INL/MIS-24-77637-Revision-0

National Reactor Innovation Center Program Review

April 2024

Bradley John Tomer

Changing the World's Energy Future

INL is a U.S. Department of Energy National Laboratory operated by Battelle Energy Alliance, LLC

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National Reactor Innovation Center Program Review

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April 2024

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 National Reactor Innovation Center

National Reactor Innovation Center

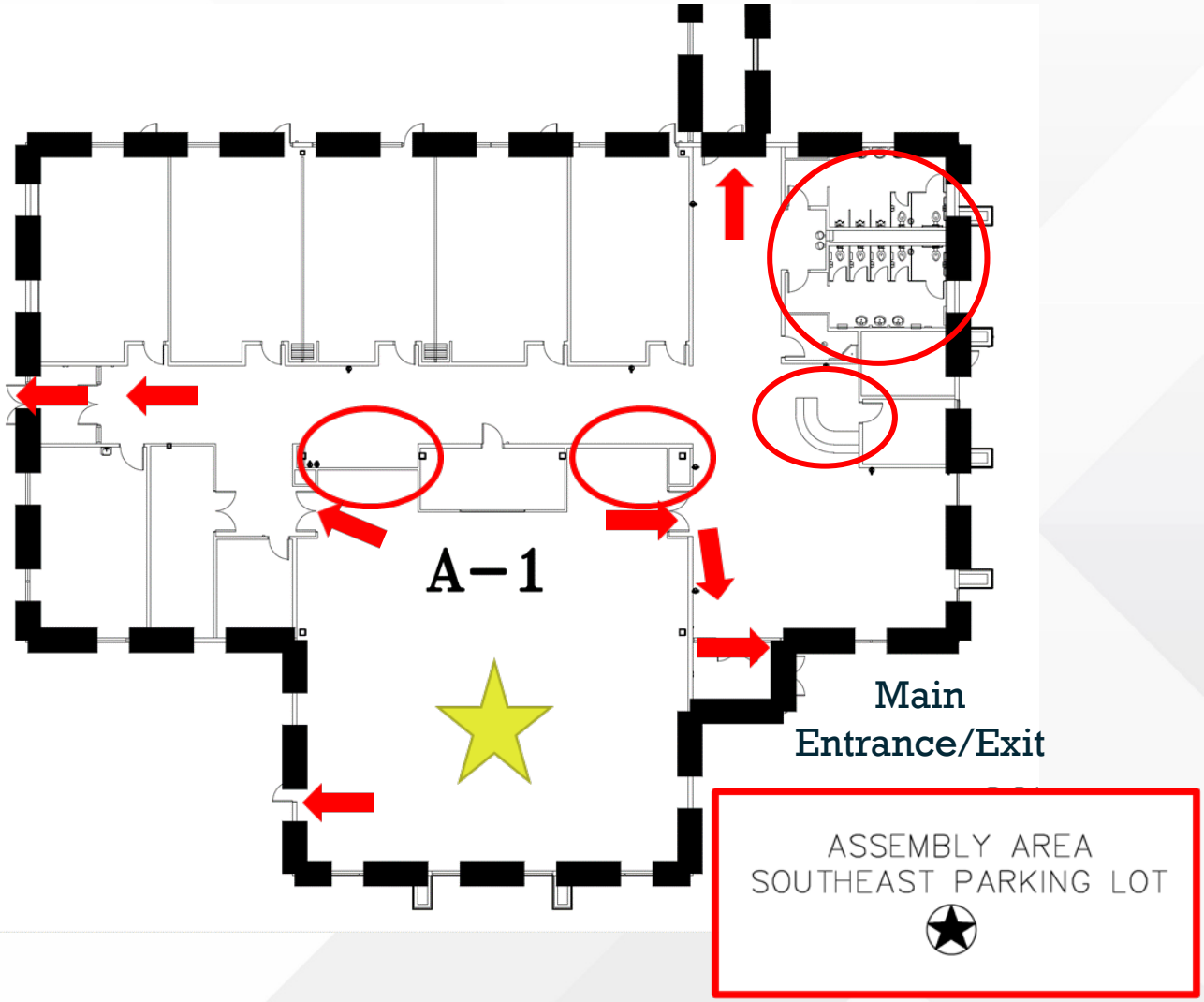
Program Review

Welcome

Please grab your name tag and agenda from the front desk

Welcome
Housekeeping Item

- Restrooms
- Coffee & Snacks
- If you need assistance:
  - A person will be available at the front desk all day, or –
  - Reach out to an NRIC representative (green badge)
- Lunch will be served buffet style
- Evacuation/Assembly Point



NRIC National Reactor Innovation Center

Tour Information

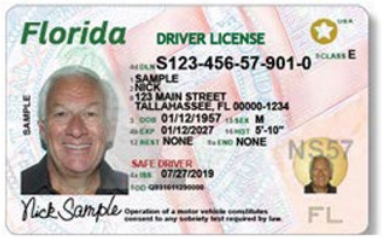
- We will load the bus outside this building (EIL) Thursday
- Please arrive by 0700 Thursday morning
- We will use the same bus all day, so you can leave personal items in your seats during tour stops. We also have EIL room reserved for the day so you can leave your items there if you prefer
- We will break into smaller groups for many of the tour stops. More detail will be provided on the bus.
- Badging will happen on the bus
  - Please make sure you bring the appropriate identification (next slide)
- Clothing Requirements and Prohibited items sent out to attendees prior to the review

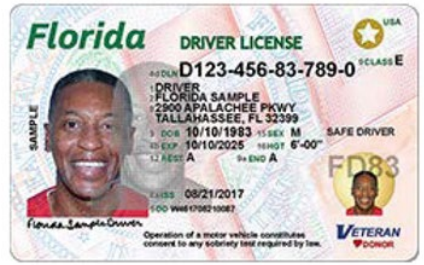
Tour Information – IDs and Badging

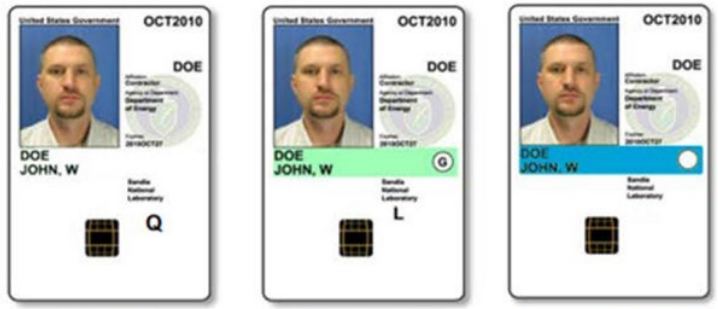
- For visitor access and badging at INL, U.S. citizens must present a REAL-ID compliant form of identification, such as a current U.S. passport or driver's license.

- International visitors must present a current passport and supporting documentation, such as a visa or green card.

- INL accepts HSPD-12 Personal Identity Verification and Department of Defense Common Access Card, or DoD CAC, badges as proper identification for site access. If you have an approved federal ID card, please bring it with you.







NRIC National Reactor Innovation Center

NRIC National Reactor Innovation Center

National Reactor Innovation Center Overview

NRIC Program Review

April 23 – 25, 2024

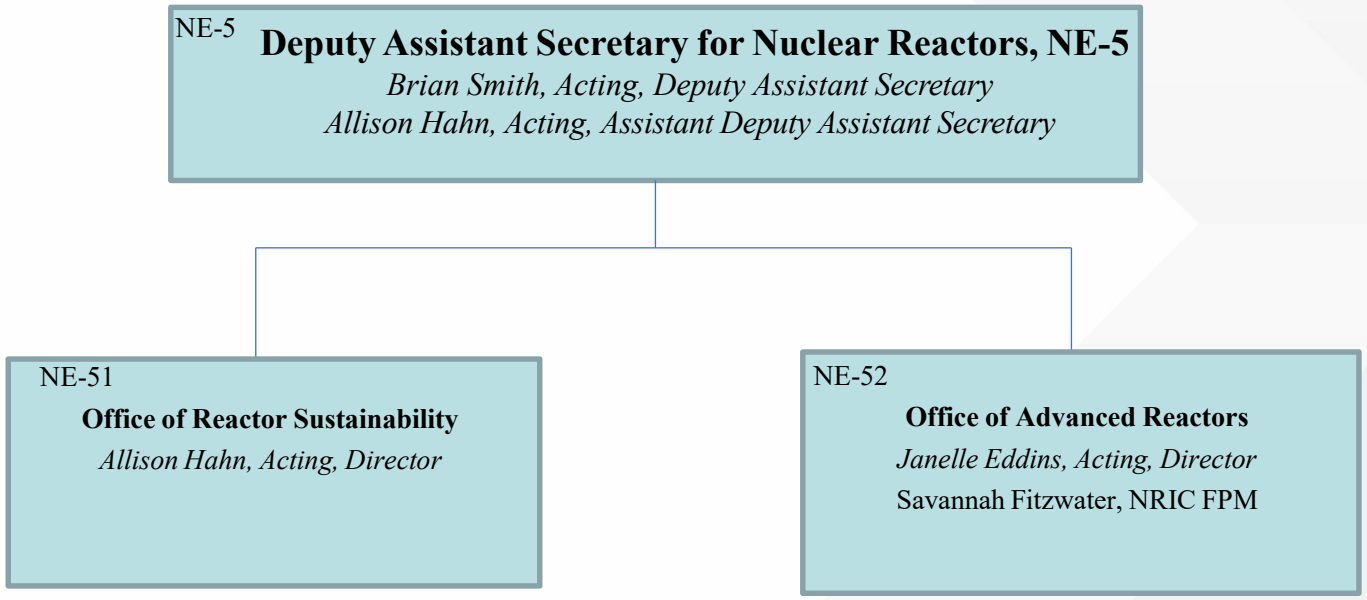
NRIC is a DOE program launched in FY'2020

NRIC Enables Nuclear Reactor Tests & Demonstrations

- Authorized by the Nuclear Energy Innovation Capabilities Act (NEICA)
  - DOE-Office of Nuclear Energy; INL Nuclear Science & Tech
- Partner with industry to bridge the gap between research and commercial deployment
- Leverage national lab expertise and infrastructure

NRIC National Reactor Innovation Center

Deputy Assistant Secretary for Nuclear Reactors, NE-5



Idaho Operations Office
Office of Nuclear Energy

Office of the Manager
L. Lacroix,
Manager, Idaho Operations Office
R. Boston, Advisor to Manager
K. Trusty, Executive Secretary, Secretary

Office of Nuclear Energy Facilities, Operations & Security
Chief Operations Officer
M. McAnulty
Acting Deputy Manager for Nuclear Energy Facilities, Operations & Security

Office of Nuclear Energy Program Support & Execution
S. Olson,
Deputy Manager for Nuclear Energy Program Support & Execution

Nuclear Programs Support Division
B. Ford, Director
K. Sterling, Secretary

Fuel Cycle Technologies
G. Kropp, Supv
C. Bunting
L. Friedel**
D. Herrin
J. Jardine
B. Merkle

Reactor Programs & Space Power
B. Brown, Supv
W. Amos
T. Haack△
S. Markovich
N. McBride
C. Vance

Idaho Cleanup Project
(Office of Environmental Management)

M. Brown,
Manager Idaho Cleanup Project

C. Flohr,
Senior Advisor to the Idaho Cleanup Project Manager

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National Reactor Innovation Center

National Reactor Innovation Center (NRIC) – C300 Acting Director
Brad Tomer

Administrative Assistant
Nelly Olivas

Chief Operating Officer
Brad Tomer

Collaboration Manager
Sanjay Mukhi

Configuration/Control Manager
AnnMarie Marshall

Department Manager
Adrian Collins

Risk Coordinator/Program Manager
Josh Kiel

Demonstration Infrastructure and Support/Demonstration Project Partnerships – C310

Technical Program Manager
Troy Burnett

Technical Program Manager
Samuel Reiss

Technical Program Manager
Chance Price

Technical Program Manager
Curtis Nielsen

Technical Program Manager
Greg Core

Technical Program Manager
Luke Voss

Project Manager
Marvin Fielding

Configuration Management Coordinator
Salome M. Swusu-Achampong

Technical Program Manager
Jacob Rhymer

Configuration Management Coordinator
Katelyn Mitchell

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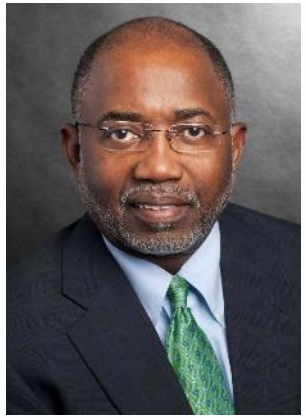
NRC Collaboration

- Congress recognized the importance of agency coordination in the Nuclear Energy Innovation Capabilities Act
- DOE/NRC MOU to "coordinate DOE and NRC technical readiness and sharing of technical expertise and knowledge on advanced nuclear reactor technologies and nuclear energy innovation, including reactor concepts demonstrations, through the [NRIC]."
  - NRIC Rotations



Fred Sock
Office of Nuclear Regulatory Research

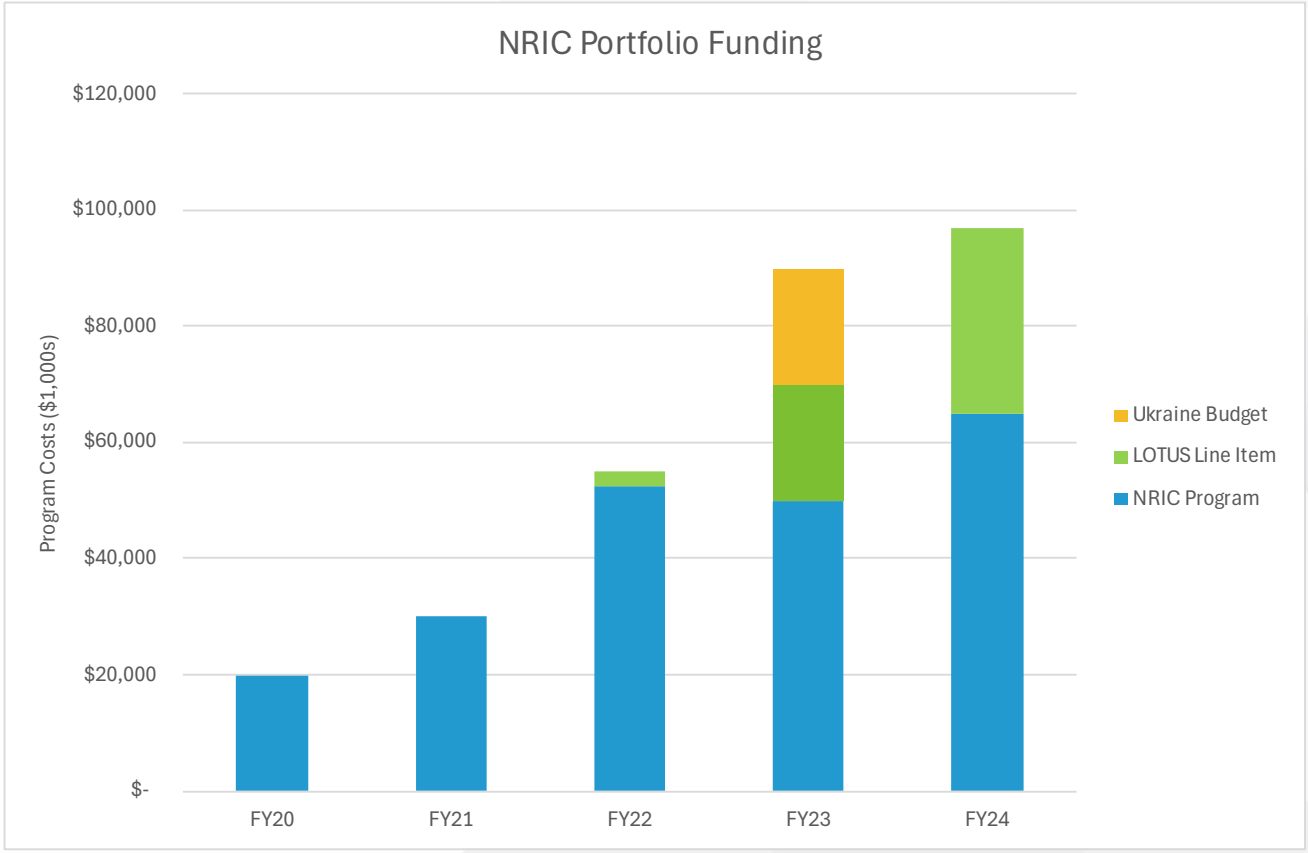
Allen Fetter
Office of Nuclear Reactor Regulation

- Monthly Coordination Calls – DOE/NRC/NRIC

NRIC National Reactor Innovation Center

NRIC Portfolio Budget (FY20-FY24)

- FY20 $20M NRIC Program
- FY21 $30M NRIC Program
- FY22 $55M : NRIC Program $52.4M, LOTUS Line Item $2.6M
- FY23 $90M: NRIC Program $50M, LOTUS Line Item $20M, Ukraine $20M
- FY24 $97M: NRIC Program $65M, LOTUS Line Item $32M



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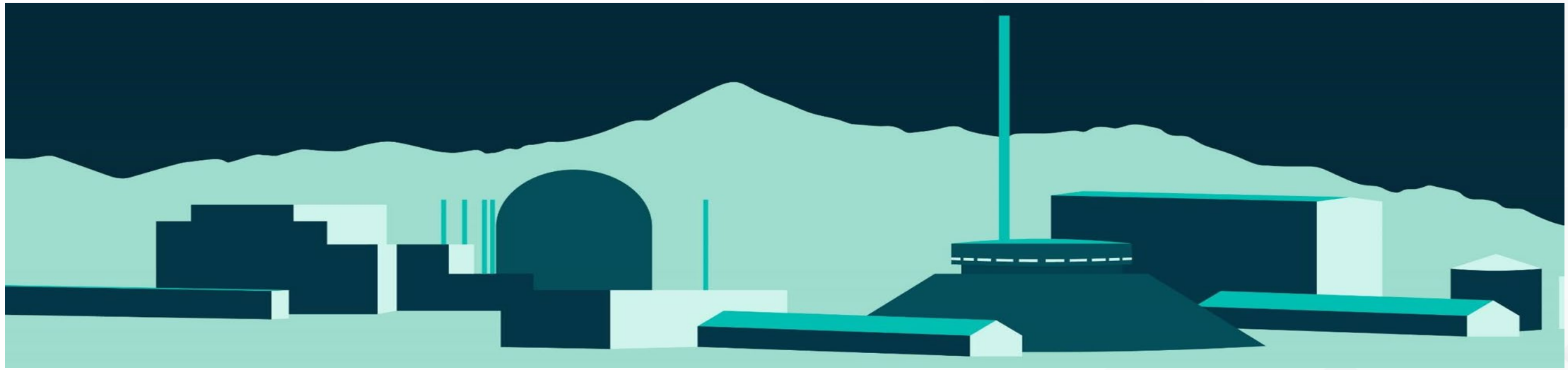
Portfolio Built to Empower Innovators



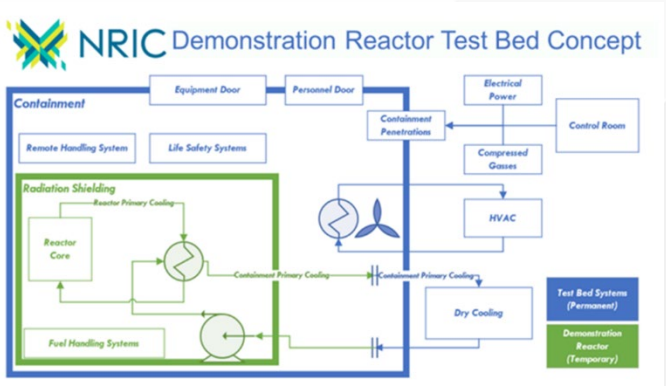
- **Building testing foundation**
  - Advanced Reactor Test Beds
  - Experimental Facilities
  - Virtual Test Bed
- **Addressing Costs & Markets**
  - Advanced Construction
  - Digital Engineering for Nuclear
  - Maritime Applications

NRIC Testbed Strategy

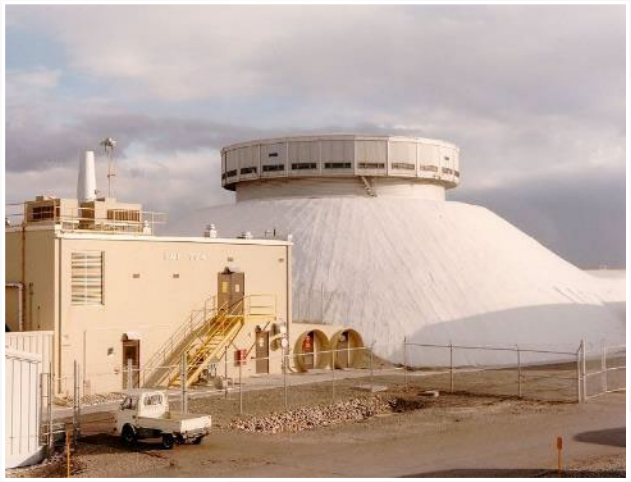
NRIC-DOME Testbed

- EBR-II Operated from 1964 to 1994
  - 62.5 MW thermal
- Repurposing EBR-II as NRIC-DOME
  - <20MW$_{th}$ <20% enriched fuels
  - Final design complete
  - Construction began 2023
  - First user expected 2026

Materials & Fuels Complex at INL

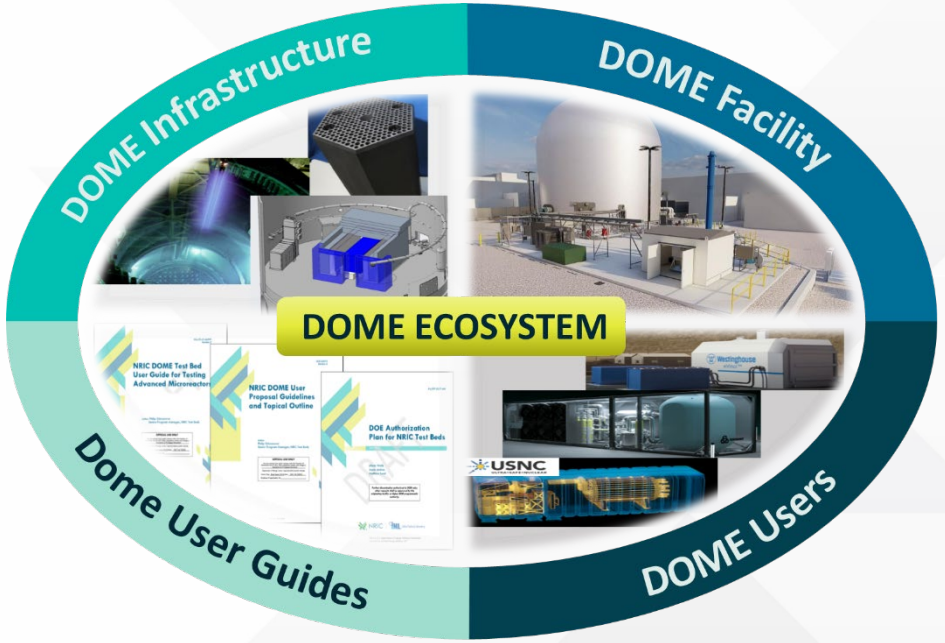


NRIC-LOTUS Testbed



- ZPPR Operated from 1969 to 1990
  - Used for transuranic and enriched-uranium material inspection/repackaging and experiments
- Repurposing ZPPR Cell as NRIC-LOTUS Testbed
  - Small KWth reactors
  - >20% enriched fuels
  - Preliminary/Final Design Initiated
  - First user expected 2027/2028

NRIC-DOME Test Bed Ecosystem



Test Bed Ecosystem Extends Beyond Facility Construction:

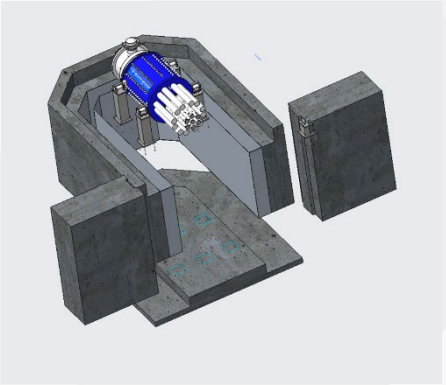
- Complete end-to-end support equipment from fresh fuel storage, supplemental shielding, testing support, and decommissioning
- Processes and procedures to ensure consistent, repeatable testing.

Support Infrastructure and Equipment

- Shielding – conceptual design complete w/fabrication in FY25
- Evaluated crane options and developed path forward for polar crane
- Secured options for fresh fuel storage in CPP 651 & irradiated reactor at RSWF
- Developing irradiated reactor removal, storage, defueling, and pathway for irradiated fuel

Processes & Procedures

- Developed new version of end-to-end user guide
- Developing draft environmental assessment of envelop of possible reactors



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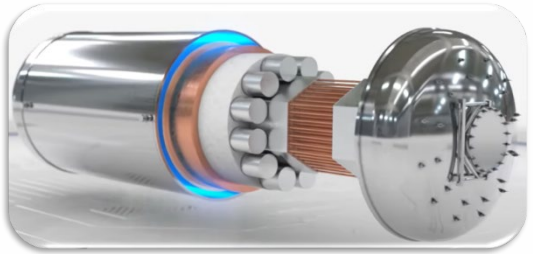
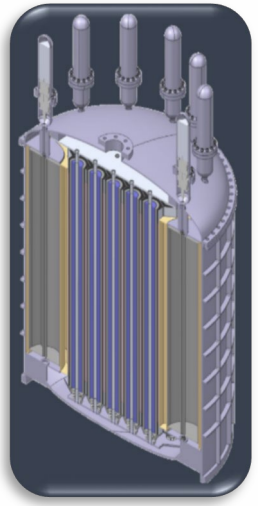
Front End Engineering & Experiment Design

- $4.5M in DOE-HQ funding w/NRIC issuing EOI/RFP
- 11 EOI responses and 5 RFP responses
- Conducted process in <5 months and awarded 3

Developer	Reactor Name	Design	Power Mwe	Power MWth	Fuel Type	Fuel Enrichment	Primary Coolant	Moderator	Refueling Interval (Years)	Power Conversion System
Radiant	Kaleidos	HTGR	1.2	3.5	TRISO	19.75%	Helium	Graphite	6	Brayton Cycle
USNC	Pylon	HTGR		1	TRISO	9.90%	Helium	Graphite		Rankine
Westinghouse	eVinci NTR	Heat Pipe	1	3	TRISO	19.75%	Sodium	Graphite	8	Brayton Cycle





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NRIC-LOTUS Test Bed

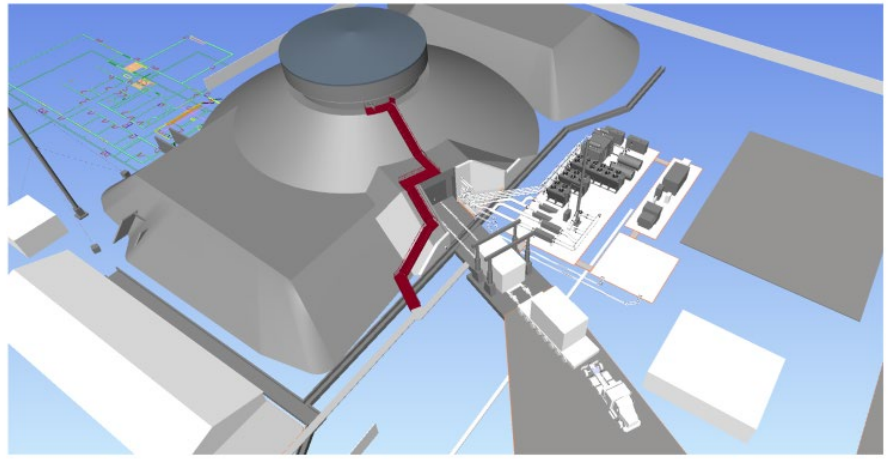
Description

- Advanced Microreactors up to 500kW$_{th}$ using high security materials
- 13ft X 13ft side entry
- 50kWth Ventilation: standalone/upgraded/neg pressure/stack
- Provides Safety-Class confinement
- 480V / 400Amp electrical Service
- ≈ 30ft diameter floor space with a 20ft ceiling, includes a recessed pit area.
- Designed up to 500kW$_{th}$ direct reactor cooling

Funding Profile

	Major Project Area	FY23	FY24	FY25	FY26	Notes
LOTUS Construction	LOTUS TEC Line Item	$22.25M	$32M	$18.75M		Total $73M
	Other Project Costs	$1M	$3M	$9M	$7.64M	Total $25M including FY21 and FY22 CO
	Totals	$23.25M	$35M	$27.75M	$7.64M	

- Cost Estimate: $66M low, $77M point; $98M high (budgeting number)
- LOTUS design & construction is a capital line-item project
- The project is managed as a DOE 413.3B project with Gerardo Islas-Rivera as the Federal Project Director and Contracting Officer Representative; NE-3 is the Project Management Executive



Schedule

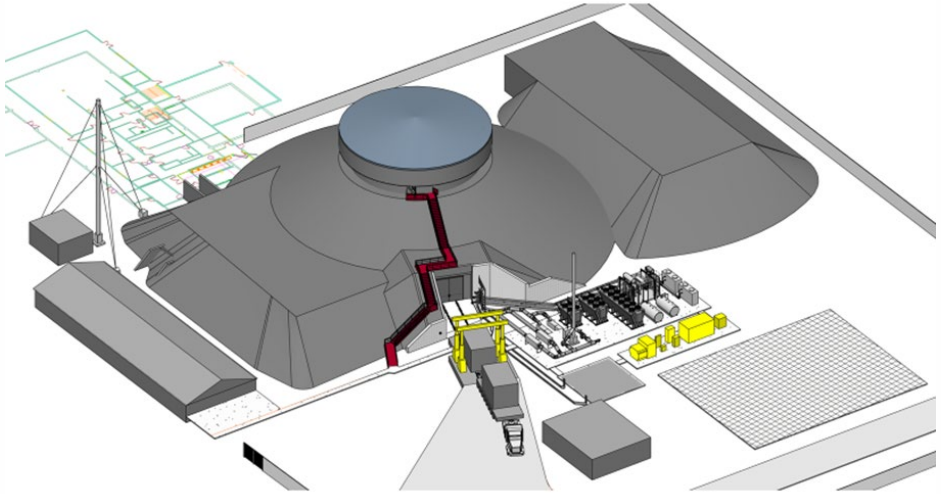
(Performance Baseline to be set at CD-2/3)

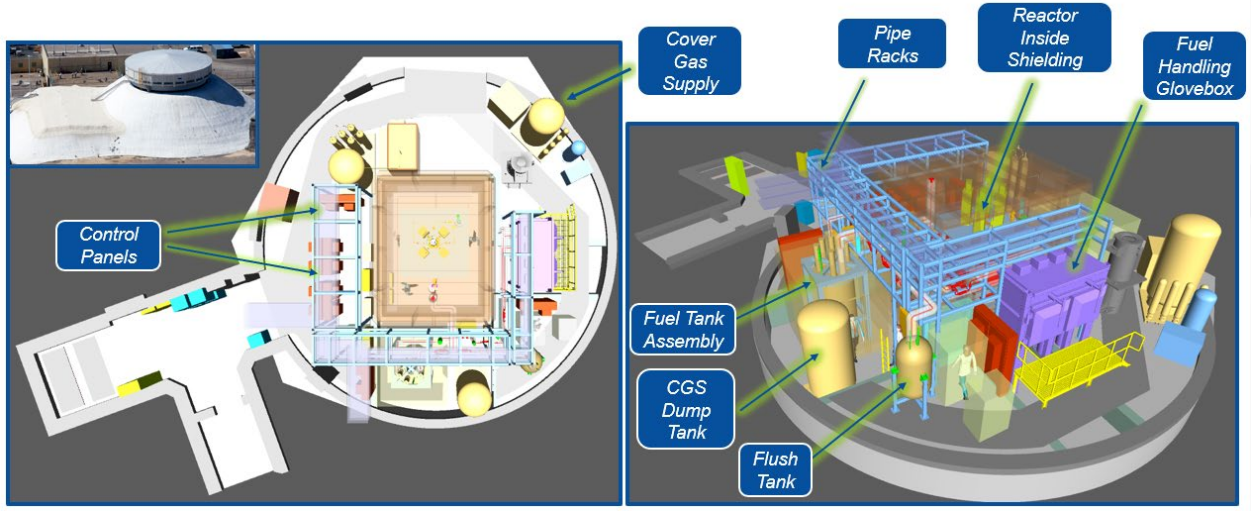
- Conceptual design completed - 12/21
- CD-0 (Mission Need) approved - 3/22
- CD-1 approved - 6/23
- Awarded prelim/final design - 6/23
- Final design complete - 4Q/FY24
- CD-2/3 approve baseline /start construction - 1Q/FY25
- Construction finish - 1Q/FY27
- Operational readiness - 4Q/FY27

LOTUS Test Bed & MCRE Integration

Laboratory for Operation and Testing in the United States

- Maintaining collaboration on interfaces, design requirements, concept of operations
- Includes interfaces and requirements for ~~the~~ MCRE ~~ARD aspects~~ (reactor, shielding, fresh fuel canister, irradiated fuel canister, fueling glovebox)





Continued MCRE ARD 3D digital integration and interface management work reduces the risk of any installation delays or infrastructure misalignment between LOTUS and MCRE.

Siting Tool for Advanced Reactor Development (STAND)

Discover areas that may be a good fit

Explore areas to identify specific sites

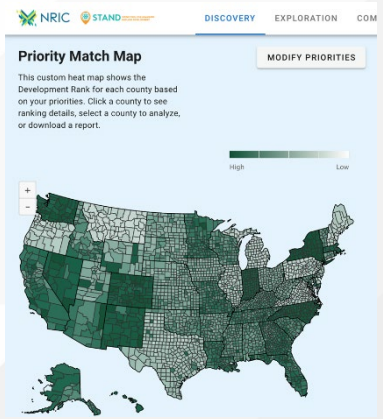
Compare sites to identify an optimal option

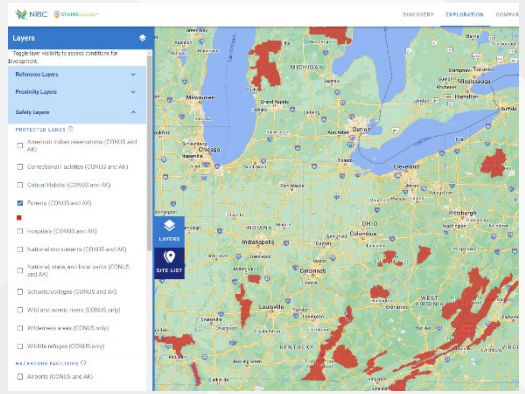
What is it?:

STAND is an integrated tool used to help identify and compare possible siting locations in the U.S. for advanced nuclear facilities based on factors related to:

- Socioeconomics
- Proximity
- Safety

A tool to help answer the question of "Where?" and "Why there?"





INL Idaho National Laboratory | OAK RIDGE National Laboratory | Argonne NATIONAL LABORATORY | NUCLEAR ENGINEERING & RADIOLOGICAL SCIENCES FASTEST PATH TO ZERO INITIATIVE UNIVERSITY OF MICHIGAN

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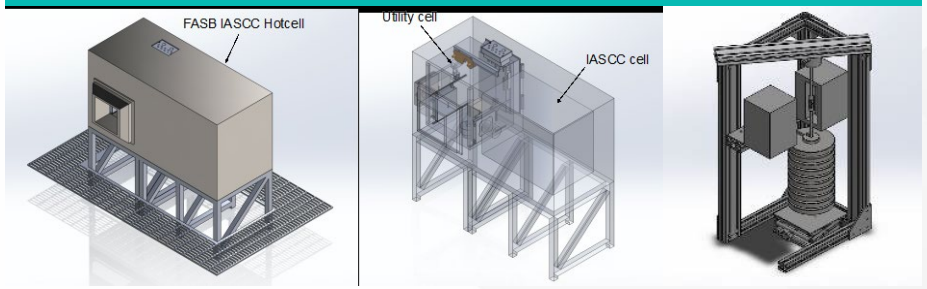
NRIC Experimental Infrastructure

Helium Component Test Facility [*2022*]

In-HotCell Thermal Creep Frame [*2025*]

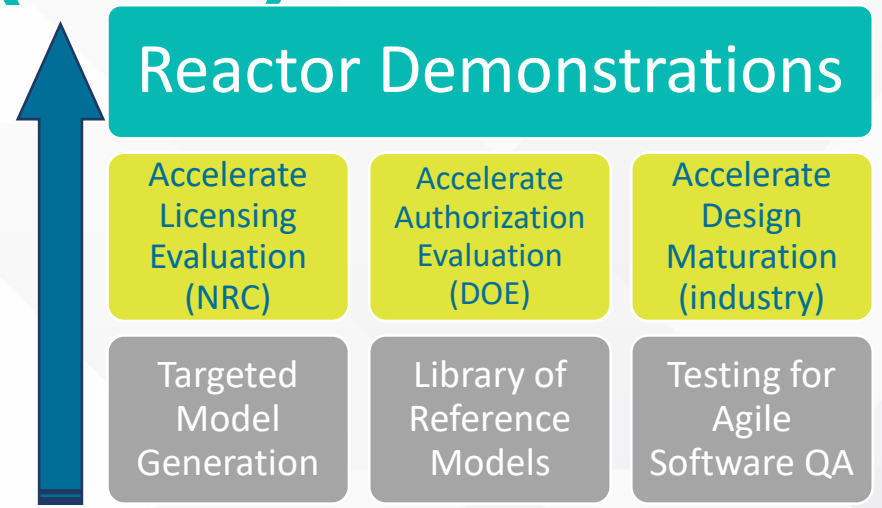


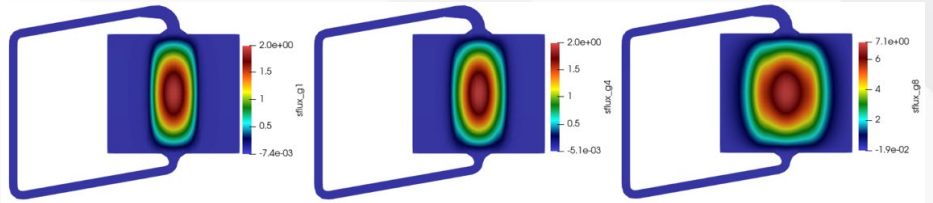
Molten Salt Thermophysical Examination Capabilities (MSTEC) [*2025*]

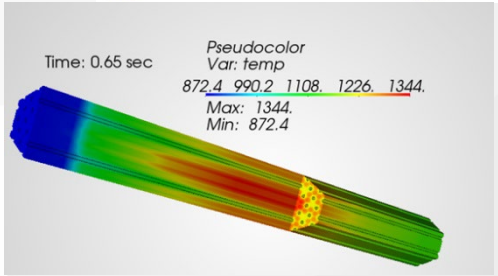
Mechanisms Engineering Test Lab (METL) [Operating]

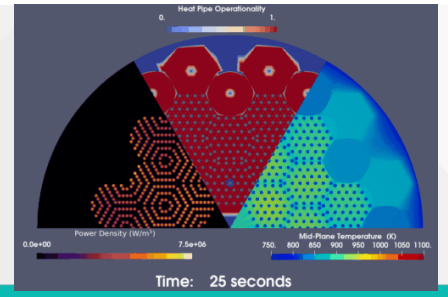
NRIC – Virtual Test Bed (VTB)

- Central location for reactor developers/stakeholders to access and leverage state-of-the art ModSim models of advanced reactors to evaluate performance and safety
- Cross-laboratory and cross-program collaboration between NRIC and DOE Nuclear Energy Advanced Modeling and Simulation (NEAMS) program
- Repository/library of simulations for. Sodium, lead, micro and molten salt reactors (continuously tested)
- Currently hosting 47 distinct models with 15 NEAMS codes
- Averaging 250+ visits/month (period Jan-March 2024)
- FY23 accomplishments:
  - Uploaded 20 new models to the repository
  - Developed reference microreactor and MSR model for DOME and LOTUS testbeds – MSR model already being leveraged for MCRE ARD confirmatory analysis
- FY24 plans
  - Develop virtual model of the NRIC physical test bed (DOME) to accelerate the process for confirmatory safety analysis for future reactor tests.
  - Continue uploading models from external programs to the VTB (NEAMS, ART, NRC, etc)
  - Improve searchability of models and enable large scale testing on the INL HPC system









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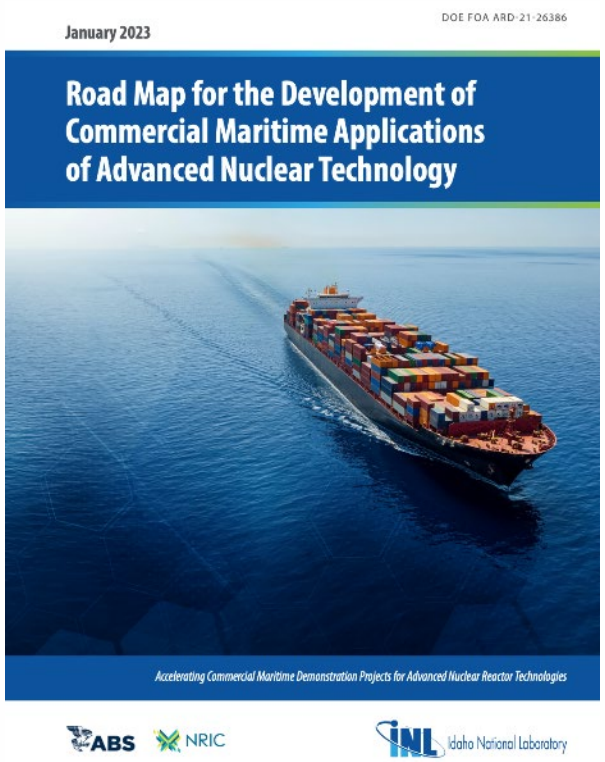
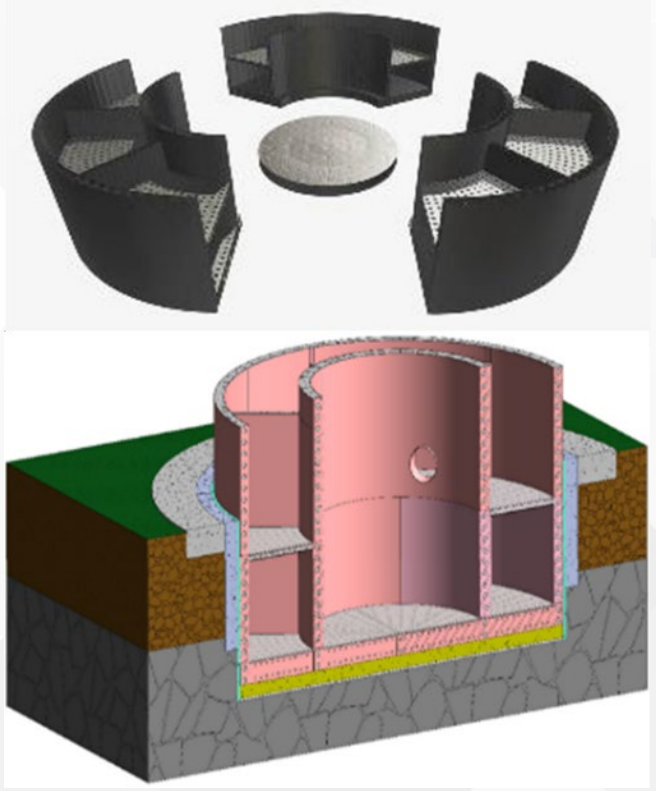
Addressing Cost and Markets

- Advanced Construction Technologies
- Digital Engineering & Knowledge Sharing/Lessons Learned
- Demonstration/Deployment Opportunities (Maritime)





Advanced Construction Technologies

Demonstrate technologies that:

- Reduce cost of new nuclear builds by 10%+
- Compress construction schedule by as much as 25%
- Reduce required site work & improve overall quality of structure
- Support long-term structure monitoring

Phase One (Expected completion July 2024)

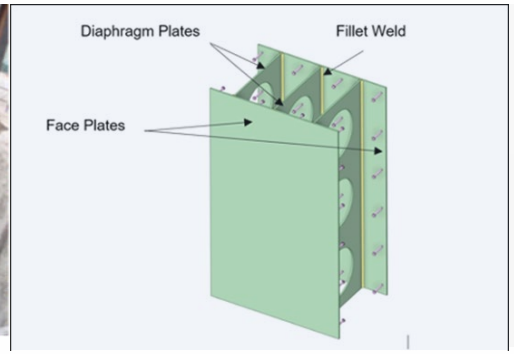
- Prototype modular steel/concrete composite walling system
- Developed non-destructive examination and welding techniques
- Demonstrated strength of wall systems

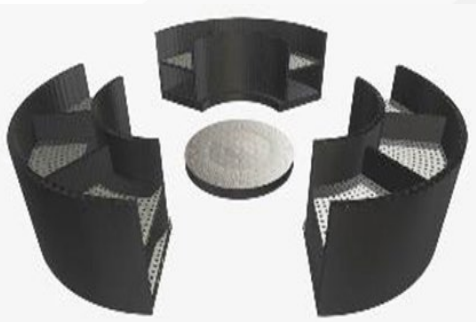
Phase Two (Expected start Sept 2024)

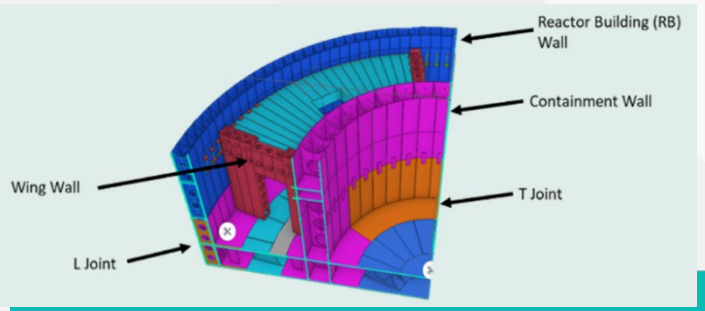
- Demonstrate 60-degree pie shape containment walling system
- Inner and outer walls, base mat integration, multi-story
- Deploy digital twin plus sensor technology for monitoring

Team – General Electric Hitachi

EPRI, Black & Veatch, Purdue, UNCC, Nuclear Advanced Manufacturing Research Centre, Caunton Engineering w/Modular Walling Systems Ltd, Aecon and Tennessee Valley Authority







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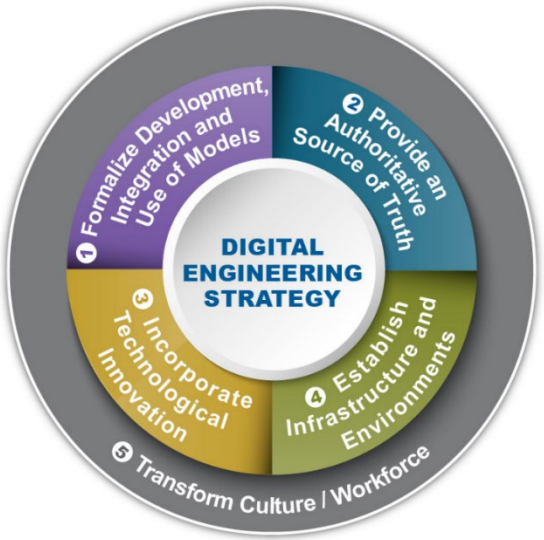
Digital Engineering (DE)



- **What?** An integrated digital approach that uses authoritative sources of truth for data and models across disciplines to support project lifecycle activities from concept through disposal
- **Why?** With typical industry project **cost overruns** of 241% and 180% in **schedule delay**, digitization of the overall processes can have a significant impact on nuclear deployment and cost viability
- **Implementation Process & Progress to Date**
  1. Transform the way organizations generate design data by deploying **model-based tools**: IBM DOORS Next, Innoslate MBSE, PTC Creo, Autodesk Revit, etc. [Complete, TRL 9]
  2. Transform the way organizations manage, store, and connect data using **digital threads** to form a comprehensive **digital ecosystem**: PTC Windchill, INL Deep Lynx Warehouse, software adapters & APIs, etc. [In Process, TRL 6]
  3. Transform the way organizations leverage data using **digital twin** technology: extended reality (XR), Unity game engine, real-time data acquisition (DAQ), machine learning (ML), artificial intelligence (AI) [In Process, TRL 3]
- **Next Steps**:
  - Progress digital ecosystem development and release “playbook” and open-source code repository
  - Develop first nuclear facility digital twin at DOME incorporating physics-based modeling, predictive machine learning, real-time data feedback, etc.

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Evaluating Maritime Applications NRIC & American Bureau of Shipping (ABS)

Maritime Nuclear Application Group

- Collaboration with ABS and Morgan & Lewis Law Firm
- Research Hub and Resource Center
- 120 members representing 40+ companies
- Gap assessment of testing capabilities for maritime nuclear applications

ABS iFOA Award

- DOE Readiness Report (Task 3)
- Upcoming: Overcoming Barriers to Nuclear-Maritime Demonstrations (Task 4)

Nuclear Energy University Program

*MNAG is a **research hub** and **resource center** that brings together experts from the maritime and nuclear energy sectors to facilitate the demonstration of advanced nuclear technologies for a range of marine applications.*

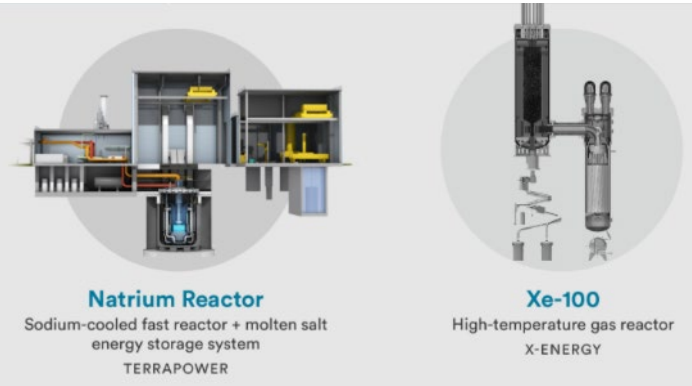
THE UNIVERSITY OF TEXAS AT DALLAS

NRIC National Reactor Innovation Center

INL Participation in ARDP Projects

- 9 projects supported
- Scope range
  - Modeling & Simulation
  - Irradiation & PIE
  - Fuel design & fabrication
- ~$175M – 7 years
  - $1M - $75M per project
- NRIC/INL Coordinator
- NRIC Deployed Digital Engineering and project management tools

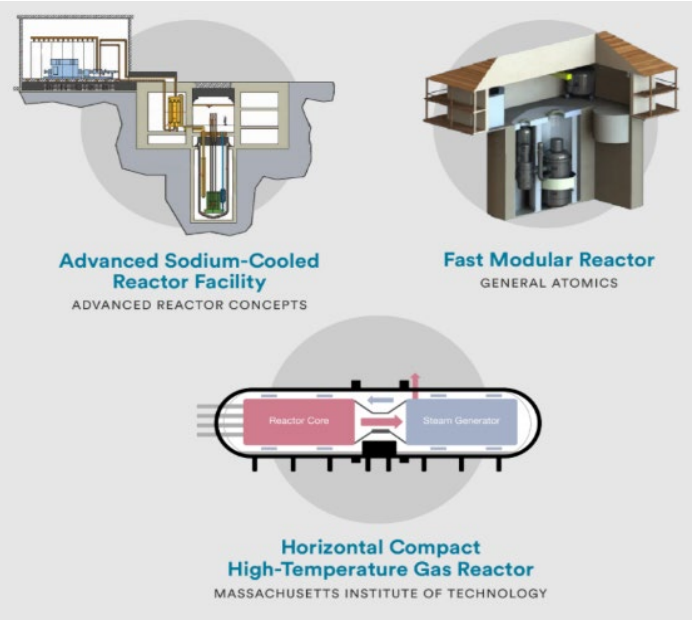
Demonstration



Natrium Reactor
Sodium-cooled fast reactor + molten salt energy storage system
TERRAPOWER

Xe-100
High-temperature gas reactor
X-ENERGY

Concept Development

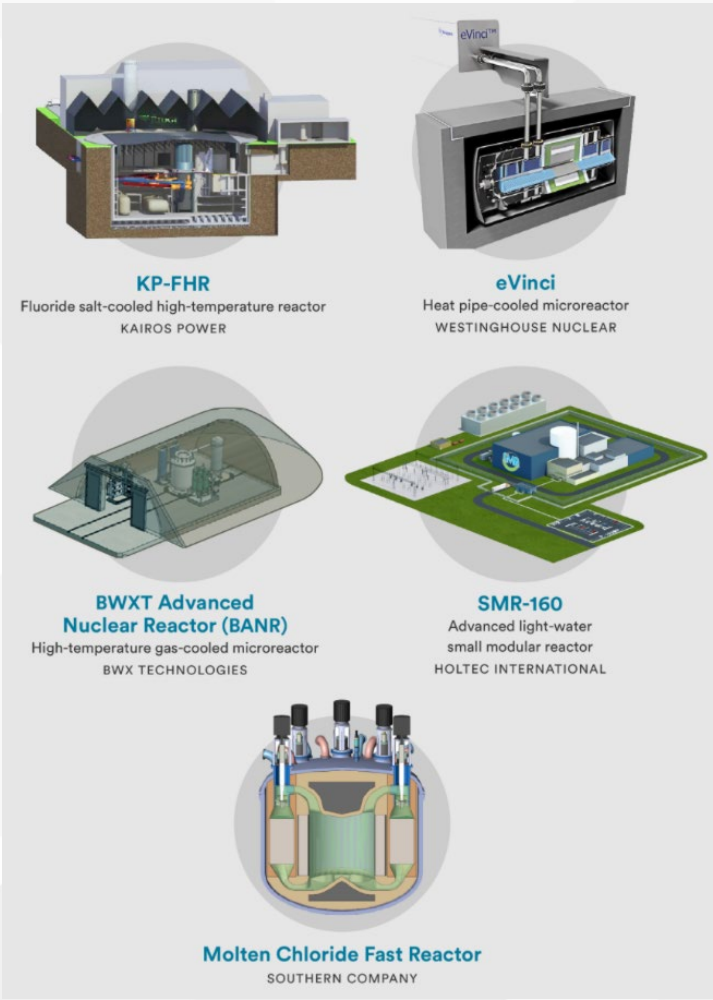


Advanced Sodium-Cooled Reactor Facility
ADVANCED REACTOR CONCEPTS

Fast Modular Reactor
GENERAL ATOMICS

Horizontal Compact High-Temperature Gas Reactor
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Risk Reduction



KP-FHR
Fluoride salt-cooled high-temperature reactor
KAIROS POWER

eVinci
Heat pipe-cooled microreactor
WESTINGHOUSE NUCLEAR

BWXT Advanced Nuclear Reactor (BANR)
High-temperature gas-cooled microreactor
BWX TECHNOLOGIES

SMR-160
Advanced light-water small modular reactor
HOLTEC INTERNATIONAL

Molten Chloride Fast Reactor
SOUTHERN COMPANY

NRIC National Reactor Innovation Center

Benefits of Testing & Demonstration

- Bridge the gap between development and commercialization
  - Providing funding to mature technology readiness and reduce risks to participants for first of a kind build
  - Facilitate partnership between technology developers, end users, national labs, universities, regulators, industrial participants
- Learn by doing reduces risks associated with first commercial build
  - Types of materials standardly available in the US vs Europe
  - Optimize design for assembly
  - Establish construction procedures – welding, lifting, NDE, etc.
  - Sequencing of operations
- Builds confidence with regulators, construction entities, and trades
- Develop supply chain

Summary: Key Accomplishments

- Testbeds
  - DOME
    - Awarded construction contract to Estech - Aug 23
    - Initiated full construction - October 23
    - Established CPP-651(INTEC) as fuel storage location
    - Established RSWF as irradiated reactor temporary storage location
    - Awarded design contract for Reactor Supplemental Shielding
    - Awarded three Front-End Engineering and Experiment Design contracts – Sept/Oct 23
  - LOTUS Test Bed
    - CD-1 approved, and design contract awarded – Jun 23
    - Preliminary design review – Jan 24
    - Technical Independent Project Review (TIPR) – Mar 24
- Experimental Infrastructure
  - MSTEC construction is moving along well – Glove box delivered and installed
- VTB developed new models and problem sets
- ACTI
  - Pivoted to new design on steel/concrete composite modular walling system
  - Extended Phase I to test new design
- Adjusted NRIC's project portfolio to focus more on core activities and eliminated efforts in:
  - Resource Team program – deferring to GAIN voucher program
  - Leading community engagement activities

Challenges

- **Challenges over past year**
  - Significant cost increases across many projects
    - Supply chain for key equipment and labor market shortages
    - NRIC trending to maintain cost and schedule on key projects
  - Advanced reactor testing requires a complex ecosystem
    - Support equipment (fueling/shielding/defueling)
    - NRIC has plan to secure these items
  - Securing needed program managers and engineering workforce to support rising workload associated with multiple tests
    - NRIC brought on new technical program managers this past year and will bring on more
- **Challenges going forward**
  - Budget needs to be sustained
  - NRIC/INL/DOE need to run as fast as our industry partners

Look Ahead

- **Test Infrastructure**
  - Complete three FEEED Efforts
  - Complete final design and submit PDSA for LOTUS
  - Complete construction of MSTEC
- **Other Program Areas**
  - Complete Phase 1 testing under ACTI program
  - Maritime gap assessment
  - Update NRIC gap assessment

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5/22/2024

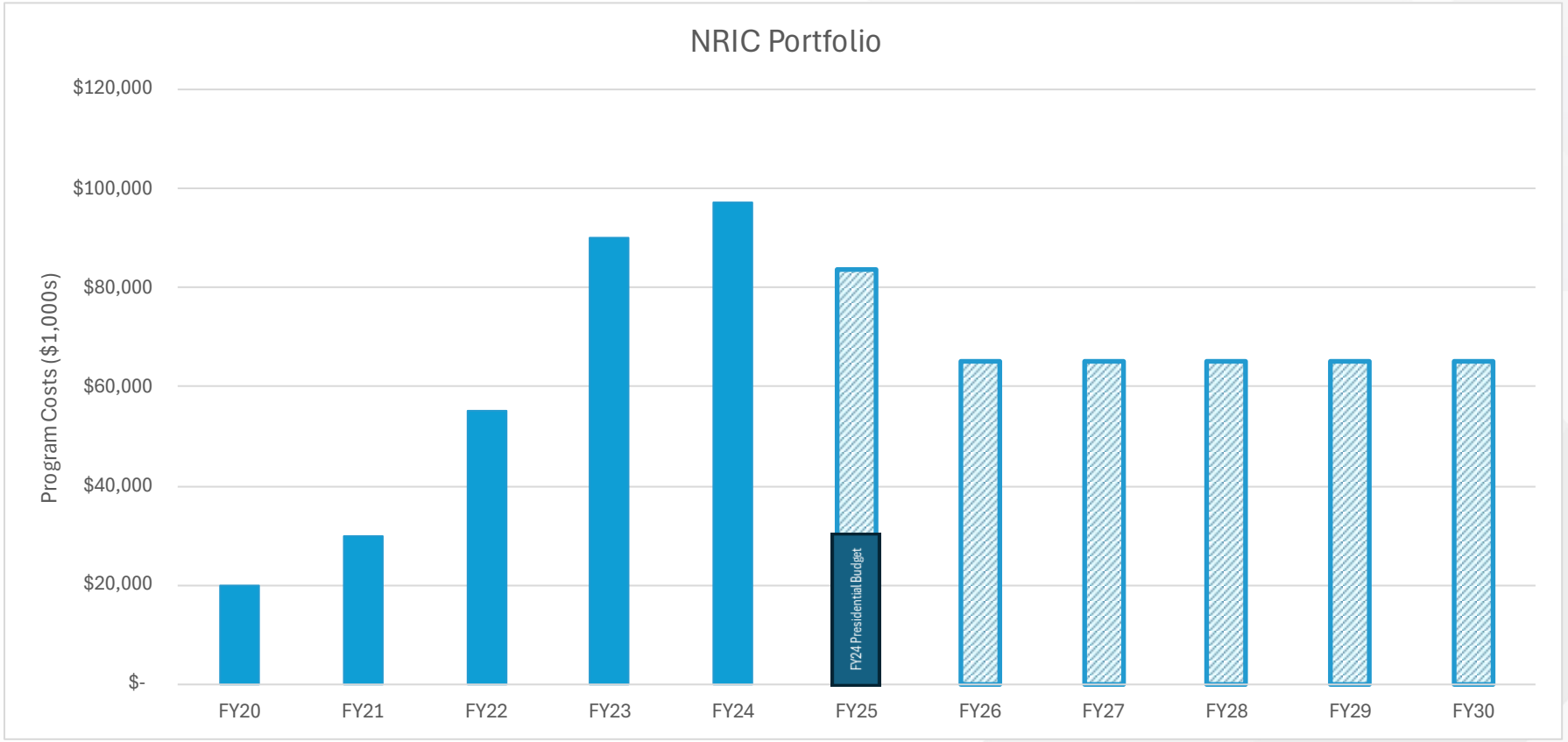
www.nric.inl.gov

Collaborative Approach

NRIC is partnering regionally and nationally to support testing and demonstrations

NRIC INL

NRIC Portfolio Budget Needs Going Forward



*LOTUS Line Item not included in totals

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