



Oct 24 2023 Tomer_ NRIC Update for NE NTD meeting

October 2023

Changing the World's Energy Future

Bradley John Tomer



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**Idaho National Laboratory
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<http://www.inl.gov>

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NRIC

National
Reactor
Innovation
Center



National Reactor Innovation Center Update

October 24, 2023

Brad Tomer, Acting Director, Chief Operating
Officer
nric.inl.gov



NRIC is a DOE program, launched in FY'2020



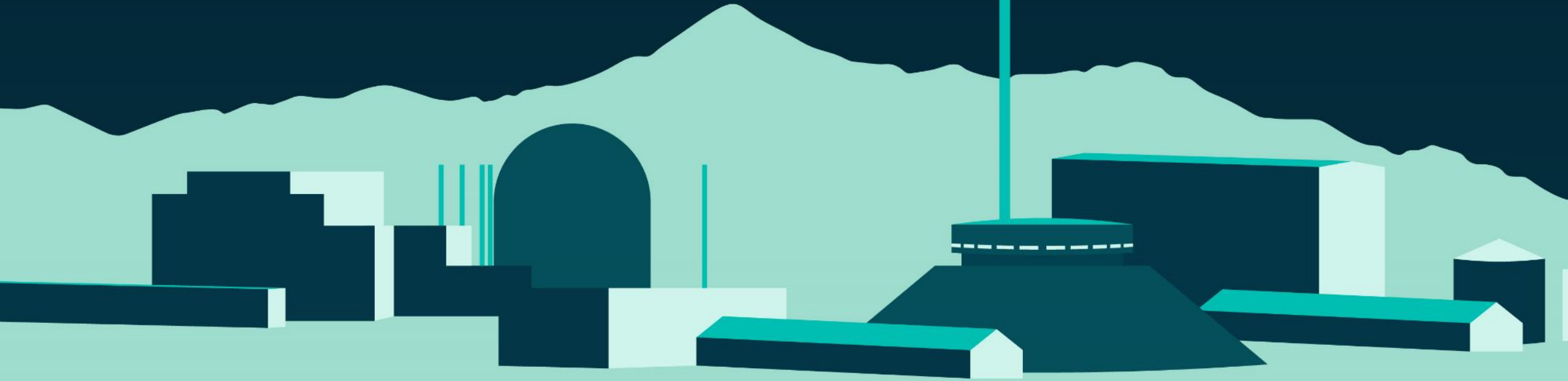
NRIC Enables Nuclear Reactor Tests & Demonstrations

- 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



Vision: Enable commercial advanced nuclear by 2030

Portfolio Designed to Empower Innovators



- Building foundation for testing
 - Advanced Reactor Test Beds
 - Experimental Facilities
 - Virtual Test Bed

- Addressing Costs & Markets
 - Advanced Construction Technologies
 - Digital Engineering for Nuclear
 - Maritime Applications

Program Goal and Objectives

- Accelerate the testing and demonstration of advanced nuclear technology by providing access to national laboratory assets and expertise:
 - Establish & maintain four new experimental facility capabilities
 - MSTEC – 2025; METL – Operational; HeCTF – Operational; Creep Frames – 2026
- Construct and operationalize two large reactor test beds for integrated technology demonstrations and experimentation - 2028,
- Complete minimum of two advanced nuclear technology tests – 2030
 - Advanced Construction Technology – 2025
 - Advanced Microreactor test in DOME – 2027 & 2029

NRIC-DOME Test Bed

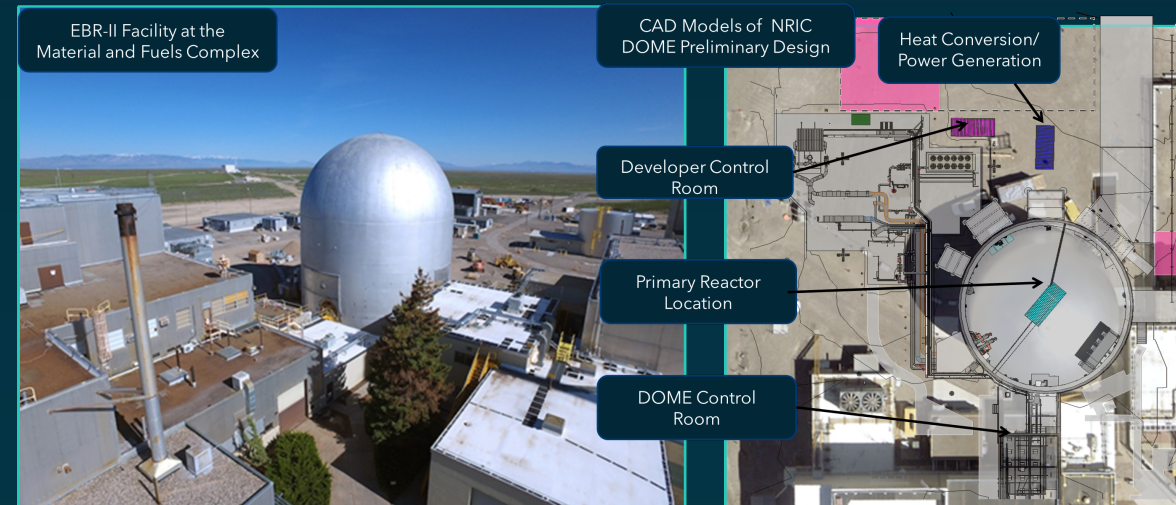
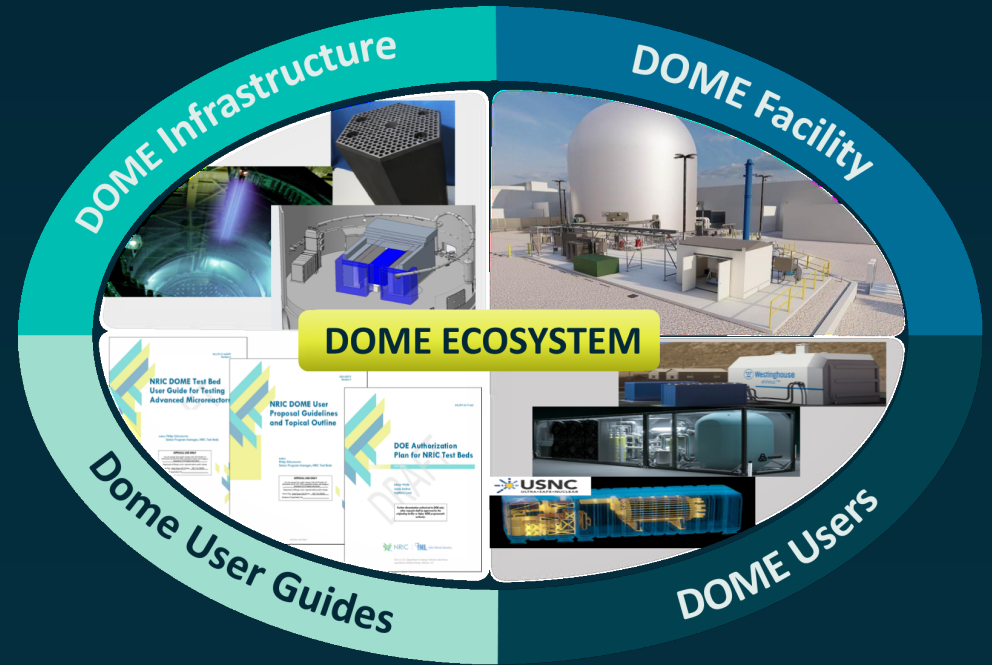
(Demonstration of Microreactor Experiments)

Test Bed Ecosystem:

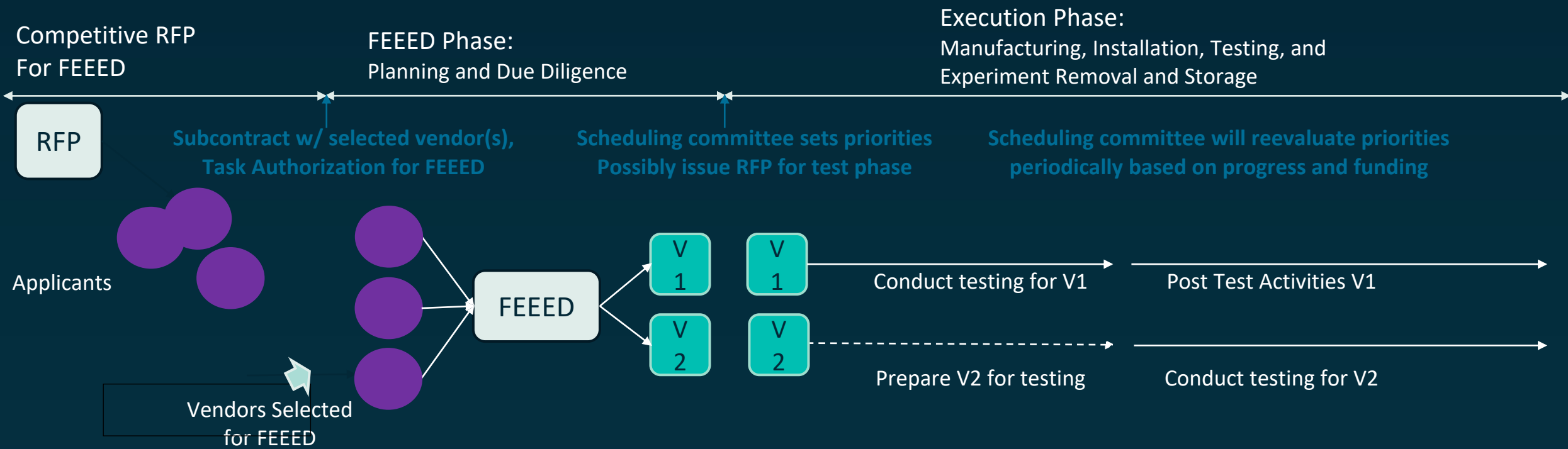
- DOME structure
- Modular reactor shielding
- Fresh & Irradiated fuel/reactor storage and handling facilities
- Complete end-to-end support equipment & user guide covering all stages of testing a reactor from design to decommissioning irradiated fuel & equipment

Progress:

- Overcame significant supply chain issues and awarded DOME construction subcontract with construction-initiated Sept 23
- Streamlined reactor authorization process w/DOE-ID approval
- Secured pivotal agreements for fresh & irradiated fuel & reactor storage (CPP 651 and RSWF)
- Completed supplemental shielding conceptual design
- Issued RFP for cost-shared FEEED process and selected 3
- Issued first "official" end-to-end user guide (living document)



Proposed DOME Reactor Testing Program Process

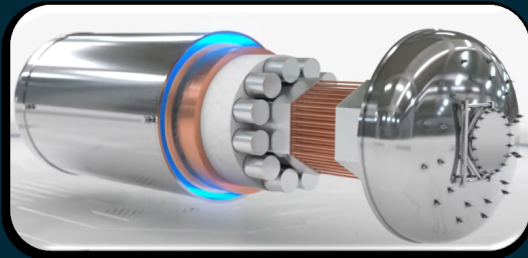


Application Process	FEEED Phase Goals	Prioritization Options	Execution Phase Goals
- Solicit applications for Front End Engineering and Experiment Design for testing in DOME - Cost-shared RFP option: Evaluate and select multiple high-ranking projects based on availability of funds - Industry funded option: evaluate and recommend path forward	Develop program plan for each advanced reactor selected under RFP including conceptual reactor design, reactor experiment test plan, safety documentation and DOE authorization plan, NEPA plan, detailed schedule and cost estimate for testing through decommissioning	- Scheduling committee consisting of NE5, INL (NS&T, NRIC & MFC), DOE-ID review results of FEEED phase and prioritize based on: Maturity of reactor design, availability of funding and funding source, access to fuel, and proposed schedule. (annual reassessment) - Based on availability of DOE funding may issue an RFP for testing phase - NE-5 final approver of priority	- Complete all outstanding design work - Manufacture, deliver, assemble, and install all hardware, software, and supporting equipment in the DOME - Execute experimental reactor test program - Remove experiment from the DOME - Deactivation and decommissioning

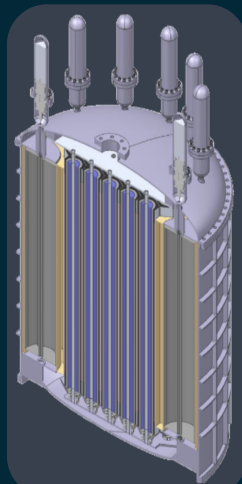
Front End Engineering & Experiment Design

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

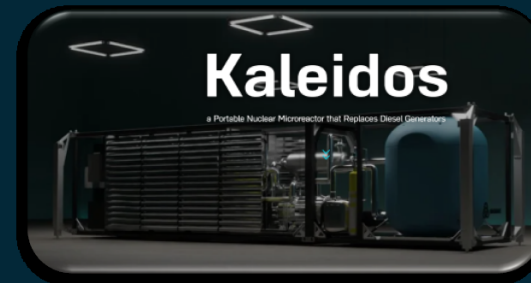
Developer	Reactor Name	Design	Power Mwe	Power MWth	Fuel Type	Fuel Enrichment	Primary Coolant	Moderator	Refueling Interval (Years)	Power Conversion System
Radiant	Kaleidos	HTGR	1.2	3.5	TRISO	19.75%	Helium	Graphite	6	Brayton Cycle
USNC	Pylon	HTGR		1	TRISO	9.90%	Helium	Graphite		Rankine
Westinghouse	eVinci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



Westinghouse - eVinci



USNC - Pylon



NRIC-DOME Test Bed

Next Steps:

- Award FEEED contracts – Oct/Nov 23
- Complete 3 FEEED processes – Sept 24
- Initiate scheduling committee – Dec 23
- Award shielding design contract – Oct 23
- Incorporate learnings/updates in user guide based – Sept 24
 - FEEED learnings
 - Fresh fuel and irradiated reactor/fuel storage procedures
 - Reactor operator training requirements
 - Shielding design
- Complete DOME construction – June 25
- Complete Operational readiness – June 26
- First reactor installed - 2026



Challenges Ahead:

- Unknowns during construction
- Simultaneous development of DOME and private sector advanced reactors creates risk for both
 - Reactor developers need certainty for investments
- Funding for/cost of shielding and support equipment
- Establishing defueling approach

NRIC-LOTUS Test Bed

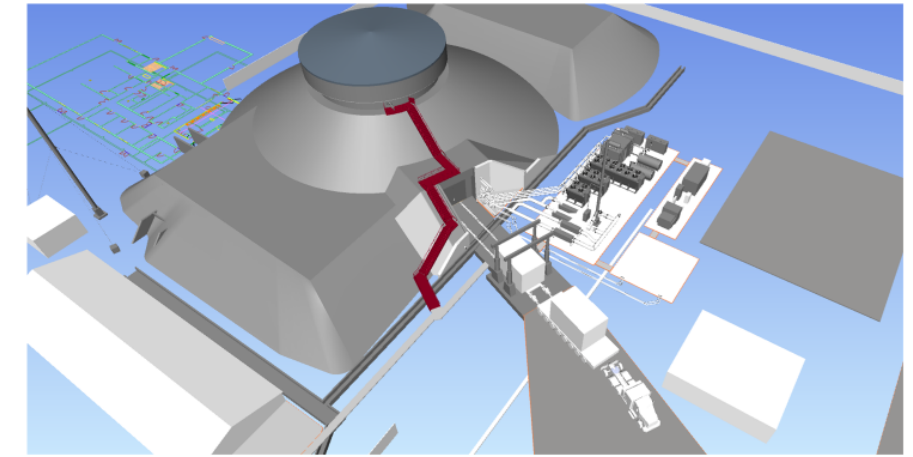
Description

- Advanced Microreactors up to 500kW_{th} using HEU
- 13ft X 13ft side entry
- 50kW_{th} 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 413.3B project with Gerardo Islas-Rivera as the Federal Project Director and Contracting Officer Representative; NE-3 is the Project Management Executive



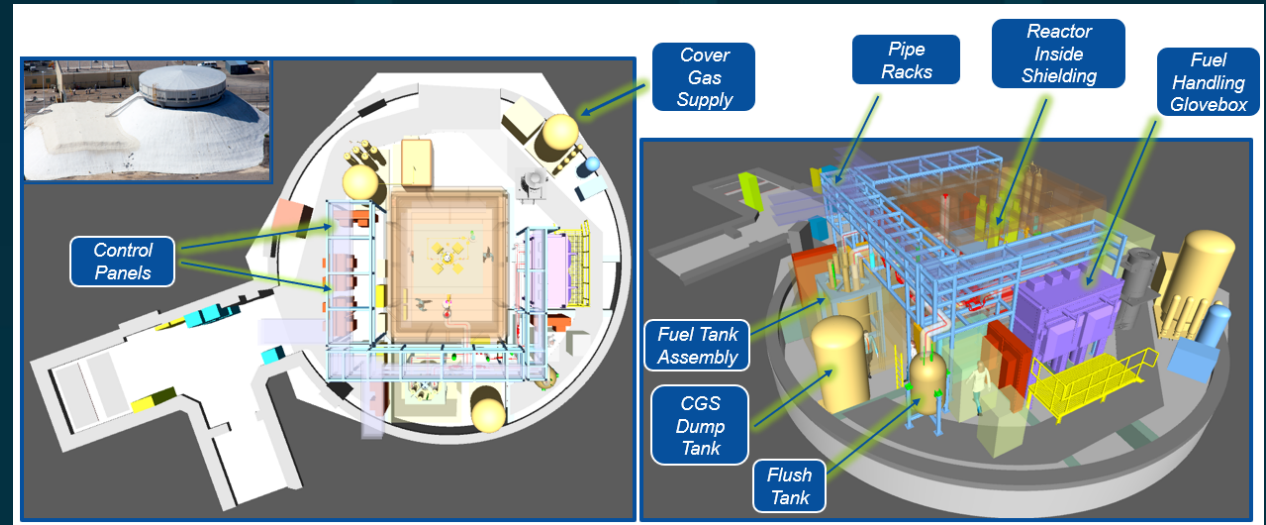
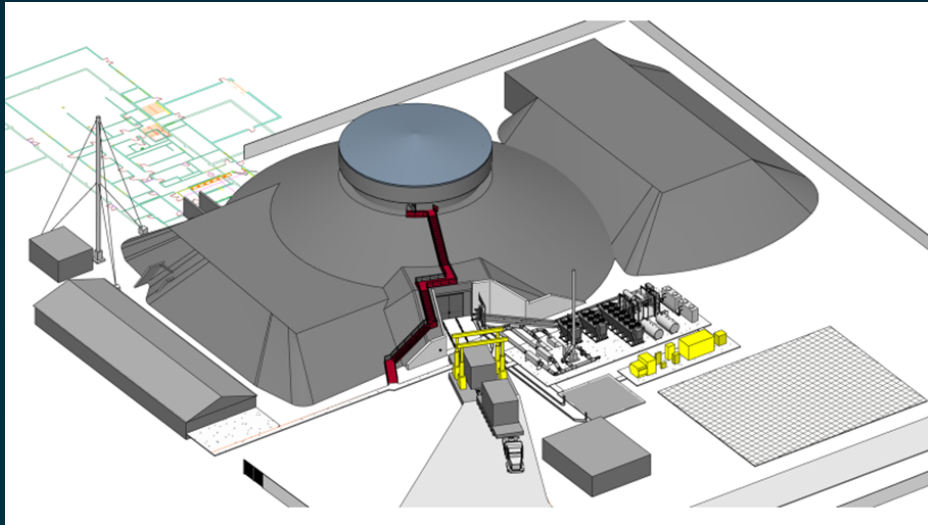
Schedule (Performance Baseline to be set at CD-2/3)

- 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

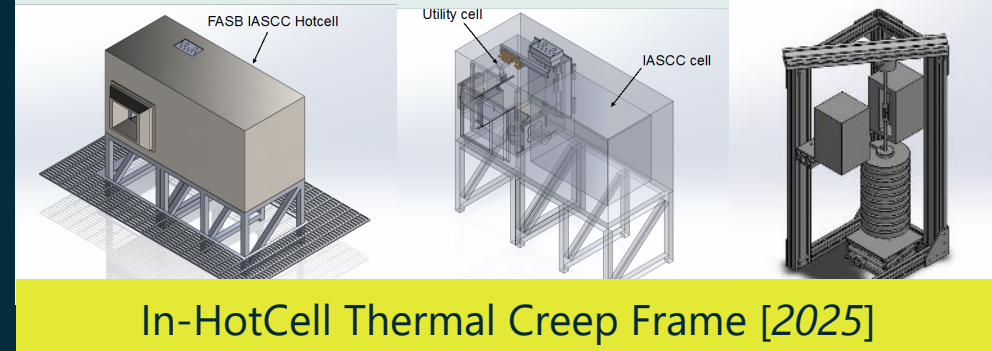
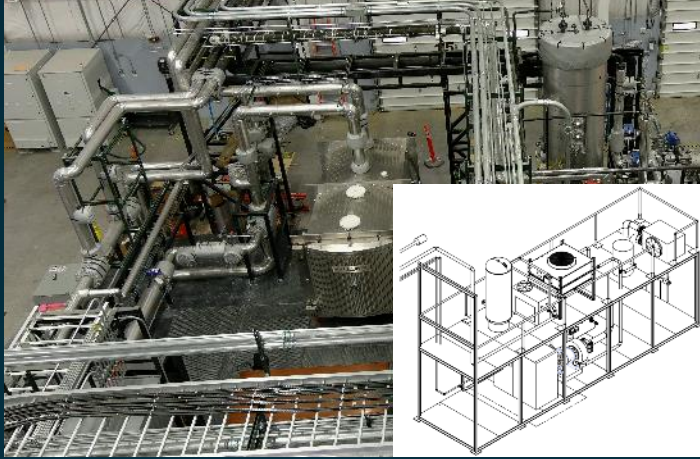
- Maintaining collaboration on interfaces, design requirements, concept of operations
- Includes interfaces and requirements for the MCRE ARD aspects (reactor, shielding, fresh fuel canister, irradiated fuel canister, fueling glovebox)



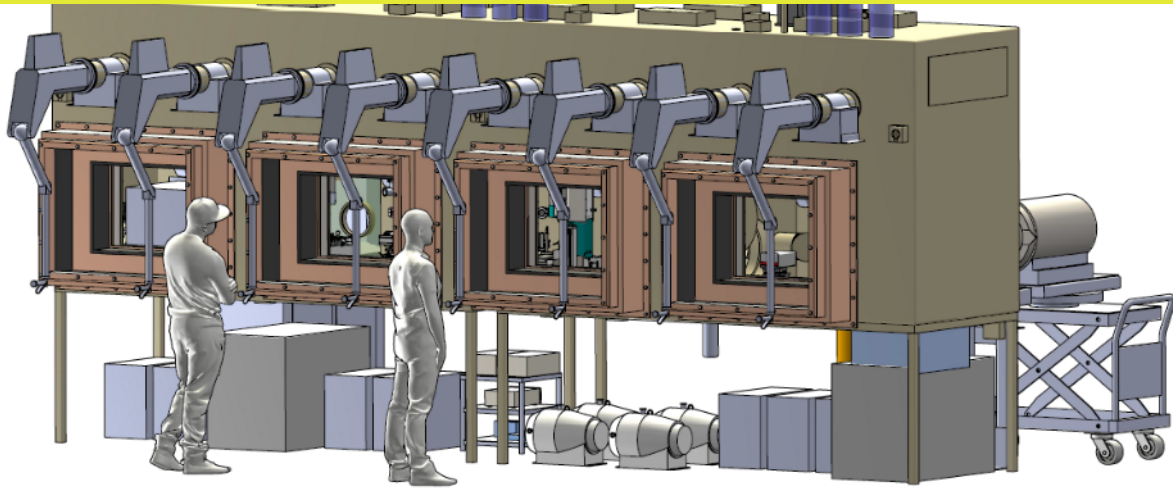
Continued MCRE ARD 3D digital integration and interface management work reduces the risk of any installation delays or infrastructure misalignment between LOTUS and MCRE.

NRIC Experimental Infrastructure

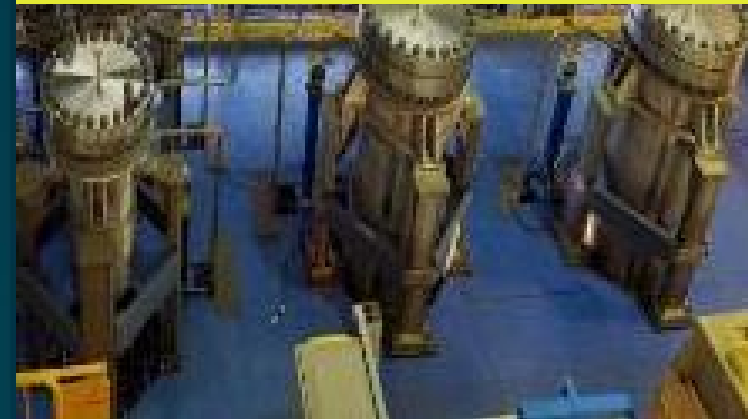
Helium Component Test Facility
[2022]



Molten Salt Thermophysical Examination Capabilities (MSTEC)
[2024]



Mechanisms Engineering Test Lab
(METL) [Operating]



MSTEC Project Status

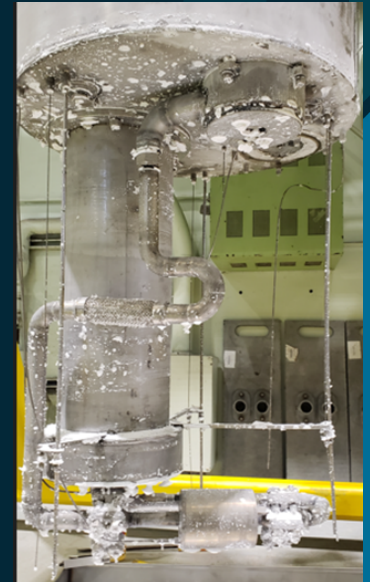
- Overview: A post-irradiation examination capability focused on fuel salts at high temperature
 - Shielded capability for high-actinide and irradiated salts
 - Thermophysical properties
 - Self-irradiation behaviors (including off-gas)
 - Versatile workspace for users (academia, industry, etc.) to test equipment on irradiated or actinide-bearing salts
- Timeline
 - FY20 – Design requirements for glovebox completed, purchased characterization equipment
 - FY21 – Issued PO for glovebox, installed characterization equipment (temporary)
 - FY22 – Facility D&D, glovebox build, scientist development on characterization equipment
 - FY23 – Completion of facility modifications, finalization of characterization equipment testing, fabrication of MSTEC
 - FY24 – Complete MSTEC fabrication, installation in FCF, and initiate acceptance testing
 - FY25 – Commissioning and readiness assessment



Agreement	Contract Value Related to Thermophysical Properties of MSR Fuel Salts
SPP with Seaborg Technologies of Denmark	\$2,500,000
CRADA with Korean Atomic Energy Research Institute	\$1,000,000
MCRE ARDP	~\$1,500,000
MRTI Molten Salt Irradiation	\$2,000,000
DOE MSR Campaign	\$500,000
NNSA	Under development
Nonproliferation Stewardship Program (NSP)	Under development, \$10-30,000,000

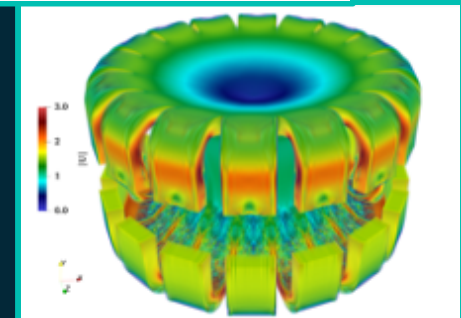
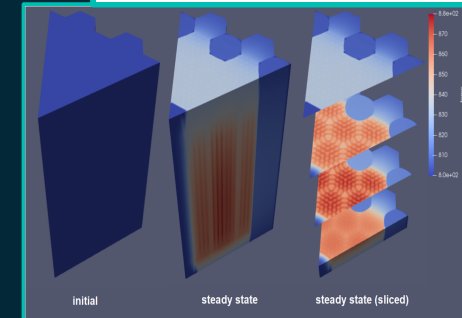
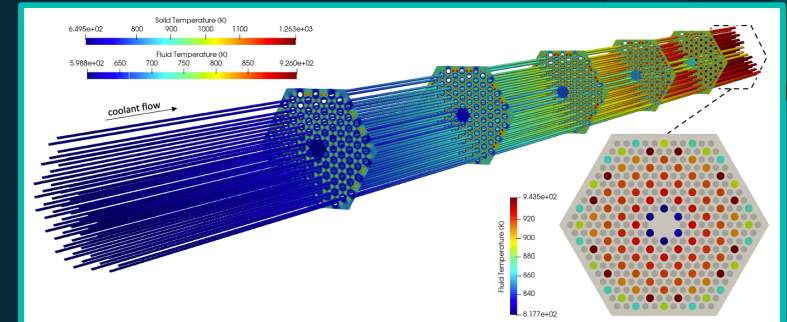
Mechanisms Engineering Test Loop (METL)

- **Purpose:** test small or intermediate scale advanced liquid metal components and instrumentation in sodium
- **FY23 Accomplishments**
 - Completed business operating plan
 - Supported testing of the Gear Test Assembly (GTA)
 - Supported removal and reconfiguration of the Thermal Hydraulic Experimental Test Article (THETA)
 - Initiated install of Test Vessel 6
- **FY24 Plans**
 - Test GTA and THETA
 - Complete installation of Test Vessel 6
 - Plan testing for an industry test article
 - Initial testing of the Flow Sensor Test Article



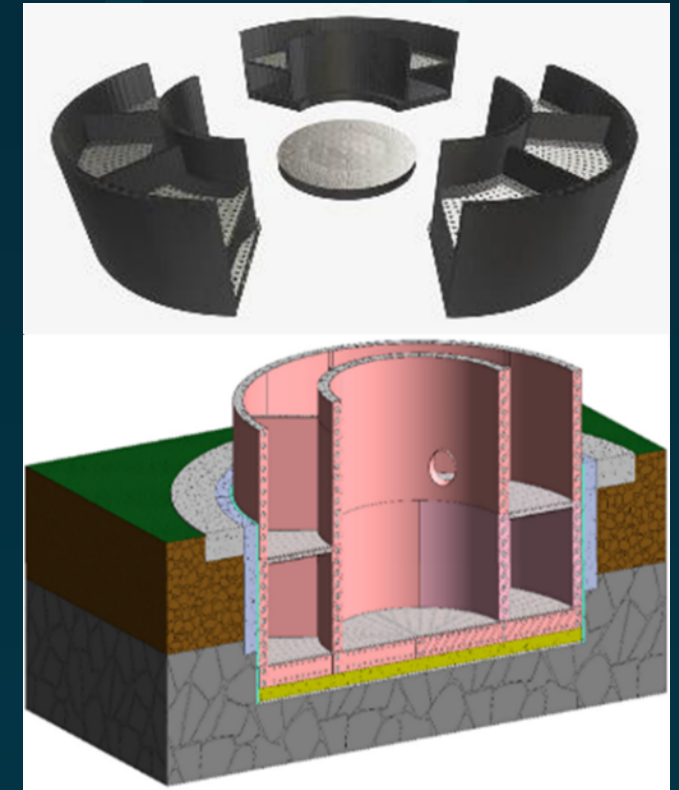
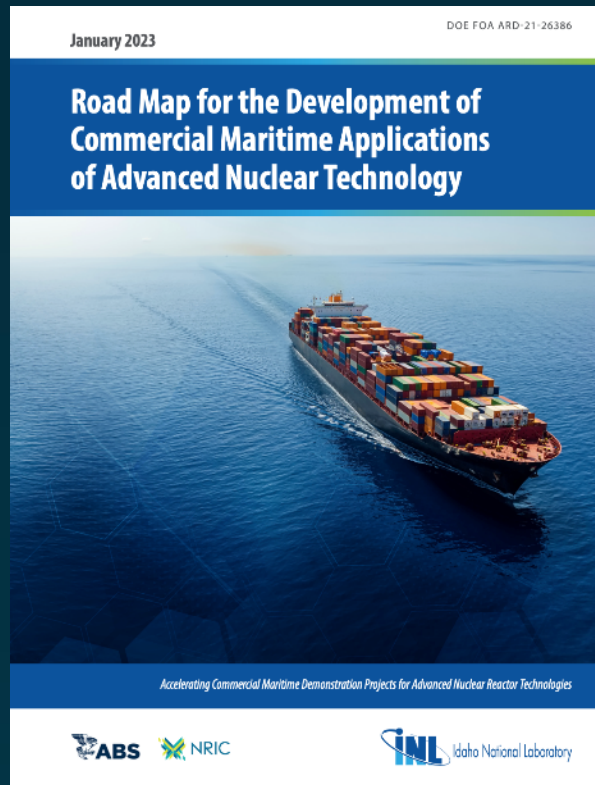
NRIC – Virtual Test Bed (VTB)

- Central location for reactor developers/stakeholders to access & leverage state-of-the-art ModSim models of advanced reactors to evaluate performance & 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, gas, lead, micro, and molten salt reactors (continuously tested)
- Currently hosting 38 distinct models with 12 NEAMS codes showcases... **More coming soon!**
- Averaging ~250 visits/month (period between July-Sep 2023) – representation from Industry/Regulators/Academia
- FY23 –
 - Uploaded 19 new models to repository
 - Developed reference microreactor and MSR model for DOME and LOTUS testbeds respectively - MSR model already being leveraged for MCRE ARD confirmatory analysis
- FY24
 - Develop virtual model of the NRIC physical test bed (DOME) to accelerate the process for confirmatory safety analysis of 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



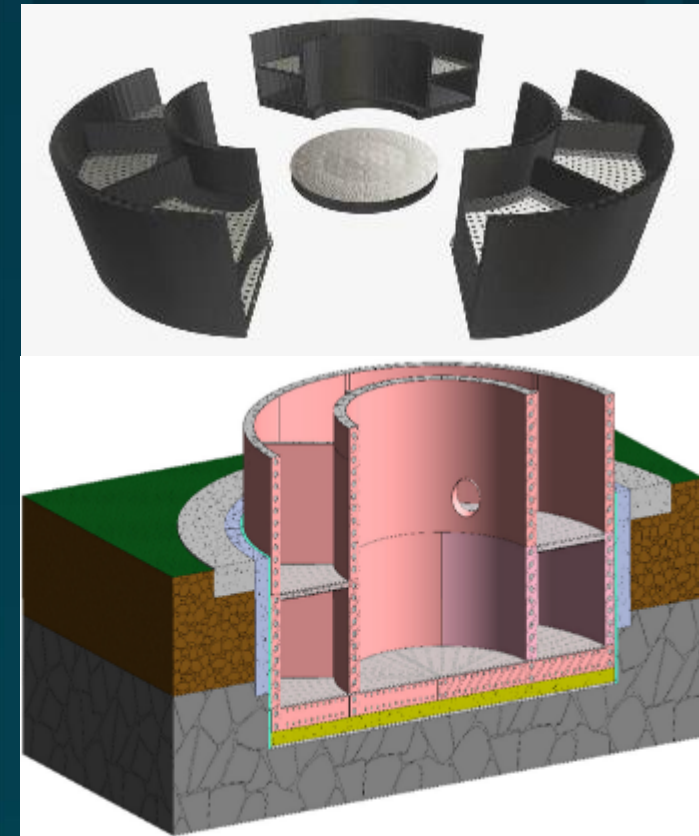
Addressing Cost and Markets

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



Advanced Construction Technology

- **Project Awarded – January 2022**
- **Team - General Electric Hitachi**
 - EPRI, Black & Veatch, Purdue, UNCC, Nuclear Advanced Manufacturing Research Centre, Cauntan Engineering w/Modular Walling Systems Ltd and Tennessee Valley Authority
- Purpose - demonstrate technologies to:
 - Reduce the cost of new nuclear builds by >10 percent
 - Speed the pace of advanced nuclear deployment
- **Two phase cost-shared project w/demo in FY2025**
 - Vertical shaft excavation techniques
 - Steel Bricks™
 - Advanced monitoring & digital twin technology



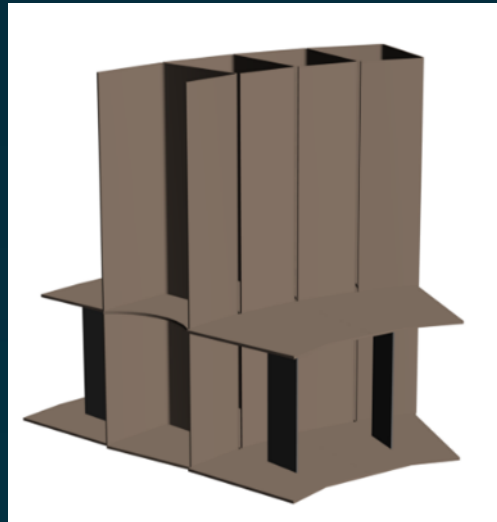
Steel Brick™ Concept



Steel Brick™ Fabricated at Shop

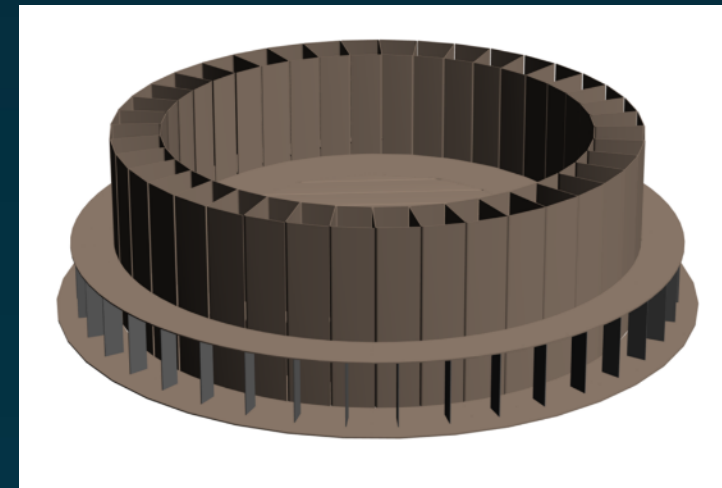
Concurrent wall fab and excavation
Reduced schedule duration

Next generation Steel Concrete Composite modules, for Seismic Category 1 structures installed in a radial configuration



Steel Brick™ Modules
Shipped to site

Reduced onsite work
Improved quality
Less rework



Assembled in field, outside of pit,
lowered into pit

Digital Twin – Advanced Construction

- State of the art replica of the structure to integrate sensor data, artificial intelligence, machine learning, and data analytics. Cradle to grave monitoring
- EPRI, University of North Carolina Charlotte, Nuclear AMRC
- Organizes all project data by component and by life-stage
 - Each module with its own rich information, models and sensors
 - Flow of information through the modules - Back and Forth
 - Ability to query, investigate, assess conditions of individual Steel Bricks™ in the structure.
 - Semi-automated procedures to update Building Information Modeling & Finite Element Analysis models from field measurements
 - Long-term monitoring combining structural models with:
 - Earth pressure sensors (lateral stress)
 - LiDAR scans of base, shaft walls and ground surface
 - Procedures to stream data from the field for real-time decision-making via wireless transmission of sensor data

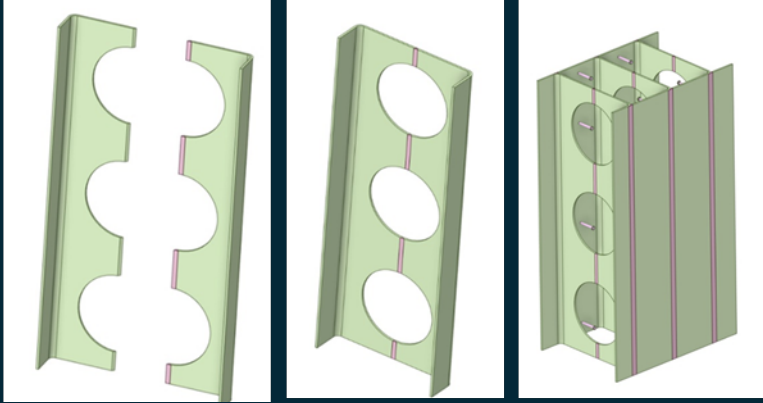
Phase I accomplishments:



- Proved concept of fabricating Steel Blocks™ assemblies in factory setting, demonstrating the ability to achieve tighter tolerances than conventional methods.
 - Demonstrated NRC methods to inspect the concrete for voids inside a steel enclosure.
 - Developed welding methods using automatic devices to improve quality.
 - Demonstrated the strength of Steel Blocks™ assemblies and displacement plate (DC) enclosures in ground-based stress calculated using NRC equations.
- Demonstrated vertical shaft construction readiness using vacuum plate and displacement plate.
- Established digital twin and monitoring techniques.
 - Demonstrated digital image capture of fabricated walls, confirmed digital twin technology, used to evaluate the fabrication of assembly.
 - Selected technology to inspect and evaluate ground reaction pressure and movement against reactor building.
- Proved design from Steel Blocks™ to Displacement Plate Steel Composite (DPSC) using SAE800 for Phase II.
- Fully engaged NRC through the relations of Fred Sock and Allen Fetter from NRC to NRC.

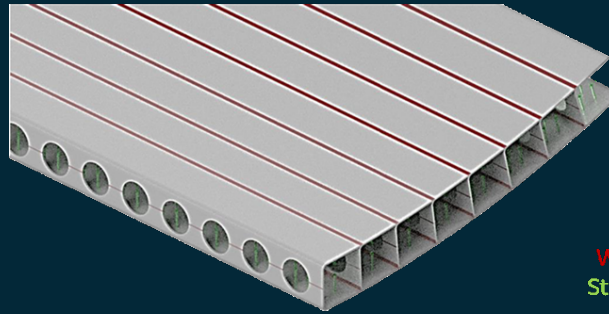
Next Steps

Fabrication Sequence for Steel Bricks™

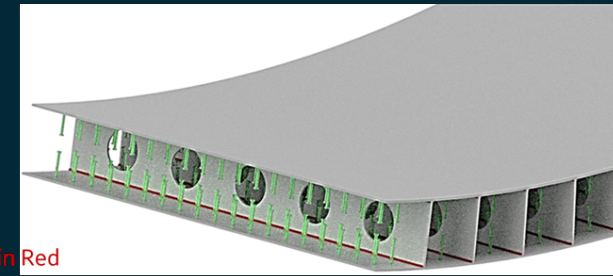


Design Pivot to Diaphragm Plate Steel Composite

Steel Bricks™ Module



DP-SC Module



Welds in Red
Studs in Green

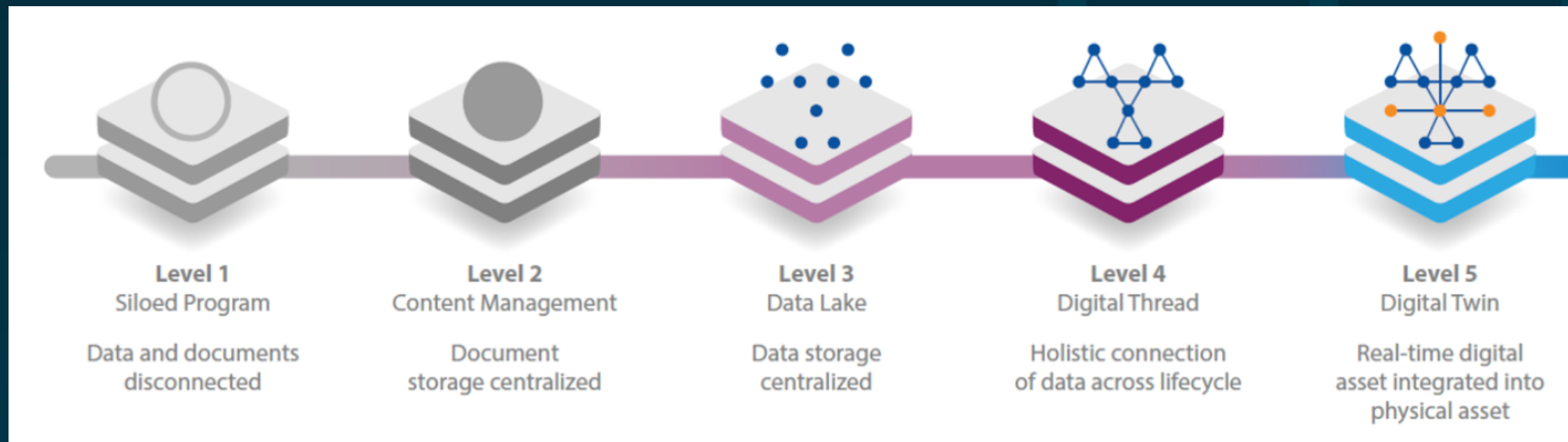
- Extend phase I up to six months
 - Fabricate and test DPSC
 - Establish design for phase II
- Award phase II for estimated 18 months
 - Build and test structure at Clinch River
 - Disassemble and decommission

Benefits of Testing & Demonstration

- Bridge the gap between development and commercialization
 - 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
 - Identify materials standardly available
 - Optimize design
 - Establish procedures
 - Sequencing of operations
- Builds confidence with regulators
- Develops supply chain

NRIC Systems/Digital Engineering Overview

- Holistic approach to the design of a complex system:
 - Design using models/data instead of documents
 - Integration of data across models to realize significant risk reduction on project cost and schedule
 - Applying state-of-the-art Model Based Systems Engineering Tools from requirements engineering through design, construction, and operations
 - NRIC-DEN (Digital Engineering for Nuclear) sharing this tool set architecture with industry partners and others to facilitate cost reductions and improve advanced reactor deployment



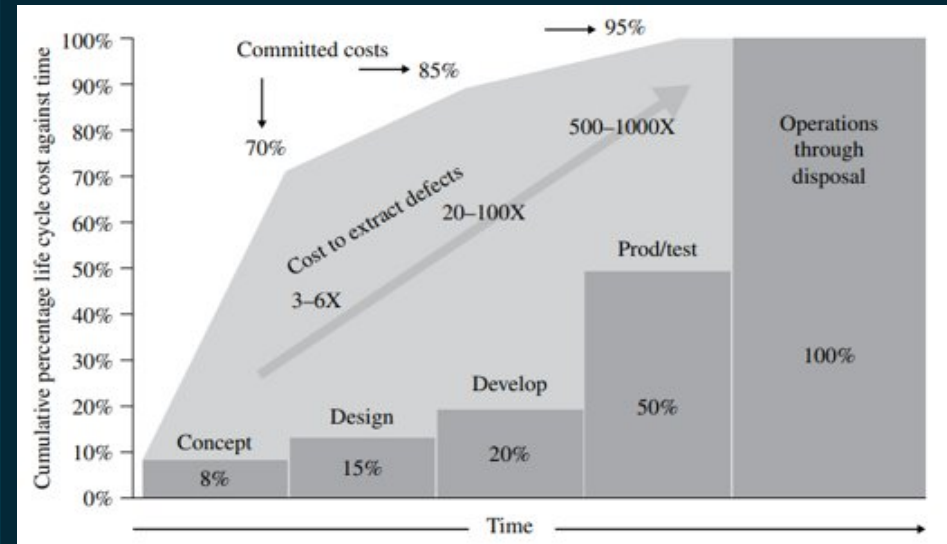
Why Systems/Digital Engineering?

- Provides for the most secure, highest quality, most accessible, fastest execution of large scale, complex projects
- Legacy & outdated systems dominate nuclear industry
 - Microsoft Word, PDFs, Spreadsheets, Paper Documents, Visio Diagrams, Legacy Systems
 - Engineering tools, if used, are disparate and siloed – lots of manually intensive rework
- NRIC sharing this tool set architecture
 - Partnering with EPRI (workshops)
 - ACTI digital twin
 - ARDP awardees

How Big Projects Performed

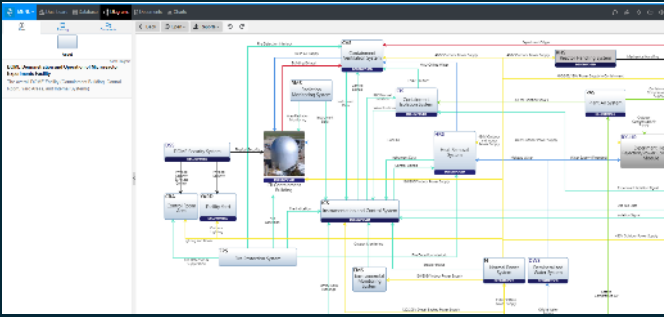
Source: Flyvbjerg Database

Project type	Mean cost overrun (%)	Projects (A) with ≥50% overruns (%)	Mean overruns of A projects (%)
Nuclear storage	238	48	427
Olympic Games	157	76	200
Nuclear power	120	55	204
Hydroelectric dams	75	37	186
IT	73	18	447
Nonhydroelectric dams	71	33	202
Buildings	62	39	206
Aerospace	60	42	119
Defence	53	21	253
Bus rapid transit	40	43	69
Rail	39	28	116
Airports	39	43	88

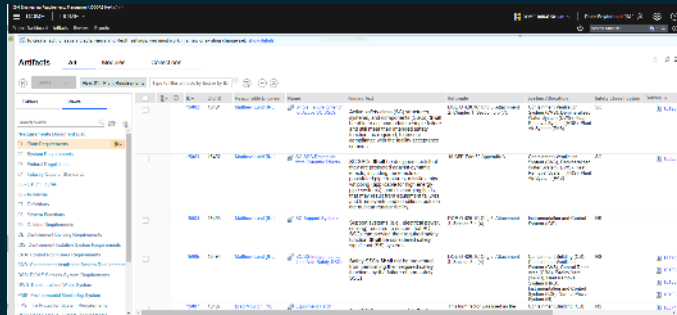




Systems Engineering



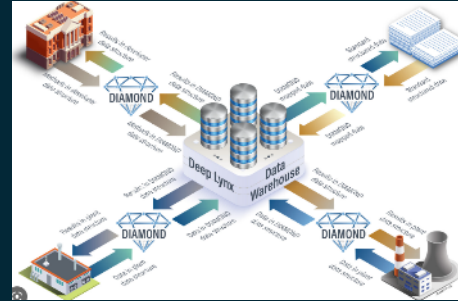
Requirements Engineering



Pull any data from one system and push to other systems – Single Source of Truth



Product Lifecycle Management



Data Warehouse: Deep Lynx

PROCORE

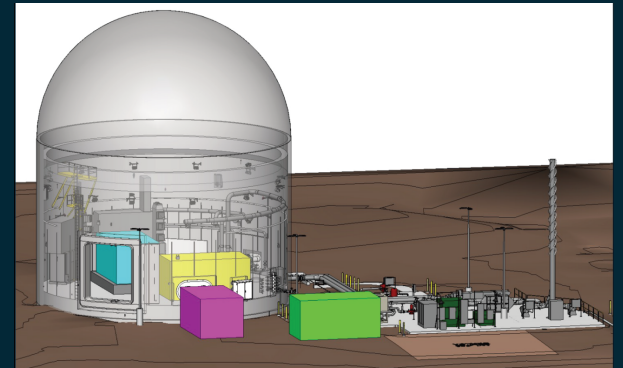
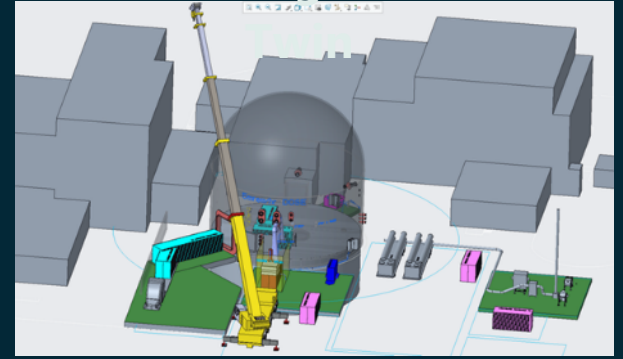
Construction Management

ABB

INL Asset Suite



3D CAD Digital



3D BIM Digital Twin

FY23: Deployed Windchill, integrated P6 schedule system, & deployed engineering V&V tool
FY24: Complete upgrade to DOME digital twin to include component information (informational digital twin)

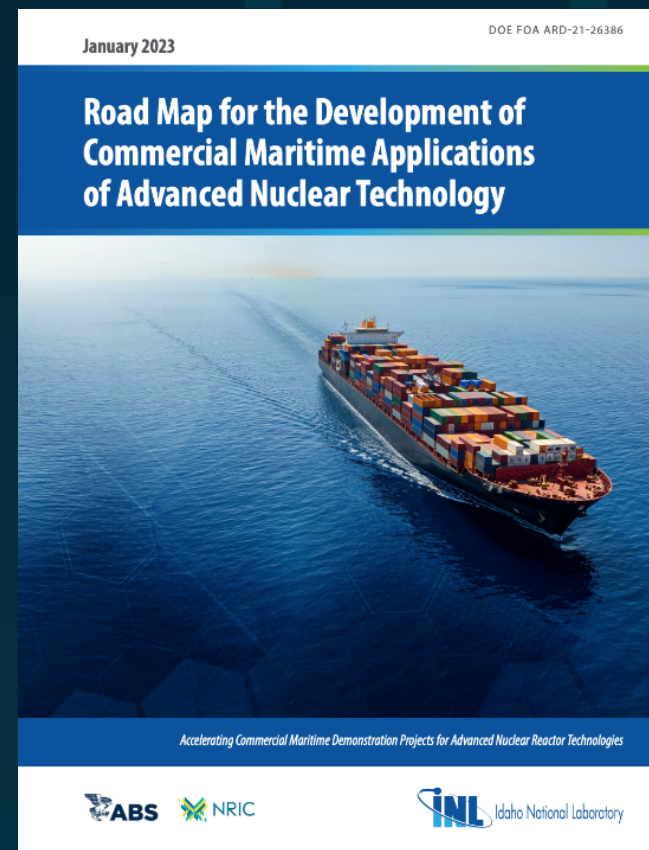
Evaluating Maritime Applications NRIC & American Bureau of Shipping (ABS)

Maritime Nuclear Application Group

- Collaboration with ABS and Morgan & Lewis Law Firm to establish a forum for the maritime and nuclear energy sectors to demonstrate advanced nuclear technologies
- Identifies domestic and international legal and regulatory hurdles, catalogs and share relevant information resources, and collaborates with global stakeholders
- 100+ members representing 40+ domestic/international companies from nuclear, shipping, and oil/gas industries including:
 - Westinghouse, NuScale, BWXT, NEI, Shell, NRC, US Coast Guard, etc.
- Conducting assessment of experimental and testing gaps to fill

Industry FOA Award 2022 - ABS Accelerating Commercial Maritime Demonstration Projects for Advanced Nuclear Reactor Technologies System

- Develop roadmap for maritime application test/demonstration projects
- Reconcile maritime and nuclear licensing and conduct a regulatory gap analysis

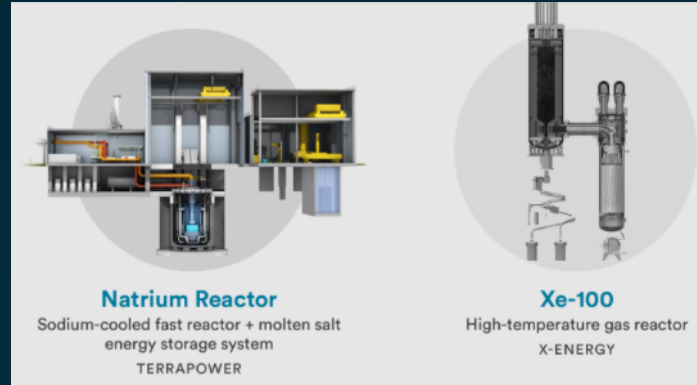


- IAEA Symposium – Deployment Of Floating Nuclear Power plants –Nov
- CORE POWER - DC – Oct

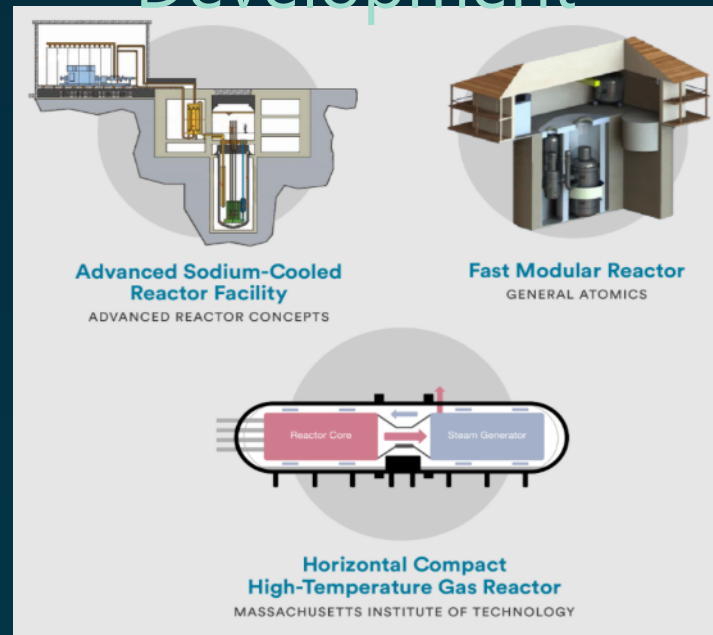
INL Participation in ARDP Projects

- 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

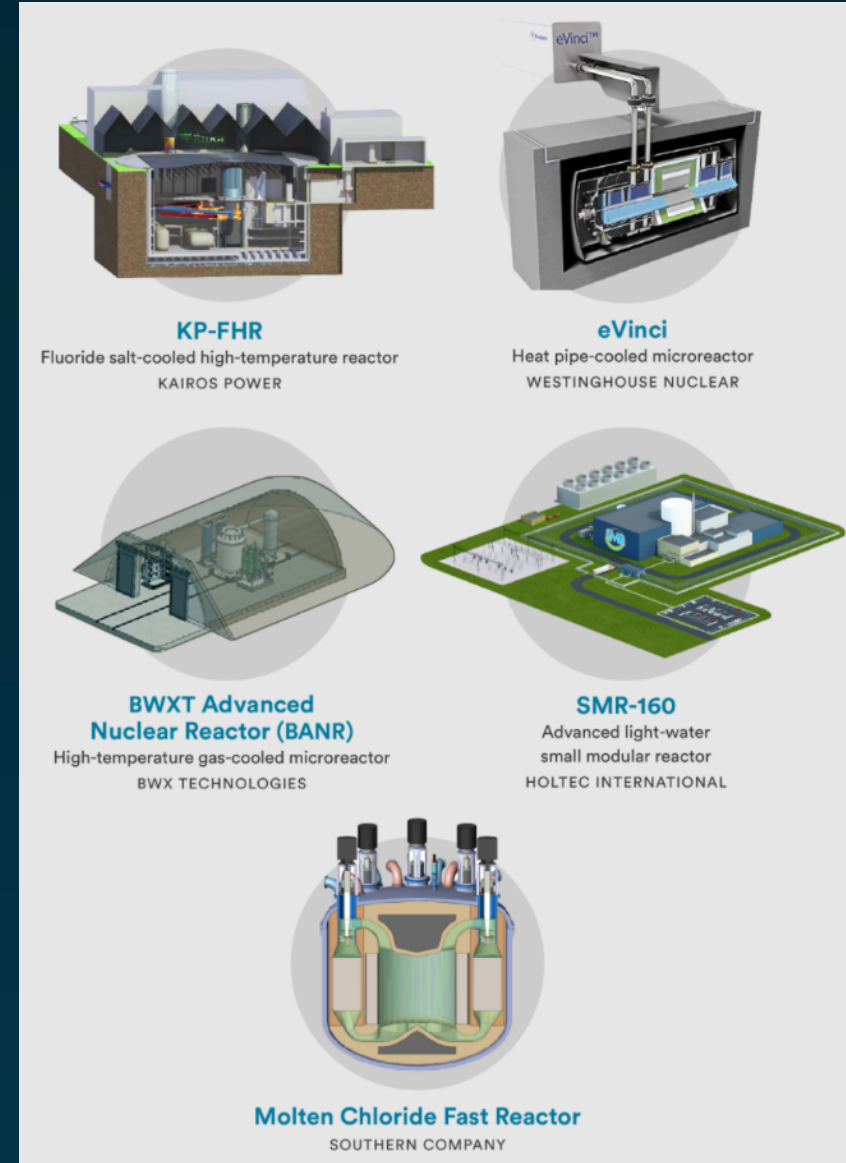
Demonstration



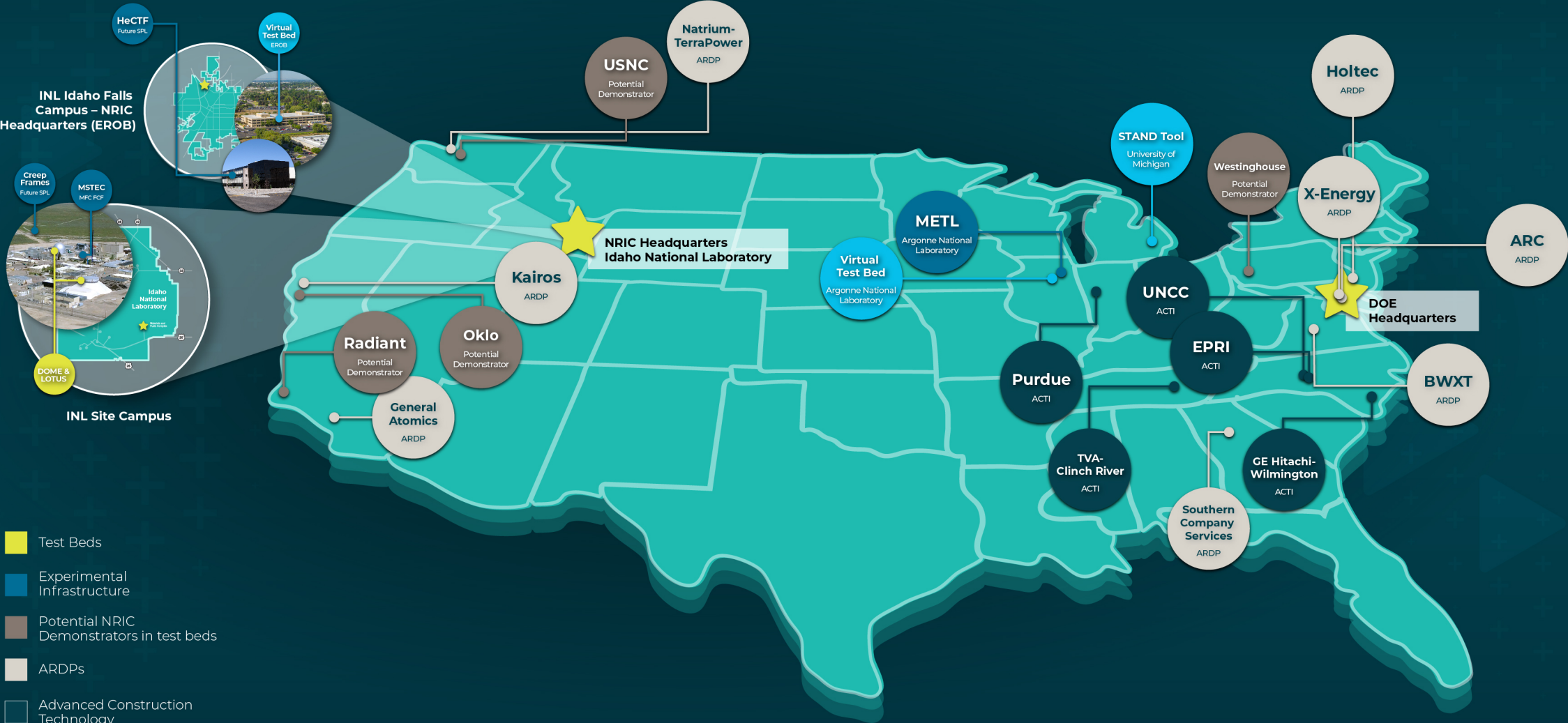
Concept Development



Risk Reduction



NRIC National Footprint



- Test Beds
- Experimental Infrastructure
- Potential NRIC Demonstrators in test beds
- ARDPs
- Advanced Construction Technology
- Industry Collaborators

Thank you!

Questions?

