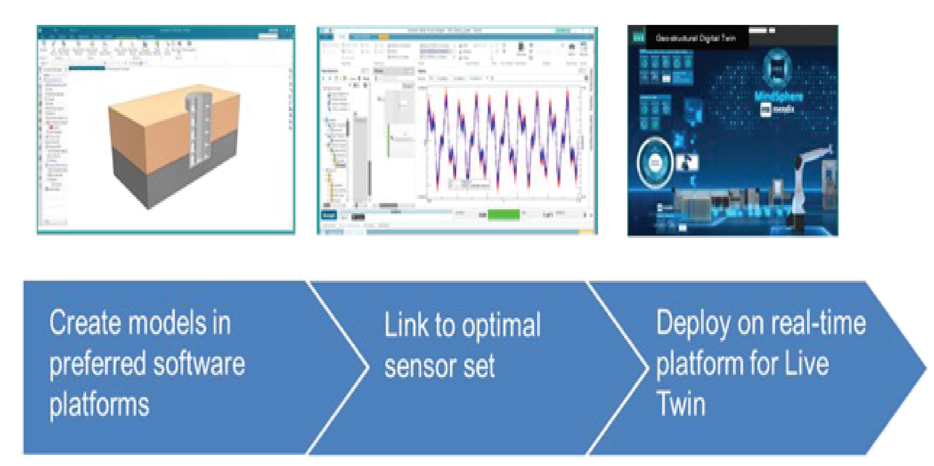



### Project Team:

- General Electric Hitachi Nuclear Energy (GEH) Team Lead
- EPRI – Digital Twin, and NDE techniques
- University of North Carolina @ Charlotte – Digital Twin
- Nuclear Advanced Manufacturing Research Centre (NAMRC) – Advanced Sensors
- Modular Walling Systems Holdings Limited (MWS) – Steel Brick ™
- Purdue University – Steel-Concrete Composite prototype testing
- Black & Veatch – Boring Technology, Construction of Demonstration, Decommissioning Plan, Scaling Prototype, & Site Selection
- Tennessee Valley Authority (TVA) – Industry Partner




The Cradle-to-Grave Digital Twin Approach




### Data Flow From Models to Real-Time Twin Development

During Phase 1, the team will develop appropriate geotechnical models to combine as part of the overall digital twin. One of the prototypes will have a geotechnical model applied during testing. These models will be combined with sensor data during demonstration at Purdue.

| Milestones for RC-22IN020404 Advanced Construction Technology initiative was RC-21IN020407 | Date |
|---|---|
| Award Contract M4-RC-22IN02040411 | 12/16/21 |
| M3 –RC-22IN0204042 ACTi Team Kickoff Meeting with Subcontractor ( met 1/27/22) | 01/31/22 |
| M3- RC-22IN204043 ACT Phase 1 30% Design Review | 05/12/22 |
| M4 – RC-22IN20444 Nuclear Reactors and Construction Standards Report (BV) | 09/15/22 |
| M2-RC-22IN204045 ACT 60% Design Review (GEH) | 09/22/22 |
| M4 – RC -22IN204046 Report on NDE techniques, Test Results, processes and SB lessons learned (EPRI) | 12/06/22 |
| M4- RC-22IN2040410 Select Demonstration Site | 01/03/23 |
| M3- RC-22IN204047 ACT Phase 1 - 90% Design Review (GEH) | 12/08/22 |
| M4-RC-22IN204048 Receive Prototype Lesson Learned Document (PUR) | 12/22/22 |
| M2-RC-23IN204049 ACT Phase 1 Final Design (GEH) | 01/26/23 |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NRIC National Reactor Innovation Center
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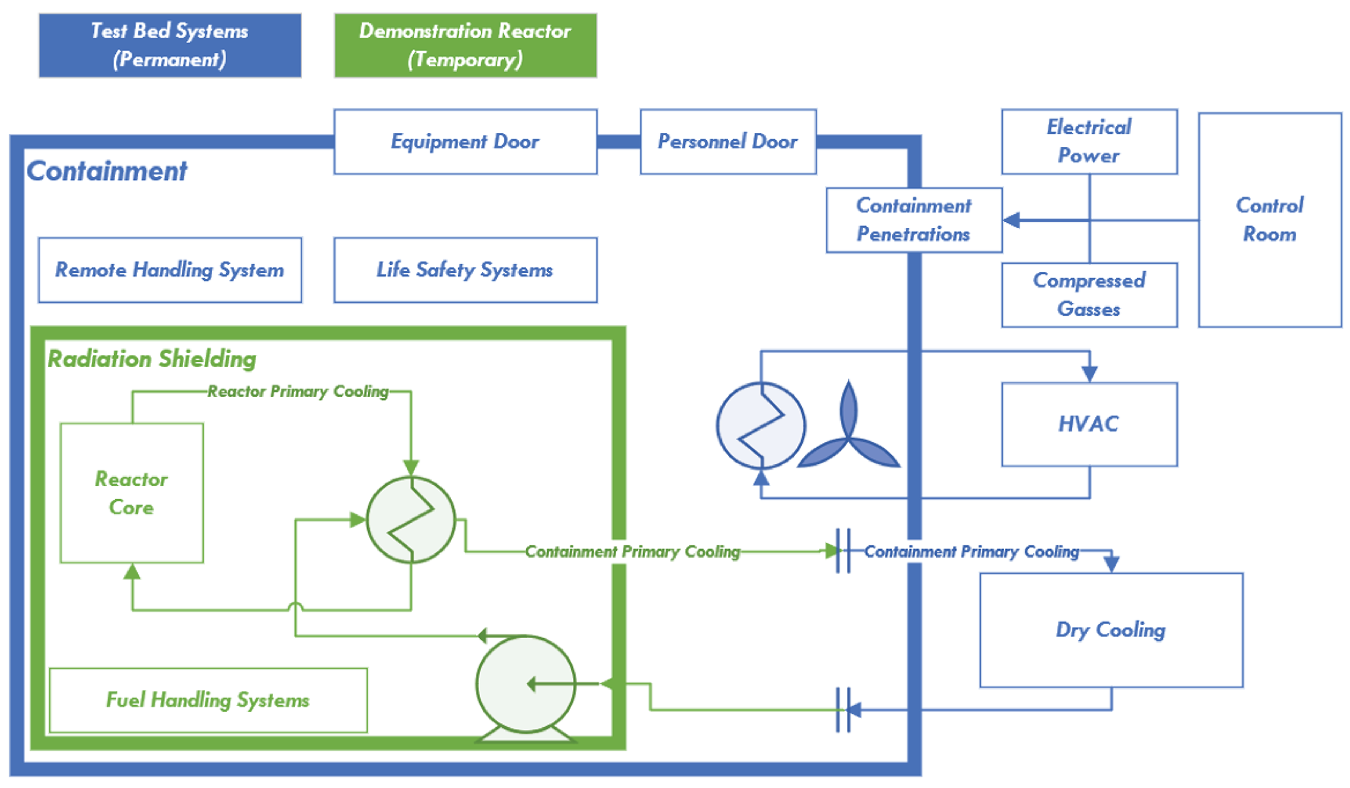
# NRIC *D*emonstration *o*f *M*icroreactor *E*xperiments (DOME) Test Bed

Enabling industry demonstrations is critical to resurgence of U.S. nuclear energy leadership.

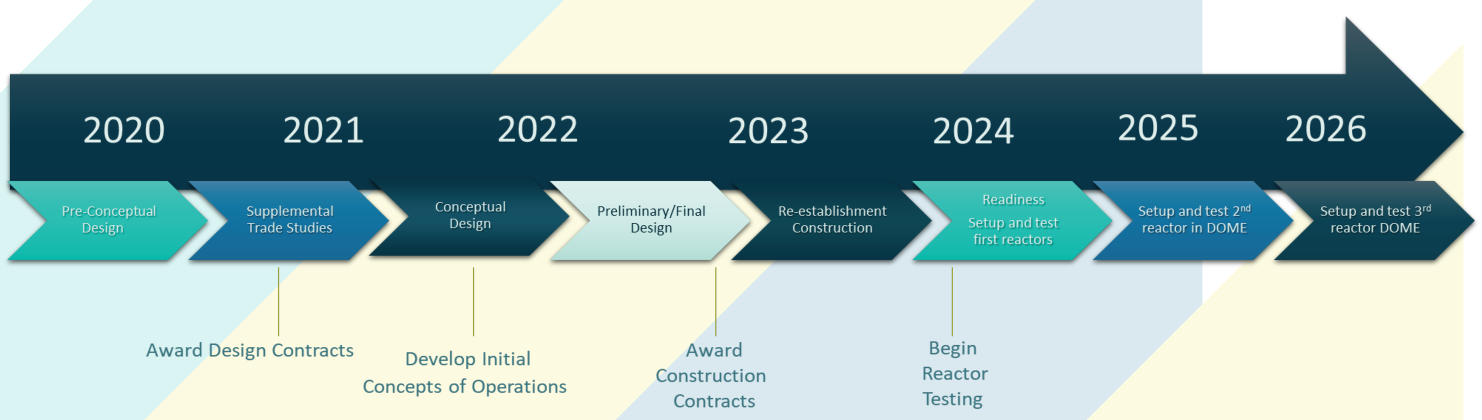
**Overview:**
NRIC DOME restores some of the capabilities of the Experimental Breeder Reactor II (EBR-II) facility and refurbishes it to host advanced reactor demonstrations:
- Advanced microreactors up to 20MWth
- High-Assay Low-Enriched Uranium (HALEU) fuels
- Safety-Significant confinement for reactors to go critical for first time




*Demonstration Reactor Test Bed Concept*

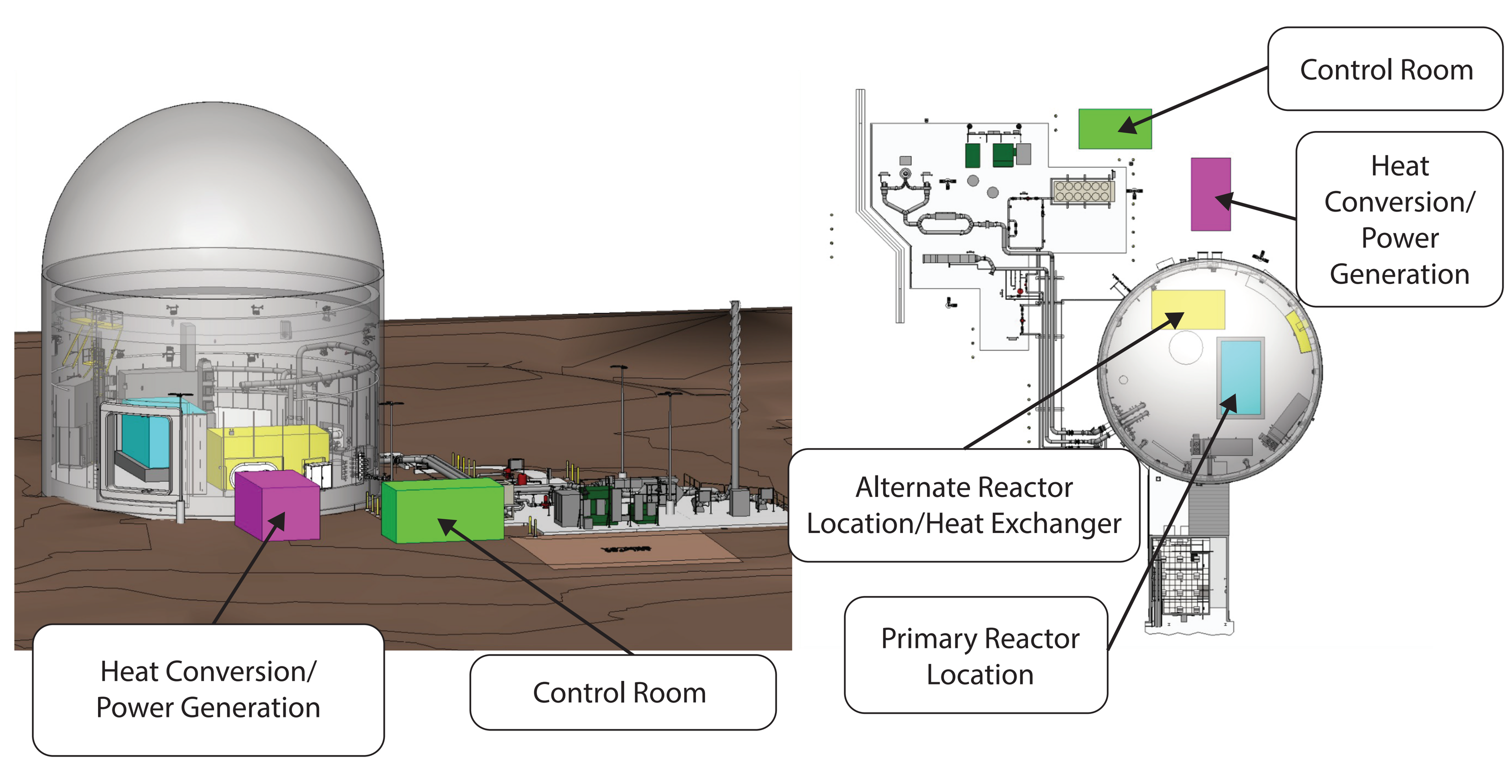
**Total estimated cost of Construction for DOME minimum viable test bed:**
$33M Range: $27M - $49M

**Strategy:**
- Repurpose EBR II which operated from 1964 – 1994:
- Establish a minimum viable test bed that is just flexible enough to test 4-5 known microreactors such as high temperature gas reactors
- Currently five reactor developers interested in testing in the NRIC DOME

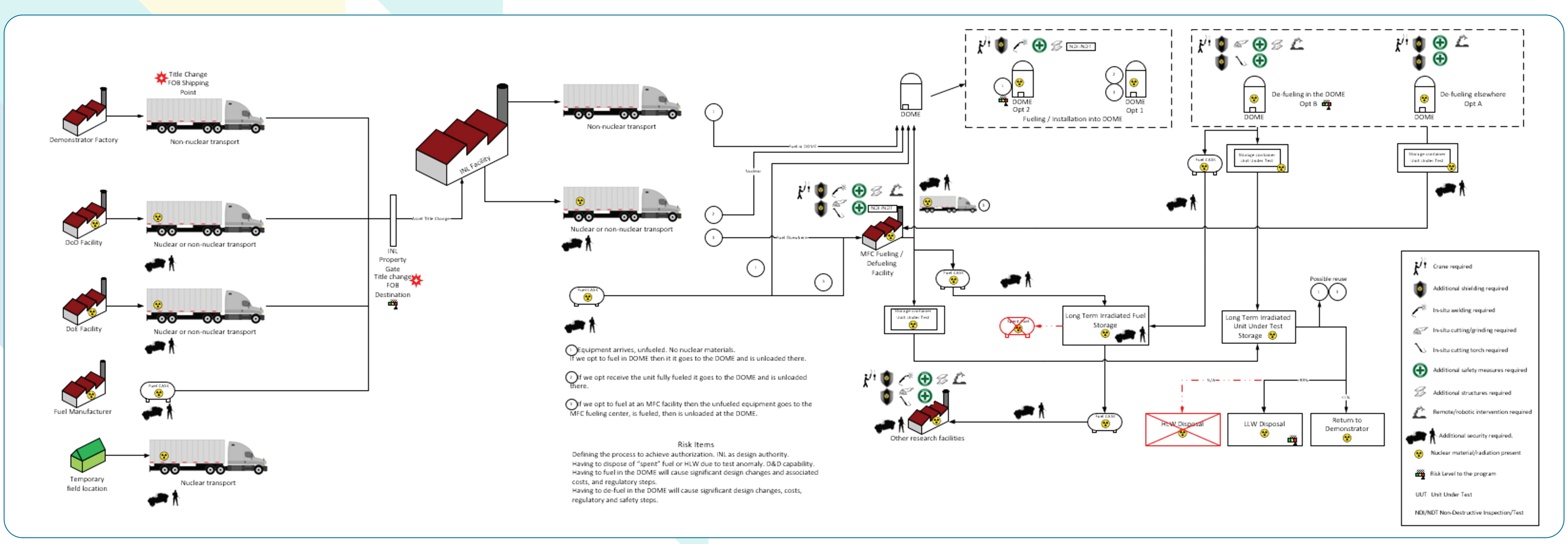



*EBR-II Facility at the Material and Fuels Complex*

**2022 Scheduled Milestones:**
- ✓ Complete Preliminary Design
- Complete Final Design
- Complete auxiliary / Modular shielding conceptual design
- Complete fueling / defueling / PIE equipment / module requirements and preconceptual design
- Complete PDSA
- Prepare Request for Proposal Package




*CAD Models of NRIC DOME Preliminary Design*



*NRIC DOME Concept of Operations*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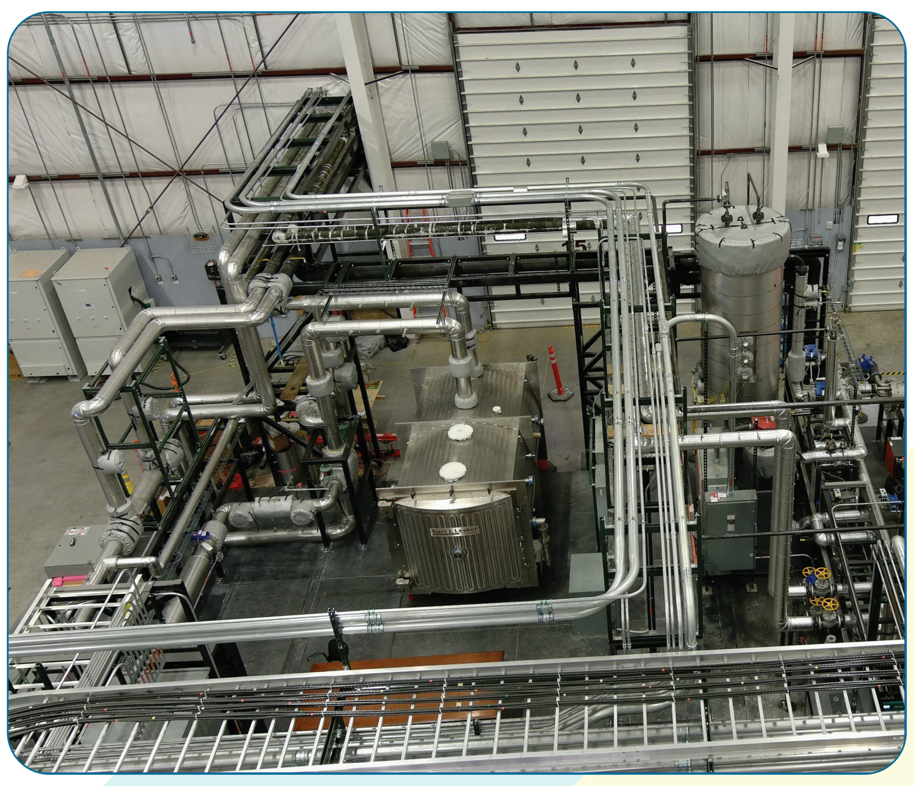
# NRIC Experimental Infrastructure

Customer input and NRIC gap analysis helps prioritize facilities needed to fill technology gaps required to commercialize advanced reactors.

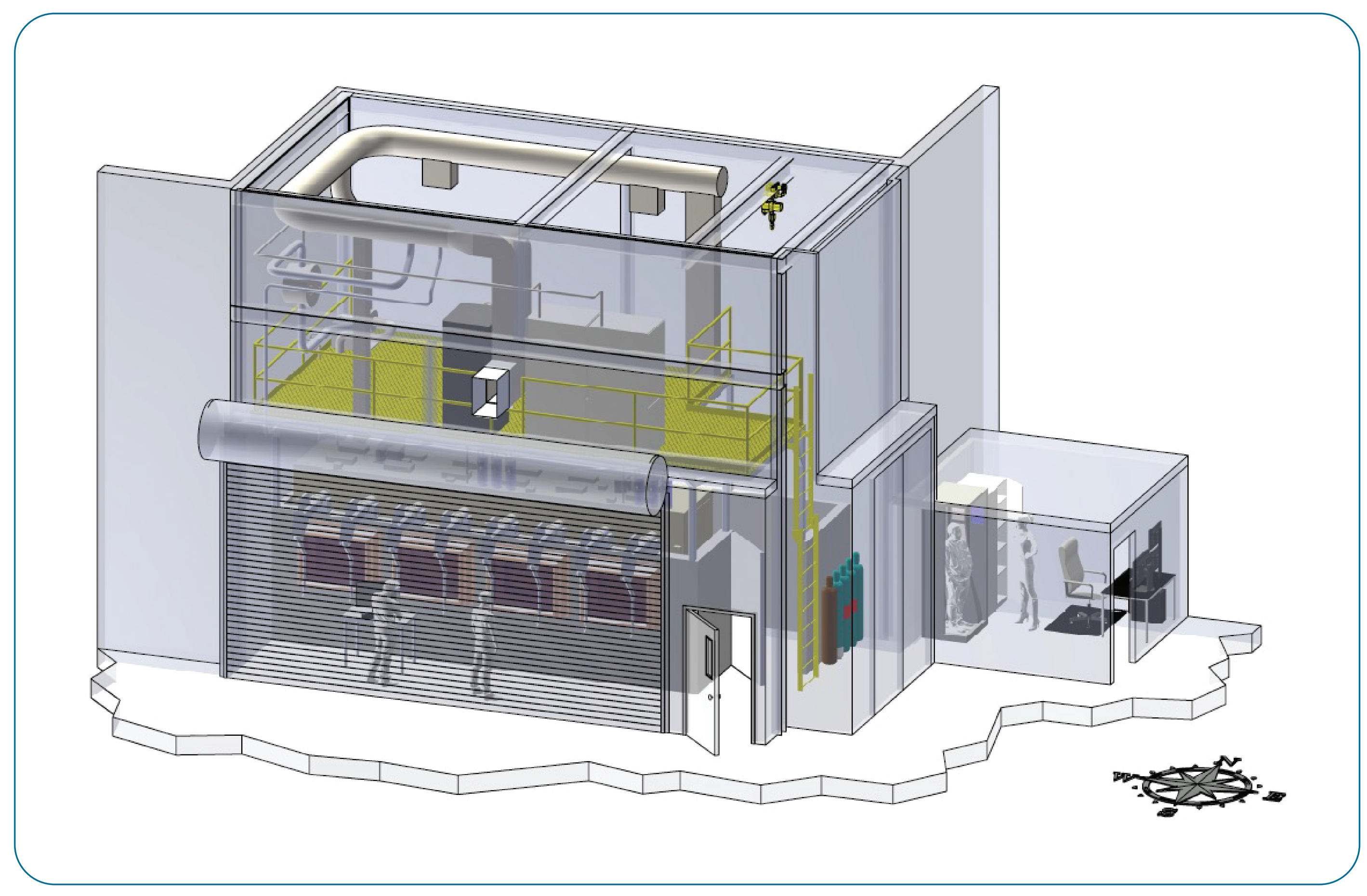


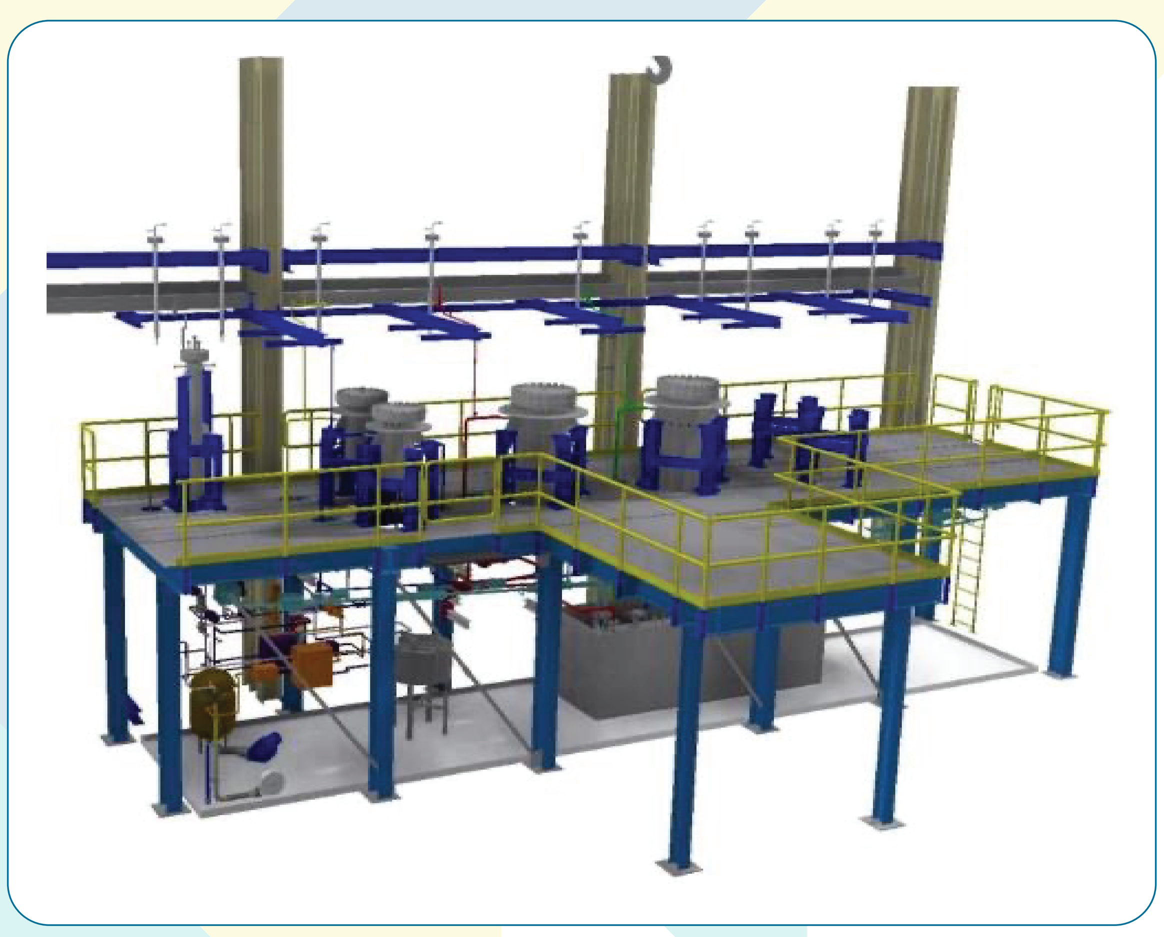
## Helium Component Test Facility (Operational 2022)

- Gas Cooled Reactor vendors can test non-irradiated reactor components that operate in a high-temperature, high-pressure helium environment
- 650° C, 22 bar, 0.7 kg/s helium supply

## Molten Salt Thermophysical Examination Capability (Operational 2024)

- Shielded modular hot cell with inert argon atmosphere
- Capable of determining thermophysical properties of irradiated liquids (e.g. molten salts)



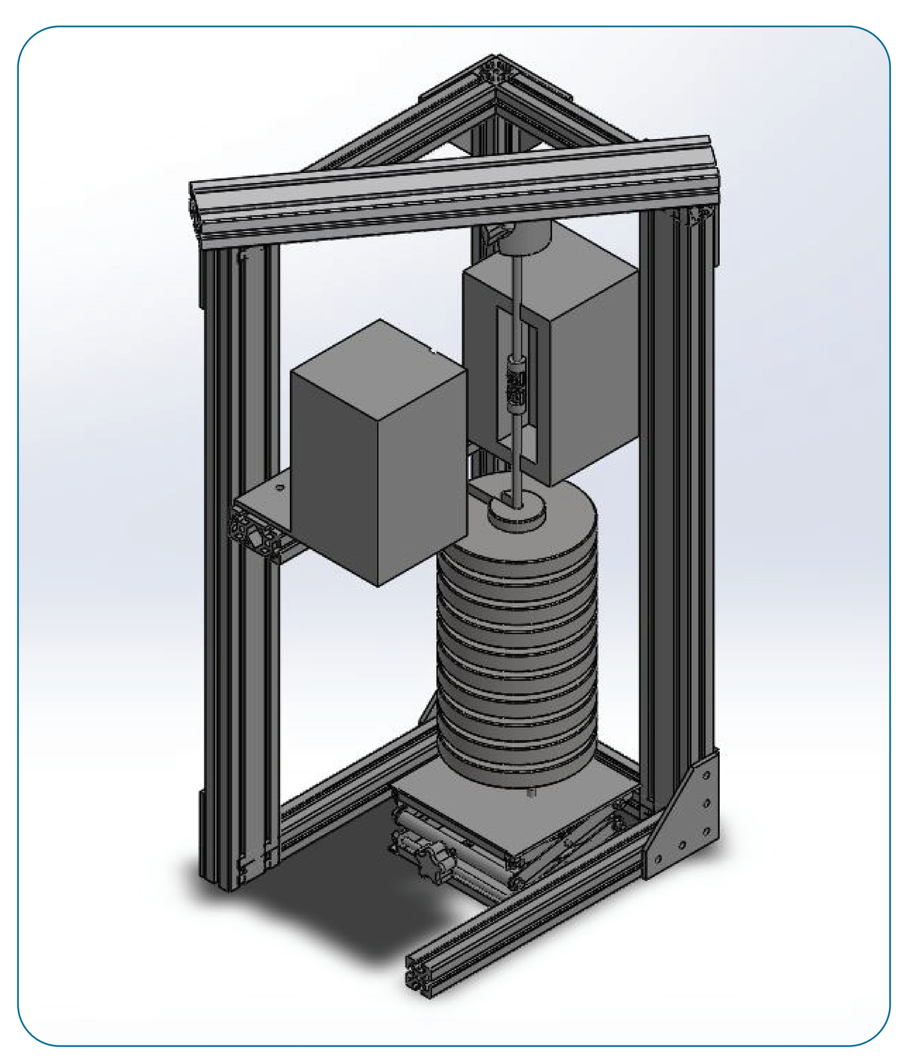


## Mechanisms Engineering Test Loop (Operational)

- Sodium environment for testing liquid metal cooled reactor components
- Four test vessels (18" and 24"), R-grade sodium, cold trap for purification

## Creep Frames (Operational 2022)

- In-cell thermal creep testing for advanced reactor materials
- 1000° C, 100lb max load



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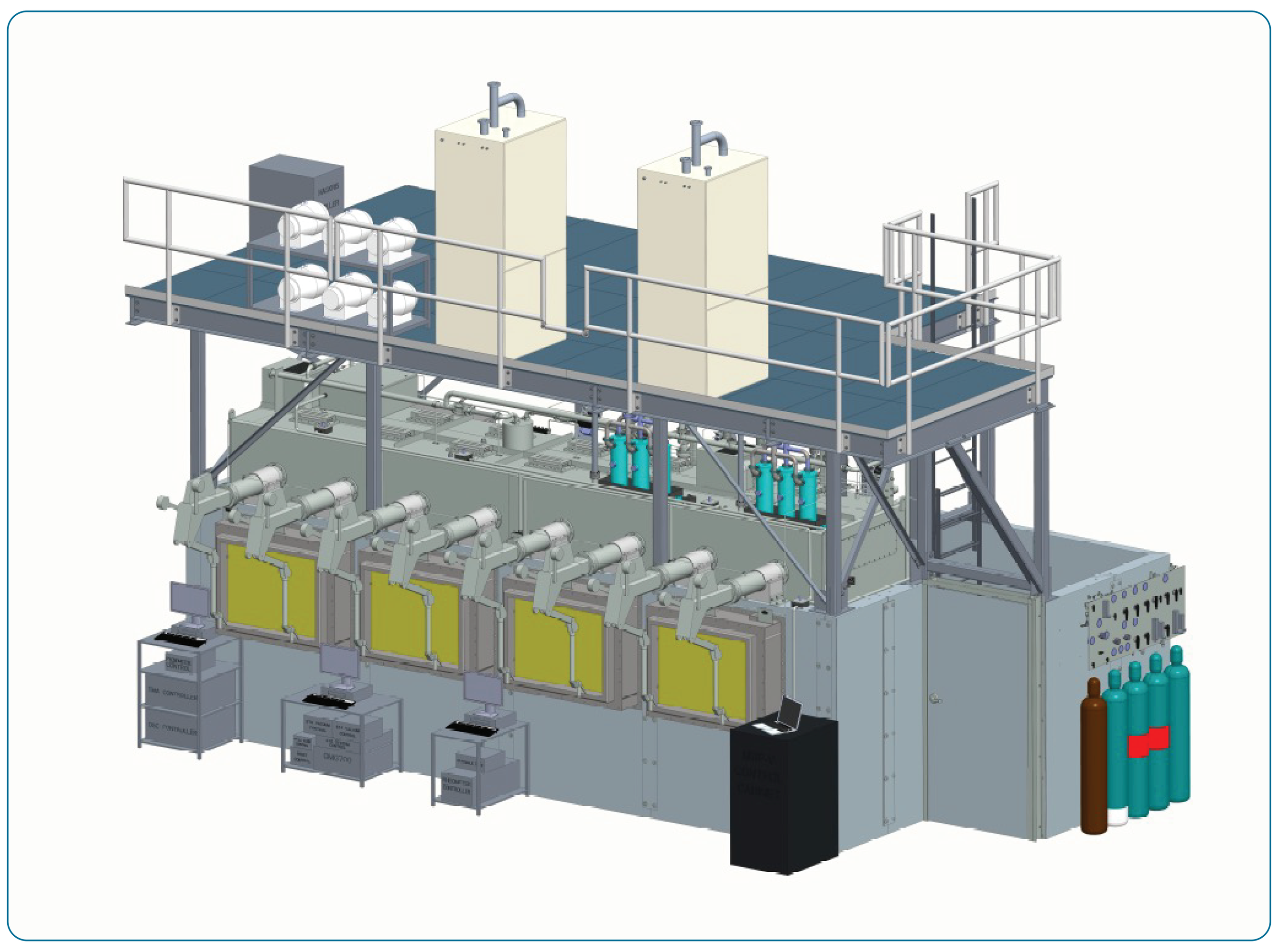
# NRIC-MSTEC

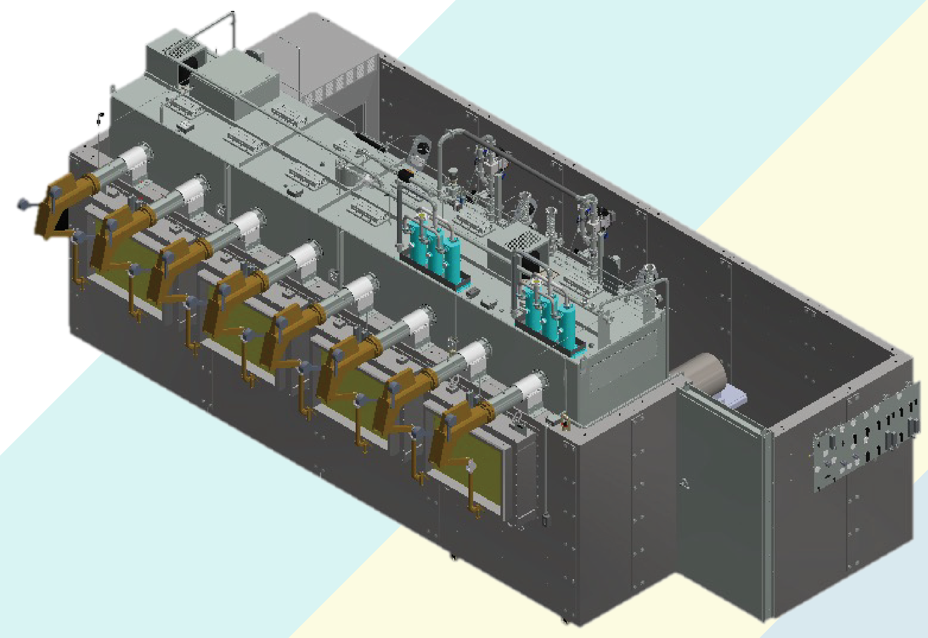
## National Reactor Innovation Center - Molten Salt Thermophysical Examination Capability

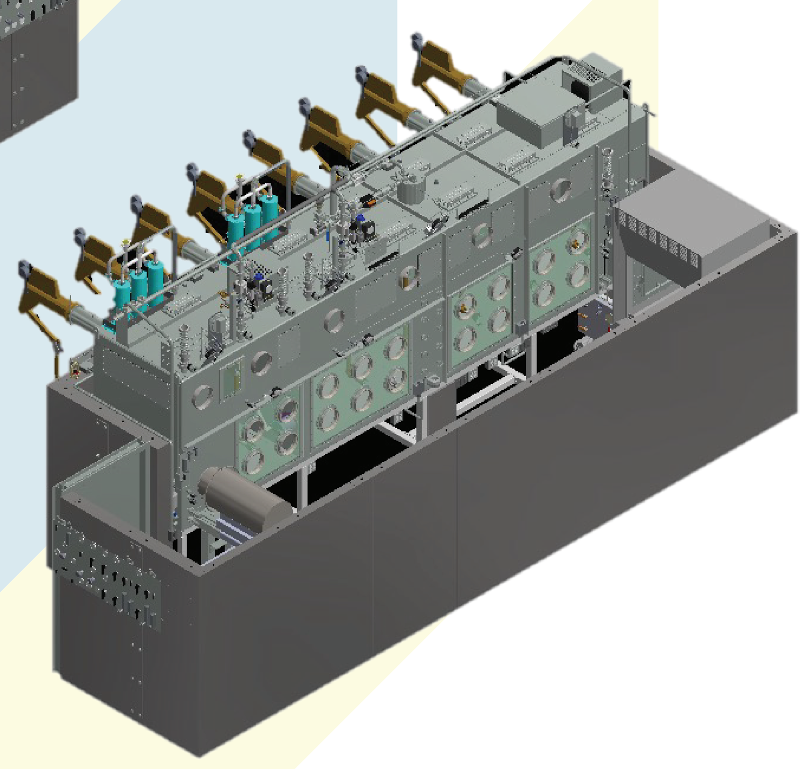
**Description:** NRIC - MSTEC is a shielded modular hot cell with an argon atmosphere, housing characterization equipment for determining thermophysical and thermochemical properties of high temperature liquids not limited to but focusing on irradiated fuel salts for advanced reactors.

**Purpose:** Provide users with characterization equipment, infrastructure, and technical staff necessary to produce critical data needed to design, demonstrate, license, and operate molten salt reactors (MSRs).

**Benefits:**
- Provide high temperature characterization capabilities nonexistent elsewhere
- Study the interaction of fuel/coolant with material of construction
- Provide a space where salts can be synthesized and characterized near facilities for irradiation testing and analytical analysis
- Provide data to aid in long-term storage or disposal solutions
- Allow for development and validation of multi-physics models and simulations
- Provide data needed to predict safe operating conditions of MSRs and determine the behavior of salts in "off-normal" conditions
- Generate data sets needed by stakeholders to design and license MSRs

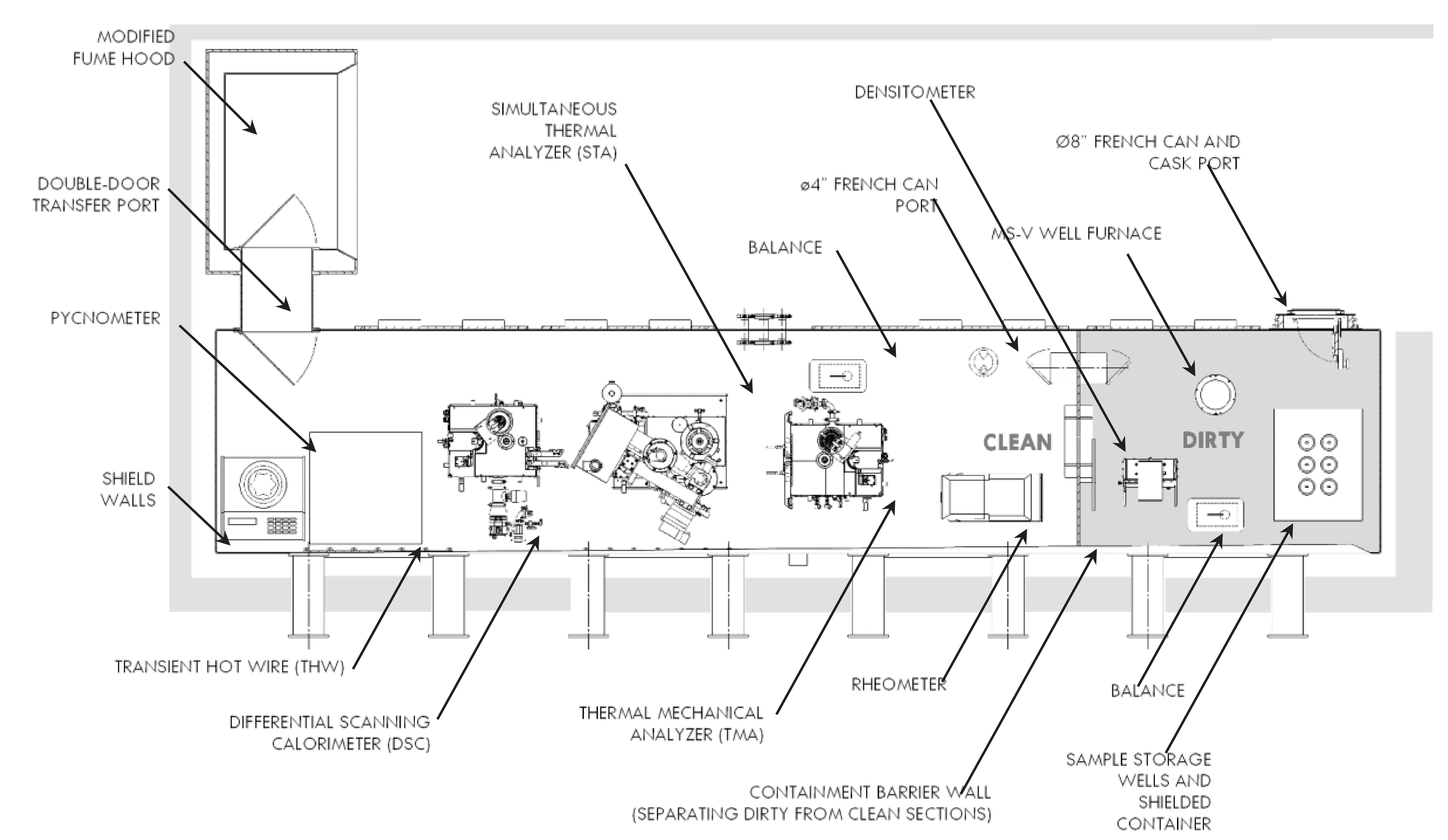






### NRIC-MSTEC Instruments

| | |
|---|---|
| **Rheometer** | Used to measure viscosity which provides an understanding of how a fluid flows without significant constraints. An accurate understanding of viscosity is critical for describing the flow through a reactor system. |
| **Pycnometer** | Device for nondestructively measuring the density of a solid first by determining the mass using a highly accurate balance followed by volume determination using argon. |
| **Archimedes Densitometer** | The density of molten salts is highly important to fuel salts. The Archimedes densitometer is an in-house design derived from the Archimedes principle, one of the simplest and most reliable methods for measuring the density of molten-salt systems. |
| **Simultaneous Thermal Analyzer (STA)** | A multifunctional instrument used for measuring weight loss and energy as a function of temperature. It is also used for phase diagram development, and determining invariant temperatures, such as phase transitions and melt/freeze points and vapor pressure. |
| **Differential Scanning Calorimeter (DSC)** | One of the most accurate instruments used to measure specific heat capacity. In addition, the DSC can also measure invariant temperatures and enthalpy. |
| **Furnace** | Provides up to a 1000°C environment for salt synthesis, density, electrochemistry, corrosion, and other general long-term molten salt experiments using irradiated molten fuel salt. Ancillary work that may be performed within the furnace includes crucible bake-out, salt mixing and melting, and salt distillation. The furnace well is featureless to enable different process operations with a variety of internals that may be inserted into the hot zone. |

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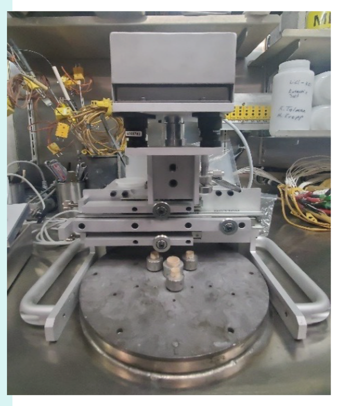
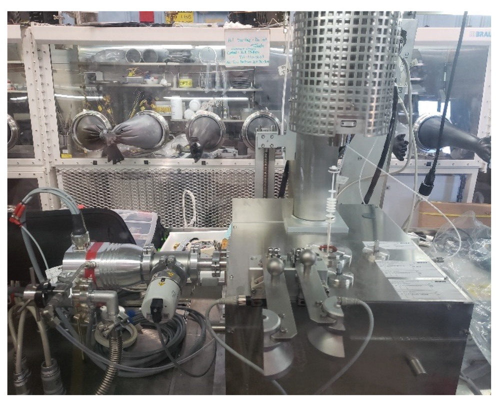


NRIC National Reactor Innovation Center

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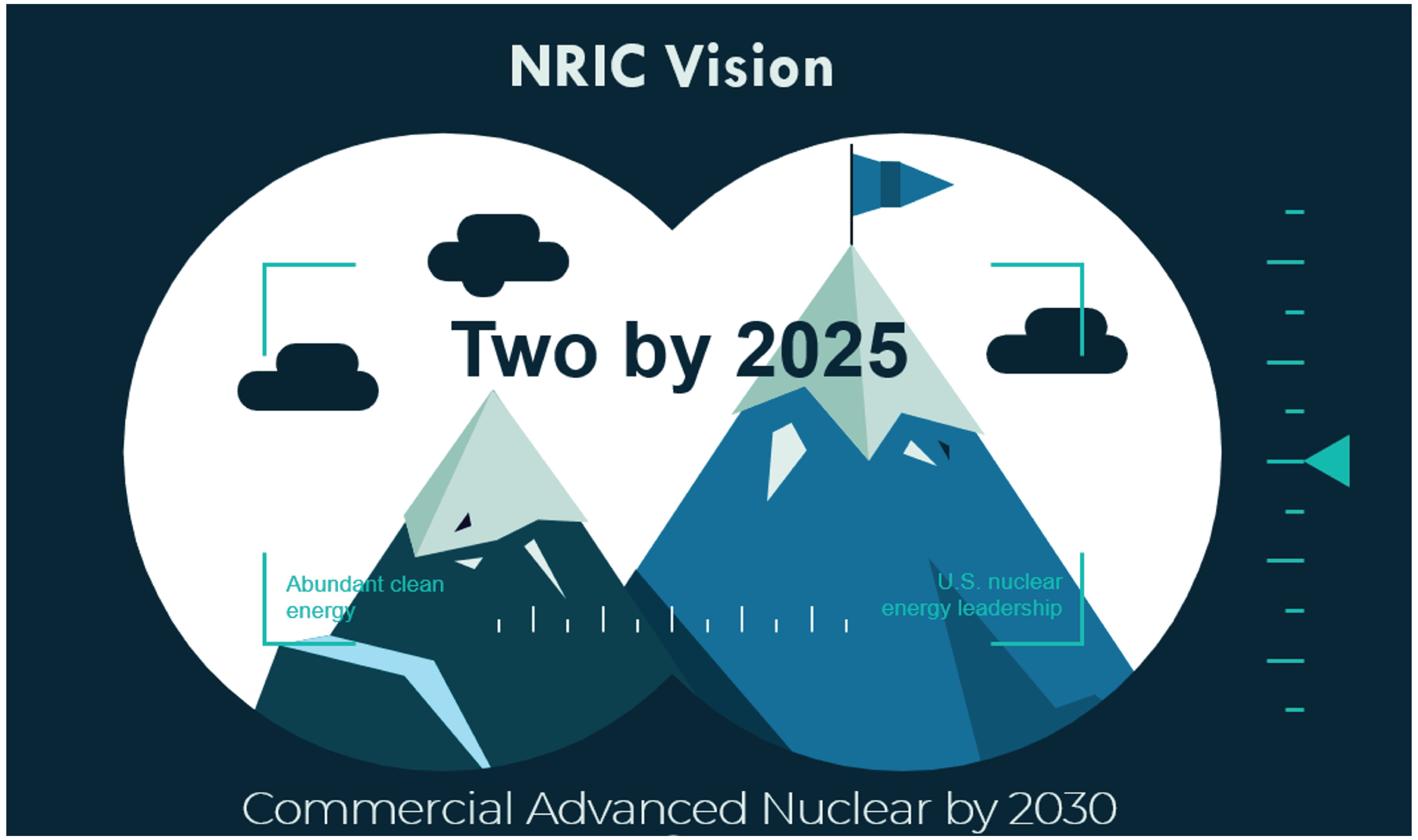
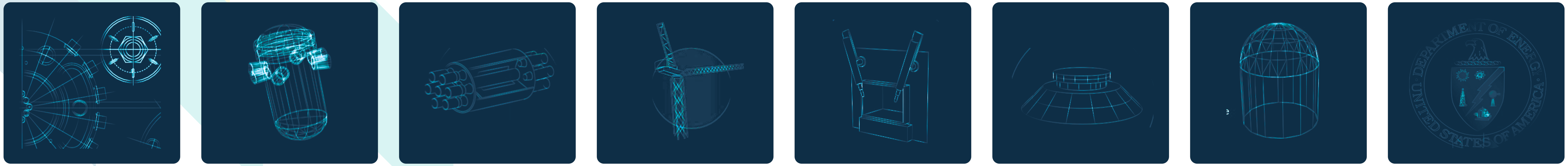
# National Reactor Innovation Center (NRIC)

NRIC accelerates the demonstration and deployment of advanced nuclear energy through its mission to inspire stakeholder and the public, empower innovators, and deliver successful outcomes.

NRIC's vision is to support the start-up of at least two advanced demonstration reactors by the end of 2025, to support commercial availability of advanced nuclear technologies by 2030, and to position the nation for ongoing innovation in nuclear energy. Achieving this vision will enable the development of abundant and affordable clean energy that is urgently needed domestically and internationally.



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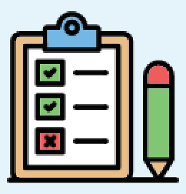
# STAND - Siting Tool for Advanced Nuclear Development

An integrated tool used to help identify and compare possible U.S. siting locations for advanced nuclear facilities based on factors related to socioeconomics, proximity, and safety.
*Launched at January 26th Tech Talk (https://nric.inl.gov/nric-tech-talks-stand-tool/)*

STAND has several different paths that can be used to identify and compare sites.

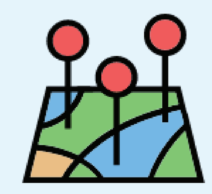


**Site Discovery**
Start here if you want to identify counties or states that may be candidates for reactor deployment.

Identify the relative importance for each of the parameters to create a National Priority Match Map

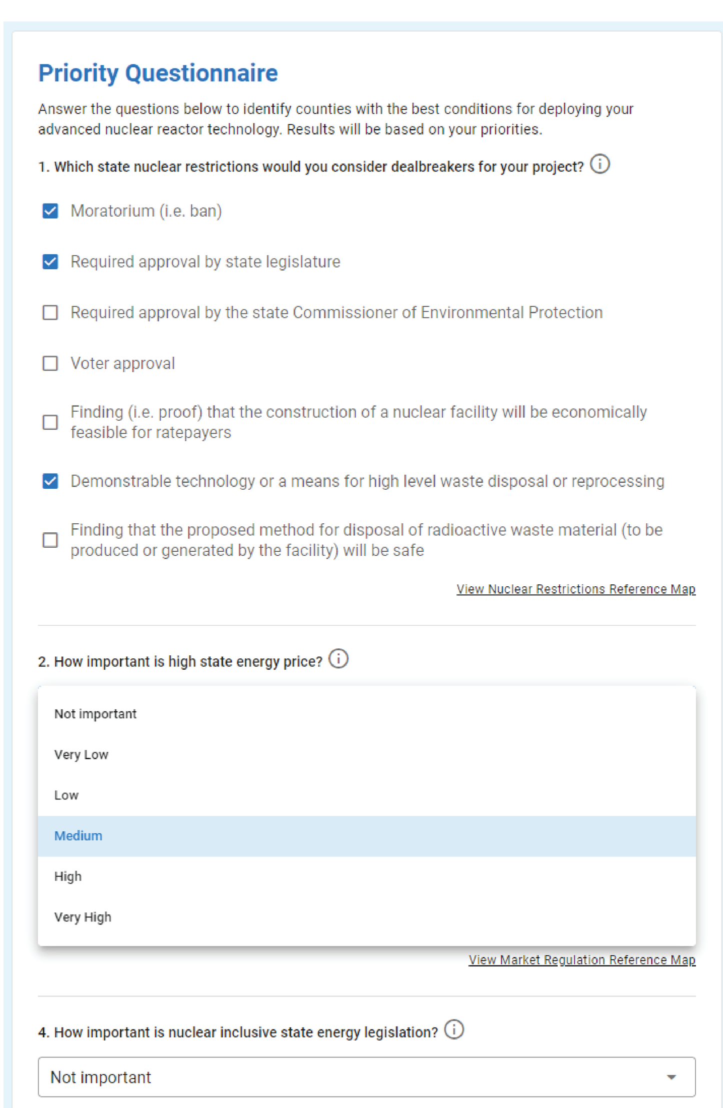
**Site Exploration**
Start here if you already have identified general areas for deployment but would like to explore regulatory data or drop points.

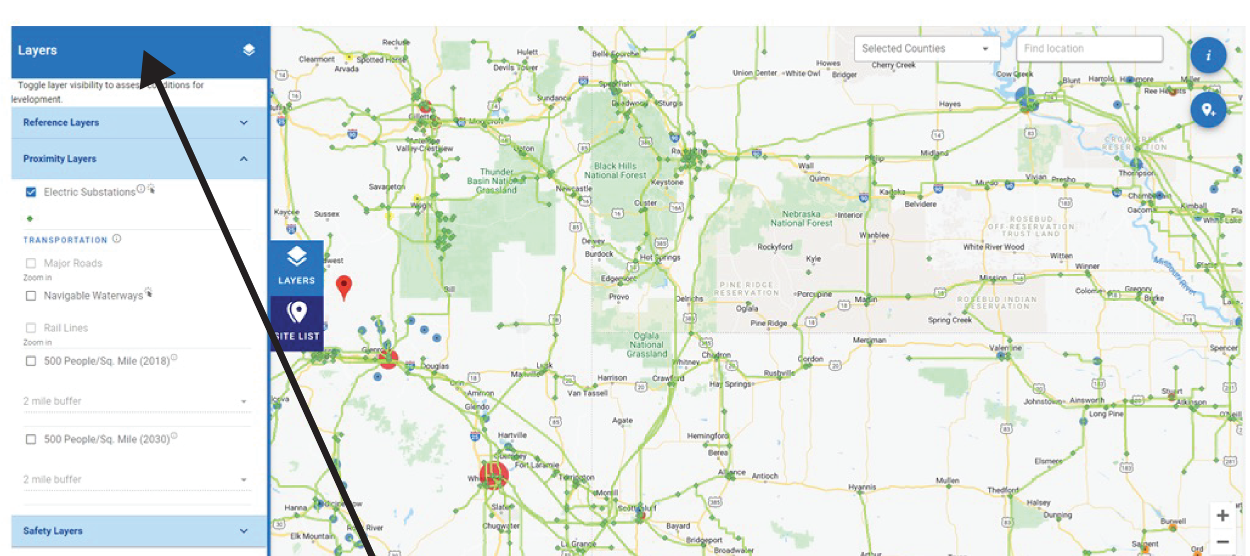
Find more information and refine search to smaller geographic location



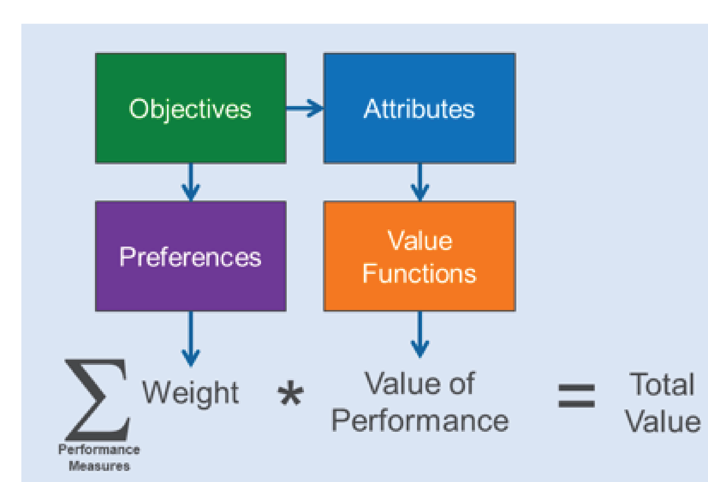
**Site Comparison**
Start here if you have identified site coordinates for deployment and would like to compare them against each other.

Use a multi-objective evaluation model to identify which sites maximize user selected attributes

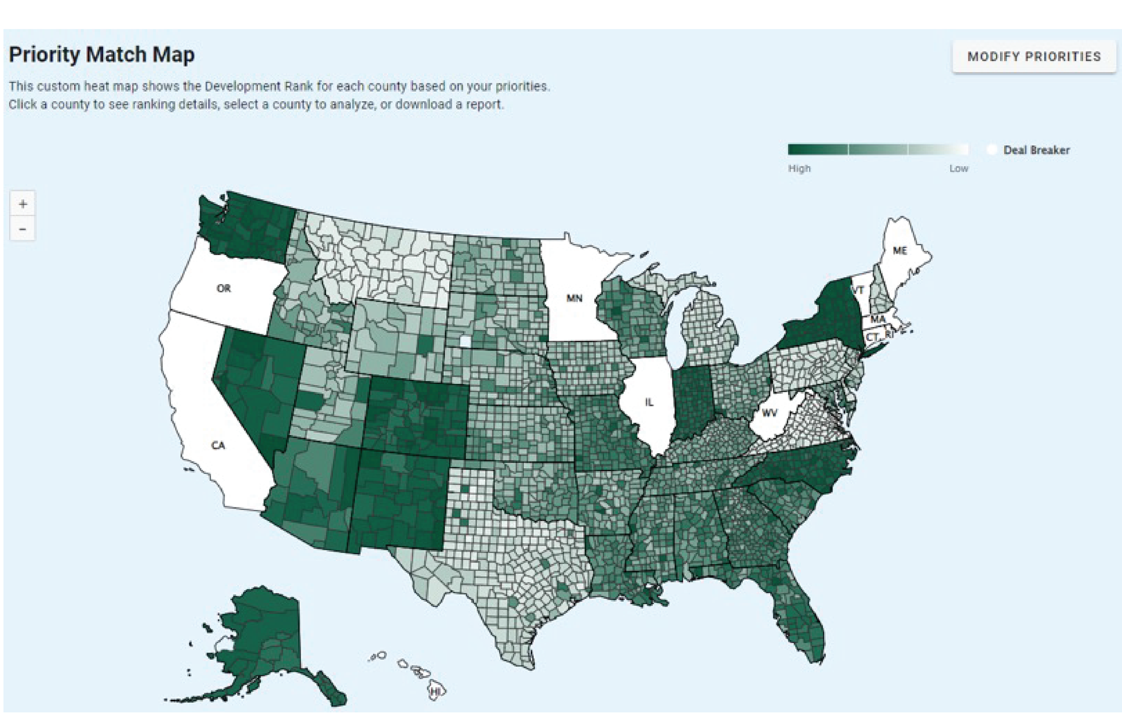


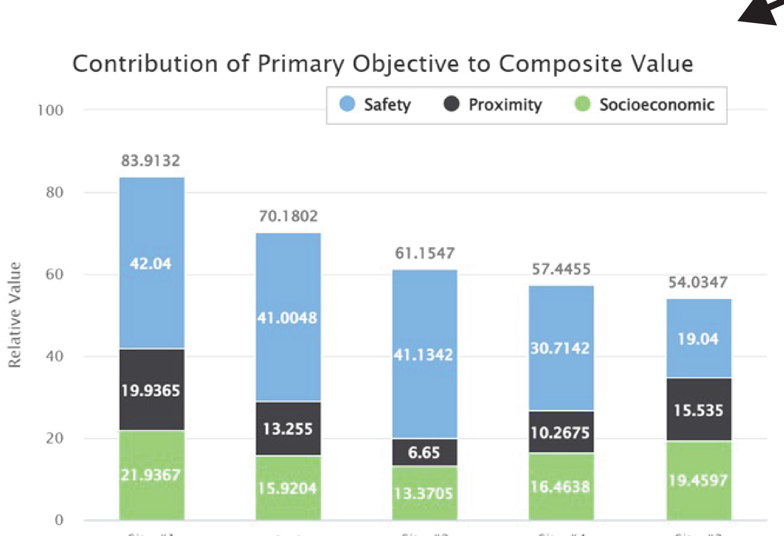



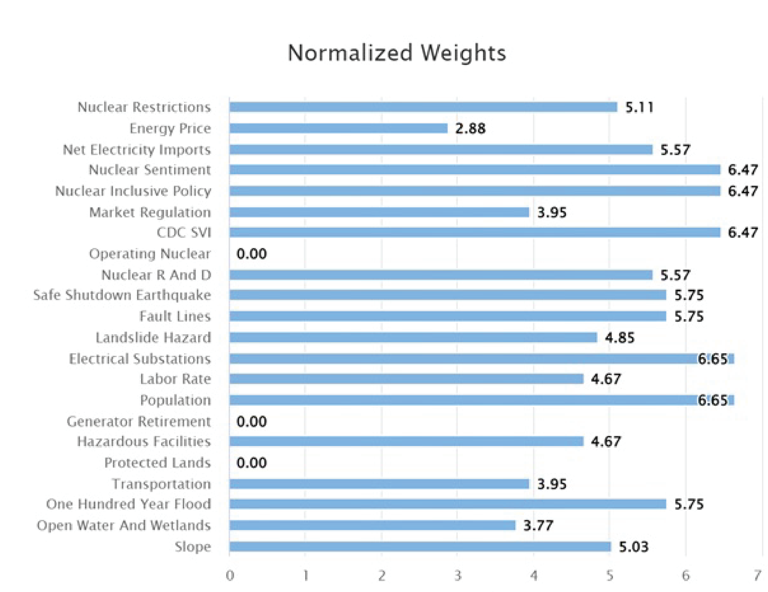
The layers drawer allows user to visualize different parameters on the map




Site Comparison results are displayed in various graphical forms that enable the user to easily understand the results



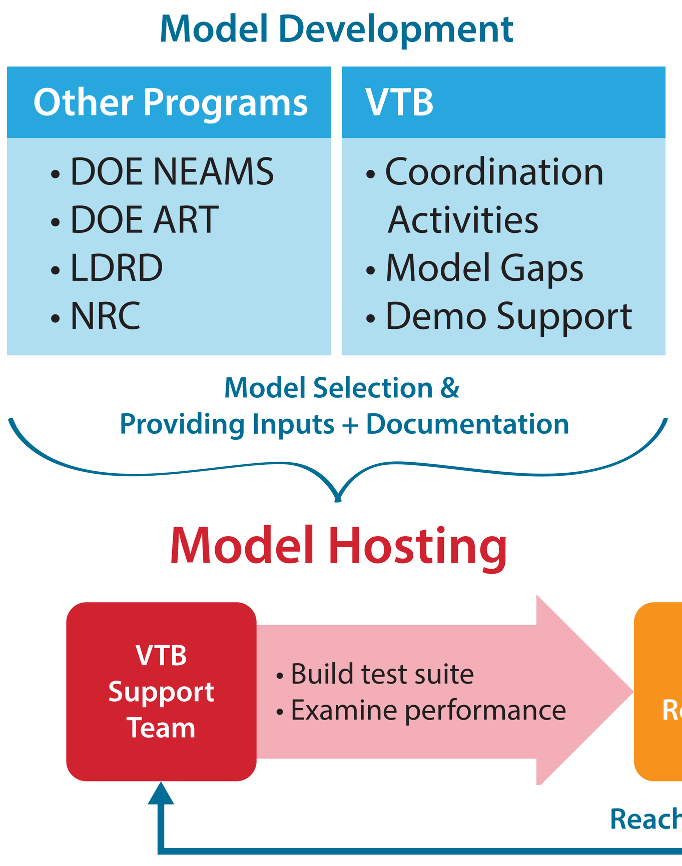

NRIC National Reactor Innovation Center | FASTEST PATH TO ZERO UNIVERSITY OF MICHIGAN | Argonne NATIONAL LABORATORY | OAK RIDGE National Laboratory | INL Idaho National Laboratory

# The NRIC Virtual Test Bed (VTB)

## The VTB Mission

Virtual Test Bed (VTB): Accelerate deployment of advanced reactors by leveraging the state-of-the-art NEAMS tools for Modeling & Simulation.

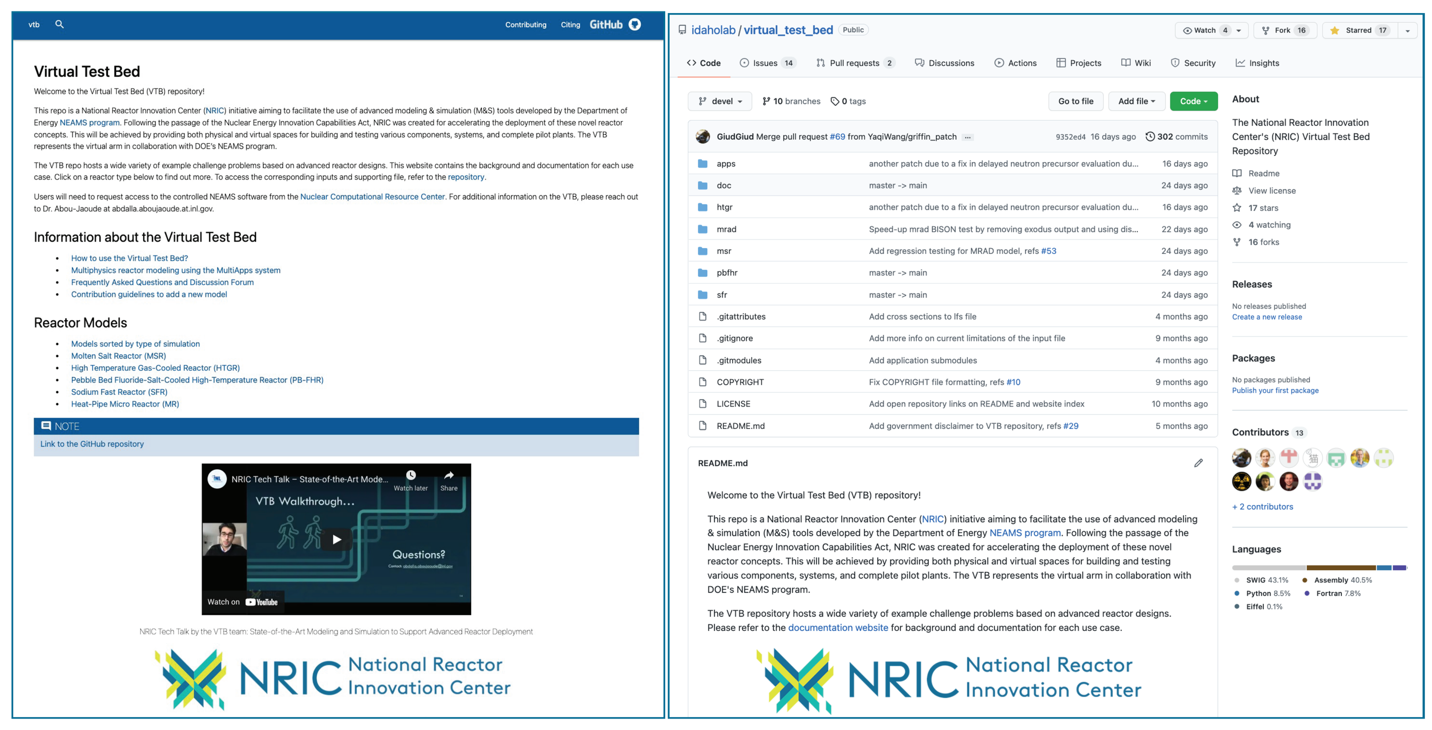
The National Reactor Innovation Center (NRIC) is enabling advanced reactor demonstrations with physical and virtual testbeds. The VTB represents the virtual arm and support development and demonstration efforts via:
1. Model Development: leverage NEAMS codes to provide powerful, highly-adaptable simulations for design analysis, safety review, and benchmarking.
2. Model Repository: storing and showcasing open use-cases developing relevant advanced reactor models and hosting them on an open-access repository.




The VTB is providing an open forum of collaboration between various DOE programs (e.g., NEAMS, ART, NRIC) at different national labs (INL & ANL) and other stakeholders (e.g., NRC) to openly share and benchmark advanced reactor models. The intent is to accelerate timelines for reactor demonstrations by enabling end-users to tailor open model examples to their proprietary specifications in order to mature designs and evaluate safety.

## The VTB Repository

The Repository went live on December 2021, and can be accessed below
- Documentation: https://mooseframework.inl.gov/virtual_test_bed
- GitHub: https://github.com/idaholab/virtual_test_bed



Continuous integration of models against the latest version of NEAMS tools ensures developers and users can keep track of rapid code development efforts that may cause issues within the VTB repository. The CIVET tool automatically checks any modifications to code/inputs against corresponding repositories via syntax and regression tests.

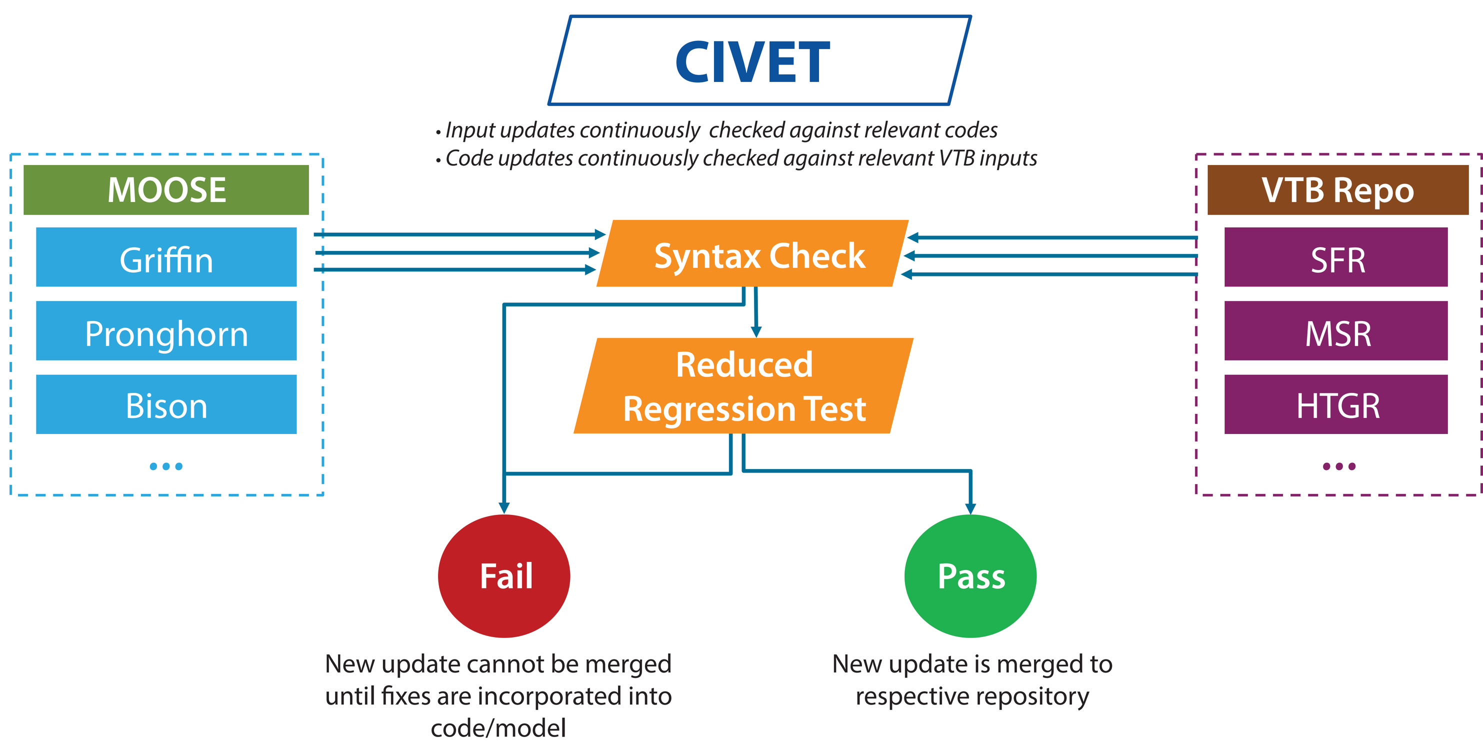
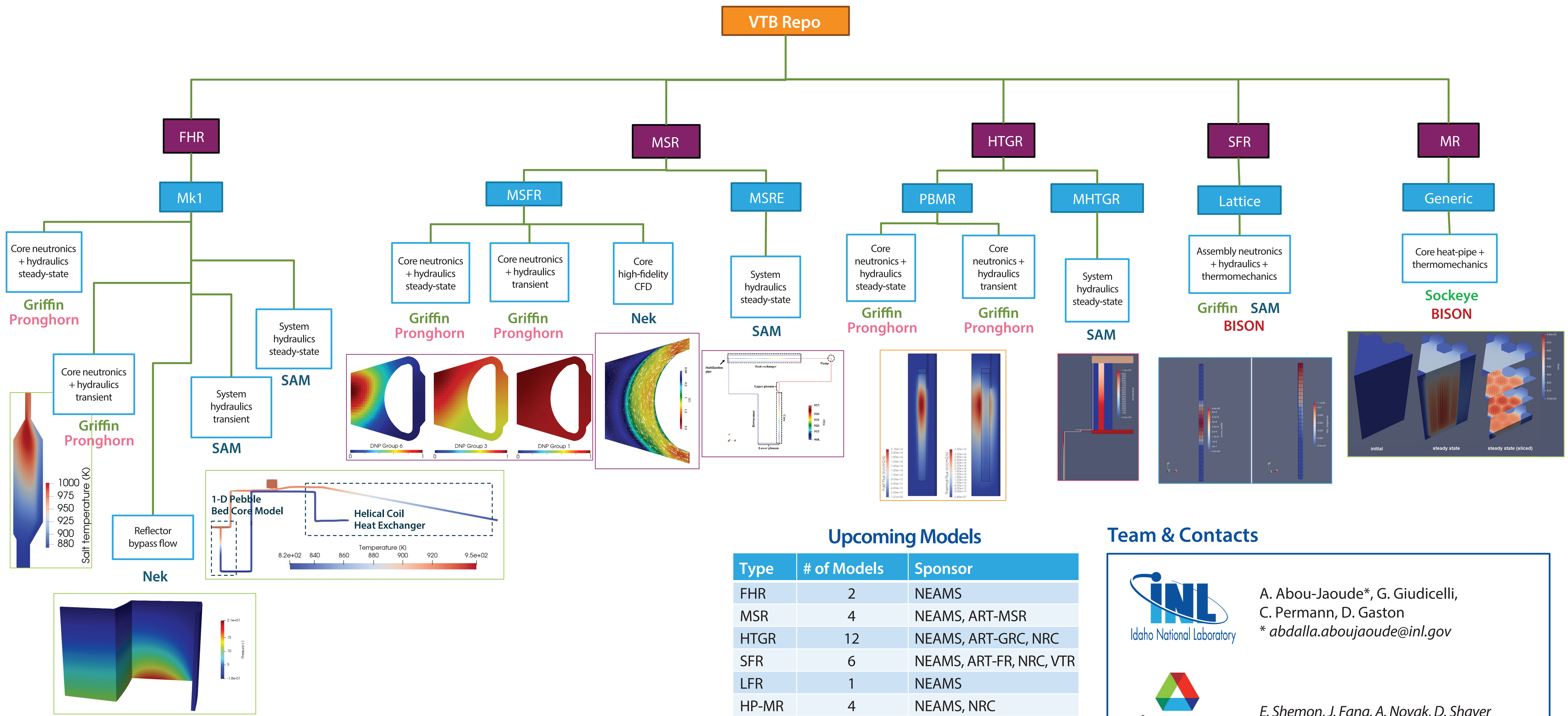



*Diagram of continuous testing in VTB*

## Models Hosted

The VTB is currently hosting 14 advanced reactor simulation 'challenge problems', representing:
- 5 advanced reactor types: Molten Salt Reactor (MSR), High-Temperature Gas Reactor (HTGR), Fluoride High-temperature Reactor (FHR), Sodium Fast Reactor (SFR), Microreactor (MR)
- 6 NEAMS tools: Griffin, Pronghorn, SAM, Nek, Bison, Sockeye
- Multiple cases: coupled multiphysics steady-state, component analysis, integrated plant analysis, high-fidelity CFD, multiphysics transients




### Upcoming Models

| Type | # of Models | Sponsor |
|---|---|---|
| FHR | 2 | NEAMS |
| MSR | 4 | NEAMS, ART-MSR |
| HTGR | 12 | NEAMS, ART-GRC, NRC |
| SFR | 6 | NEAMS, ART-FR, NRC, VTR |
| LFR | 1 | NEAMS |
| HP-MR | 4 | NEAMS, NRC |
| GC-MR | 1 | NEAMS |
| Material | 3 | NEAMS, LWRS |

### Team & Contacts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NRIC National Reactor Innovation Center | NEAMS Nuclear Energy Advanced Modeling and Simulation | Argonne National Laboratory | Idaho National Laboratory

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