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National Reactor Innovation Center Annual Report

2024

NRIC National Reactor Innovation Center

DISCLAIMER

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ACTING DIRECTOR'S MESSAGE

It is my privilege to present this year's National Reactor Innovation Center (NRIC) annual report. Now rounding out our fifth year of operation, NRIC is delivering results that position us to successfully deliver our most foundational promise: to accelerate the testing and demonstration of advanced nuclear technology by providing access to national laboratory assets and expertise.

NRIC's mission is to partner with industry and national labs to bridge the gap between research and deployment of advanced nuclear technology. NRIC accomplishes this through building new or enhancing existing U.S. Department of Energy (DOE) infrastructure to facilitate testing of components and systems, and, by partnering with industry to conduct testing efficiently and effectively. NRIC's vision is that by 2028, we will have establish four new experimental facilities and two large reactor test beds for integrated technology demonstrations and experimentation by 2028 and completed at least two advanced nuclear technology tests by 2030.

Our team is committed to tackling the necessary tasks and challenges to identify and fill gaps that hinder advancing nuclear energy. This includes engaging with regulators and stakeholders and improving the DOE national laboratory infrastructure and capabilities.

To that end, this report provides a detailed accounting of progress made under NRIC work packages for Fiscal Year (FY) 2024, which includes among other things the following:

- Initiating and progressing construction of the NRIC DOME test bed.
- Partnering with three advanced reactor developers to complete Front End Engineering and Experiment Design (FEEED) phases to prepare them for testing in DOME.
- Submission of Draft National Environmental Policy Act Analysis for Operations of the DOME test bed to DOE-ID.
- Completing the final design of the LOTUS test bed
- Completing testing of modular steel/concrete composite walling systems for advanced nuclear plants in partnership with General Electric
- Fabricating and installing the glovebox for the Molten Salt Thermophysical Examination Capability (MSTEC)
- Partnering with the American Bureau of Shipping to understand the possibilities of and barriers to advanced nuclear reactors in Maritime applications and to coordinate activities of the Maritime Nuclear Advisory Group which saw exponential membership growth in 2024.

In addition to our programmatic accomplishments, NRIC realized signficant growth in industry partnerships this year as industry recognizes our ability to achieve significant results. I am confident the NRIC program is on track to successfully empower the nuclear energy sector to meet our nation's needs. The investments in processes and infrastructure that NRIC made in 2024 will greatly benefit the broader nuclear innovation community. The NRIC team is energized for the future as we continue to build momentum. Thank you for your support of our mission and your interest in our program.

Best Regards,

Brad Tomer, Acting NRIC Director

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FIGURES

TABLES

ACRONYMS

3D	Three-Dimensional
ABS	American Bureau of Shipping
ACTI	Advanced Construction Technology Initiative
ANL	Argonne National Laboratory
API	application programming interface
ARC	Advanced Reactor Concepts
ARDP	Advanced Reactor Demonstration Program
CAD	computer-aided design
CD	critical decision
CNSC	Canadian Nuclear Safety Commission
DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOE-HQ	U.S. Department of Energy, Headquarters
DOE-ID	U.S. Department of Energy, Idaho Operations Office
DOE-NE	U.S. Department of Energy, Office of Nuclear Energy
DOME	Demonstration of Microreactor Experiments
EA	Environmental Assessment
EBR	Experimental Breeder Reactor
EOI	Expression of Interest
EPRI	Electric Power Research Institute
FCF	Fuel Conditioning Facility
FEEED	Front-End Engineering and Experiment Design
FY	Fiscal Year
GAIN	Gateway for Accelerated Innovation in Nuclear
GEH	GE-Hitachi Nuclear Energy Americas, LLC
GFE	government-furnished equipment
GTA	General Test Assembly
HALEU	high-assay low enriched uranium
HeCTF	Helium Component Test Facility
HFEF	Hot Fuel Examination Facility
HTGR	High-Temperature Gas Reactor
INL	Idaho National Laboratory
LOTUS	Laboratory for Operations and Testing in the United States

M&S	modeling and simulation
MCRE	Molten Chloride Reactor Experiment
METL	Mechanisms Engineering Test Loop
MFC	Materials and Fuels Complex
MNAG	Maritime Nuclear Application Group
MSR	molten-salt reactor
MSTEC	Molten-Salt Thermophysical Examination Capability
NAMRC	Nuclear Advanced Manufacturing Research Centre (UK)
NASA	National Aeronautics and Space Administration
NEAMS	Nuclear Energy Advanced Modeling and Simulation
NEPA	National Environmental Policy Act
NNSS	Nevada National Security Site
NRC	U.S. Nuclear Regulatory Commission
NRIC	National Reactor Innovation Center
OPG	Ontario Power Generation
ORNL	Oak Ridge National Laboratory
PLM	Product Lifecycle Management
PNNL	Pacific Northwest National Laboratory
R&D	research and development
RFP	Request for Proposal
SAR	Safety Analysis Report
SPL	Sample Preparation Laboratory
STAND	Siting Tool for Advanced Nuclear Development
THETA	Thermal-Hydraulic Experimental Test Article
TREAT	Transient Reactor Test
U.S.	United States
UK	United Kingdom
UNCC	University of North Carolina Charlotte
V&V	verification and validation
VTB	virtual test bed
ZPPR	Zero Power Physics Reactor

National Reactor Innovation Center Annual Report FY 2024

1. PROGRAM OVERVIEW

The National Reactor Innovation Center (NRIC), established in August 2019, is a national United States (U.S.) Department of Energy (DOE) program. NRIC's mission is to partner with industry and national laboratories to bridge the gap between the concept, demonstration, and commercialization of advanced nuclear technology NRIC accomplishes this goal through building new or enhancing existing US Department of Energy infrastructure to support testing of components and systems that are key to successfully deploying advance nuclear technology. NRIC works to inspire stakeholders and the public, empower innovators, and deliver successful outcomes through efficient collaboration and coordination with partners.

NRIC's vision is that by 2028, NRIC will be partnered with industry and accelerating the demonstration and deployment of advanced nuclear technology using US Department of Energy national laboratory infrastructure and expertise. NRIC will establish four new experimental facilities and two large reactor test beds for integrated technology demonstrations and experimentation by 2028 and complete two advanced nuclear technology tests by 2030.

Achieving this vision will enable urgently needed abundant and affordable clean energy both domestically and internationally. NRIC's success will inspire our nation and the global community to embrace the promising contribution of innovative nuclear reactor technologies to the clean energy economy and re-establish the U.S. as the global leader in advanced nuclear energy.

NRIC is tasked with expediting the development of advanced nuclear energy technologies by bringing together private-sector technology developers and the world-class capabilities of the DOE national laboratory system. Through this program, the U.S. private sector is given access to the physical infrastructure available at DOE national laboratories to test and demonstrate their reactor concepts. NRIC works closely with the Gateway for Accelerated Innovation in Nuclear (GAIN), which is the DOE-Nuclear Energy (NE) program granting access to technical, regulatory, and financial support for commercializing nuclear energy. As observed in Figure 1, NRIC builds upon these new reactor concepts and technology successes to effectively strengthen U.S. nuclear leadership.

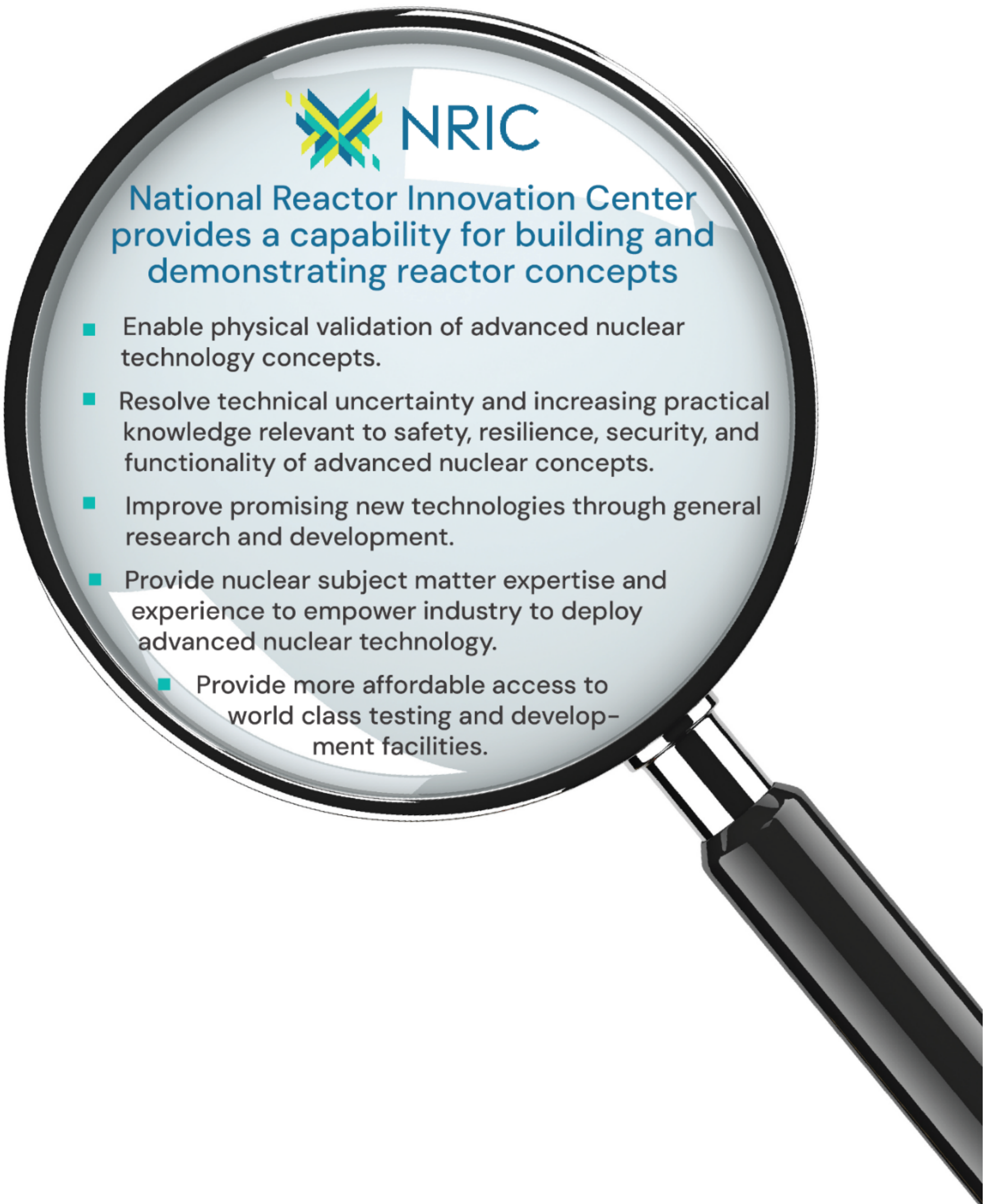


Figure 1 NRIC provides capabilities for reactor concepts.

2. NRIC AND DOE NATIONAL LABORATORIES

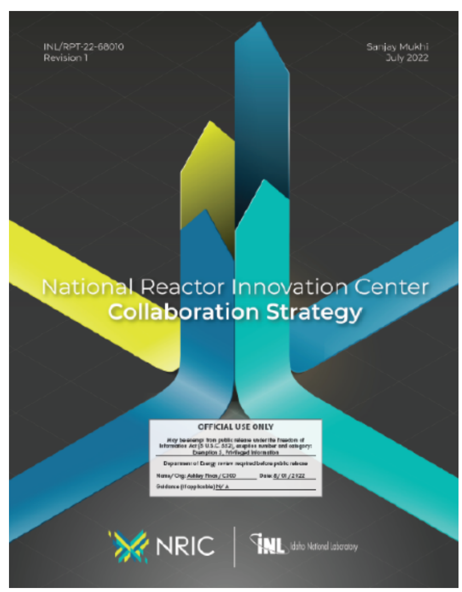
NRIC's headquarters are located at Idaho National Laboratory (INL), in Idaho Falls, Idaho, which is considered DOE's premier nuclear energy lab. Although INL is known as the lead for nuclear energy, the advanced research and development (R&D) conducted at INL includes national security research and testing, energy and environmental research, analytical chemistry, space, and security power systems, and applied and digital engineering. NRIC draws upon these diverse capabilities and partners with complementary INL programs to achieve the NRIC mission. The unparalleled desert geography and the research, testing, and analysis capabilities at INL encourage the integration of science, engineering, and operations.

NRIC also actively collaborates with other DOE national laboratories across the country because successful demonstration of advanced nuclear energy on the prescribed timeline will require a team effort making use of our essential research strengths. NRIC's Demonstration Resource Network Tool, launched in Fiscal Year (FY) 2021, highlights the national laboratory capabilities across the country. Key partner laboratories for NRIC include Oak Ridge National Laboratory (ORNL), Pacific Northwest National Laboratory (PNNL), Argonne National Laboratory (ANL), Los Alamos National Laboratory (LANL), Lawrence Livermore National Laboratory (LLNL), and the Nevada National Security Site (NNSS). NRIC looks to strengthen and expand these partnerships in FY 2025.

3. PROGRAM PARTNERSHIPS

NRIC is a national program and requires extensive collaboration with many organizations. NRIC has established partnerships with the U.S. Nuclear Regulatory Commission (NRC) and DOE and anticipates future collaboration with other federal agencies, such as the U.S. Department of Defense (DoD) and the National Aeronautics and Space Administration (NASA). In addition to the six other national laboratories, NRIC has established projects with several major DOE-NE R&D programs, including the Nuclear Energy Advanced Modeling and Simulation (NEAMS) program. NRIC has also formed and expanded partnerships with several U.S. advanced nuclear companies through project coordination and via memoranda of understanding and will further these efforts in FY 2025.

NRIC developed a collaboration strategy (see INL/RPT-22-68010) that sets a framework for partnerships on a national level among private industry, regulators, national labs, and market users. The goals are to leverage our partner network to decrease the risks associated with new technology deployment and to provide access to capabilities, facilities, and tools essential for demonstration of these technologies.



4. FUNDING

The FY 2024 congressional appropriation for DOE provided $80.95 million for NRIC, which includes $18.75 million for the Laboratory for Operation and Testing in the United States [LOTUS] as a capital line item, to support testing, demonstration, and performance assessment in the acceleration and deployment of advanced reactors. The FY 2025 presidential request for NRIC was $31 million with language to support spending up to $18.75 million in capital expense on support for the design of test beds. The House and Senate marks for 2025have been released and both indicate $65M for NRIC along with the $18.75M in capital for the test beds.

Funding of new budget authority and carryover was allocated to the work packages and scope areas depicted in Table 1 in FY 2024.

Table 1 FY2024 funding for NRIC initiated projects

Work Package Title	Control Account/ Work Package	FY 2024 Total Funding ($)
Program Management		
NRIC Program Management at INL	RC-24IN010101	1,907,010
NRIC Operations		
NRIC Operations	RC-24IN020101	10,677,797
Stakeholder Engagement		
Collaboration Initiatives	RC-24IN020201	935,028
Demonstration Reactor Infrastructure		
Demonstration of Microreactor Experiments (DOME) Test Bed Operation Support Equipment and Infrastructure Support	RC-24IN020301	10,318,155
Siting Tool for Advanced Nuclear Development - ANL	RC-24AN020302	128,034
DOME Construction	RC-24IN020303	37,769,891
DOME Government-Furnished Equipment (GFE)	RC-24IN020304	7,473,715
DOME Reactor Siting and Environmental Regulatory Support - ORNL	RC-24OR020305	149,528
Front-End Engineering and Experiment Design (FEEED) for Testing Advanced Microreactors	RC-24IN020307	4,382,598
LOTUS Design and Construction OPC	RC-24IN020310	3,097,885
Detailed Design and Long-Lead Procurement	RC-24IN020312	5,000,000

Work Package Title	Control Account/ Work Package	FY 2024 Total Funding ($)
Regulatory and Economic Risk Reduction		
Development and Demonstration of Digital Engineering Systems	RC-24IN020401	1,145,540
National Environmental Policy Act (NEPA) Roadmap for Advanced Reactor Testing – PNNL	RC-24PN020402	39,838
NEPA and Siting Evaluation Activities	RC-24IN020403	255,192
Regulatory and Economic Risk Reduction	RC-24IN020404	933,278
Transportation Probabilistic Risk Assessment (PRA) – PNNL	RC-24PN020405	52,468
Advanced Construction Technology Initiative (ACTI) Phase I Completion	RC-24IN020406	3,119,015
ACTI Phase 2	RC-24IN020407	18,048,254
Engineering Analysis and Evaluation		
NNSS Demonstration Reactor Support Activities	RC-24NN020501	27,080
Experimental Infrastructure		
Mechanisms Engineering Test Loop (METL) Operations, Testing, Maintenance, and Improvements	RC-24AN020601	4,278,457
Virtual Test Beds (VTBs)	RC-24IN020602; RC-24AN020603	1,424,142
Hot Fuel Examination Facility (HFEF)-15 Cask Modifications	RC-24IN020604	1,836,818
Molten-Salt Thermophysical Examination Capability (MSTEC)	RC-24IN020605	3,928,171
Integrated Energy Systems and Nonelectric Applications		
Maritime Applications of Nuclear Energy Studies	RC-24IN020701	1,359,652

5. MULTI-YEAR STRATEGY

The vision and strategy for NRIC is expressed in INL/RPT-23-73785, “NRIC Strategy and Execution Plan,” which also explains how NRIC manages and coordinates with other programs and participants.

Together, the NRIC mission and vision are to close the gap between concept, demonstration, experimentation, and commercialization by inspiring stakeholders and the public, empowering innovators, and delivering successful outcomes. NRIC activities should align with some, or all, of the following principles, guiding decision-making in pursuit of success:

- Reduced Timeframe: NRIC activities should strive to reduce the timeframe necessary to achieve safe operation of demonstration or commercial reactors.
- Reduced Costs: NRIC activities should strive to reduce the costs for safe deployment of demonstrations or commercial reactors

- Improve Predictability: NRIC activities should strive to improve the predictability of advanced reactor deployment, building the confidence of developers, investors, and stakeholders. Timeframes and cost estimates, including regulatory approval, are well understood, reliable, and reproduceable, and this reduces the risks of deploying advanced reactors.
- Improved Safety: NRIC activities should strive to improve the safety performance of advanced reactor technologies.
- Improved Performance: NRIC activities should strive to increase the performance of advanced reactor technology, including increased reliability and efficiency
- Leverage NRIC Capabilities: NRIC activities should leverage the intellectual capabilities, facilities, and sites within the national laboratory system to the maximum benefit of NRIC partners.

6. NRIC-INITIATED PROJECTS

In FY 2024, NRIC continued work on a set of projects developed in FY 2023 and initiated several new projects aimed to support the vision of a national program dedicated to enabling private-sector testing and demonstration of reactor concepts. These NRIC projects serve as the basis for achieving NRIC's mission, leveraging and improving innovative technologies, and developing new infrastructure and competencies within the DOE laboratory complex.

NRIC projects are designed and implemented to address key issues regarding advanced reactor demonstration, including safety, siting, environmental impacts, technological assessments, and reactor demonstrations. NRIC's guidance on siting, stakeholder engagement, advanced technology, implementation, and regulatory requirements will ensure a timely implementation of advanced concepts and will provide the foundation for future U.S. advanced reactor development. Therefore, in FY 2024, NRIC took the necessary steps to make further progress on and/or initiate the mission critical projects listed in Table 1

6.1 Program Management

Project Start Date:	October 2020	Work Package Manager	Brad Tomer

6.1.1 Objectives

The objective of this effort is to provide execution of NRIC Program Management and to ensure the NRIC program is responsive and coordinated with industry, as well as responsible for the overall performance of the NRIC program. Strategic support to NRIC's leadership in developing and improving the overall strategic plan and specific strategies and collaborations with other programs, agencies, and nuclear energy demonstration efforts. High level objectives include:

- Establishing and updating a systematic approach to NRIC operations
- Growing the NRIC organization in a way that it can be effective, agile, and scalable, including hiring necessary staff to support the program needs for the foreseeable future
- Strengthening and developing program coordination with other national laboratories, DOE programs, and potential partners
- Establishing processes that enable innovators to access facilities, sites, materials, and expertise to demonstrate advanced reactors.

6.1.2 Progress

Milestones accomplished in FY 2024 include:

- The completion of the NRIC FY 2024 Annual Report (INL/RPT-24-80085) in August 2024, which details the major NRIC activities, projects, and accomplishments that were achieved in FY 2024.
- The updated NRIC Gap Assessment, which is an M2 milestone for FY 2024. This milestone is not scheduled for completion prior to the issuance of this report and will be included in next year's annual report.

In 2020, NRIC conducted an NRIC Gap Assessment to identify the national laboratory capabilities that were missing and needed to enable demonstration of industry reactor concepts. Input was gathered for this gap assessment using the NRIC Demonstration Reactor Capabilities Survey (DRCS), from experience with the "Advanced Reactor Demonstration" proposal development process, and through the industry-led Technology Working Group (TWG) letters. Thirty-seven reactor concepts from industry were considered in the Gap Assessment and 20 fundamental problems were identified.

NRIC initiated several efforts to close the identified gaps by providing access to the capabilities, facilities, and tools essential for the demonstration of new reactor technologies (see Table 1 in the INL/EXT-20-59834 Gap Assessment). The gap assessment confirmed the commercial deployment of advanced nuclear technology can be accelerated through NRIC's mission to inspire stakeholders and the public, empower innovators, and deliver successful outcomes through efficient coordination of partners and resources.

NRIC has kicked off the project to update the 2020 NRIC Gap Assessment, which will identify the areas that NRIC can most effectively address to fill the current and predicted gaps in testing programs, laboratory facilities, and capabilities. The results of this revised gap assessment will be presented in the FY 2025 NRIC Annual Report.

6.1.3 Next Steps

In FY 2025, the NRIC Program Management work package will be used only to provide funding for the NRIC Director and the NRIC Chief Operations Officer.

6.2 NRIC Operations

Project Start Date:	October 2021	Work Package Manager:	AnnMarie Marshall

6.2.1 Objectives

The Operations work package covers the necessary INL and subcontractor support staff at NRIC who manage and execute activities and develop associated processes. These staff members provide administrative assistance; program management; coordination of program initiatives and projects; project management and configuration management for NRIC operations; and engineering to support NRIC's project scoping and startup, scheduling, budgeting, and controls for the program. NRIC staff work internally within INL, with our national laboratory program partners, and externally with industry experts to develop a holistic approach to further develop and execute the NRIC mission.

The cross-functional NRIC team includes staff across a diverse set of engineering disciplines, in addition to world-class expertise in the deployment of new technology, communications, and project management. The objective is for NRIC to maintain an aggressive schedule to demonstrate advanced nuclear reactors while responsibly managing technology and project risk, the complex interfaces among private-sector collaborators, and nuclear reactor systems.

6.2.2 Progress

Despite shortages in the labor market, NRIC made significant progress in recruiting staff to support project execution. The labor market is tight and competitive, resulting in NRIC losing several employees to promotions and higher pay elsewhere. In FY 2024, NRIC brought on an additional Configuration Management Coordinator and an Experiment Design Manager and has multiple additional postings pending. See Appendix A for the latest NRIC organization chart.

NRIC held its annual program review with DOE Headquarters (DOE-HQ), DOE Idaho Operations Office (DOE-ID), the NRC, and NRIC′s industry stakeholders in April 2024 at INL. Over 170 participants registered to attend, with over 100 attending in person. Our partner national laboratories and universities were also represented among the attendees. The program review included tours for participants of multiple facilities at INL′s Materials and Fuels Complex (MFC). Figure 2 provides a look at some of the highlights of the meetings.

Figure 2 Attendees and presenters at the Annual NRIC Program Review in April 2024

6.3 Collaboration Initiatives

Project Start Date:	October 2020	Work Package Manager:	Curtis Nielsen

6.3.1 Objectives

NRIC defines stakeholders broadly, to include project teams, industry partners, national laboratory programs/teams, federal and state regulators, and state and local elected officials, regional community organizations, environmental organizations, and businesses. However, with the consolidation of stakeholder engagement activities occurring within DOE, NRC, and the maritime, the need for stakeholder engagement activities due to increasing public interest, legislative activities within states, and federal activities, as well as the desire for NRIC to narrow its focus, NRIC has tightened its activities in this space.

NRIC expects to update its stakeholder engagement strategy in August 2024 as a part of the FY 2024 NRIC Collaboration Initiatives Annual Report. NRIC's current Collaboration Initiatives stakeholder engagement program is built on two pillars:

- Support to Innovators: Project management support from NRIC's innovators team, as well as organizations at the community, regional, and state levels.

- Stakeholder Engagement: Engage with our industry, commercial, DOE, NRC, and maritime partners to better understand the needs and capabilities for advancing nuclear reactors.

By engaging with innovators and industry, as well as the regulators, NRIC can both prioritize its support of innovators seeking to demonstrate advanced reactors while also providing information to the public regarding NRIC, national laboratory resources, and industry innovations. NRIC is keenly aware of how nuclear energy in previous decades posed a challenge to the public trust. NRIC's stakeholder engagement strategy, therefore, mirrors the innovative approach of the private industry technologies it supports, builds on the technological prowess of the past, and stakes a firm claim on a future that is transparent, inclusive, and just.

6.3.2 Progress

The following milestones associated with the Collaboration Initiatives work package were accomplished in FY 2024:

- In June 2024, NRIC held a developer workshop (M3RC-24IN0202013):
  - The topics for this workshop included reactor physics assessments, transportation and shipping, testing facility capabilities at multiple National Laboratories, and fuel information for testing tristructural isotropic (TRISO) and molten-salt fuels.
  - A total of 40 attendees varied from advanced reactor developers, industry partners, personnel from multiple national laboratories, DOE representatives, and NRIC personnel. The target audience of advanced reactor developers also had a good showing with more than 15 attendees from Aalo, AlphaTech, BlueEnergy, BWXT, Radiant, Southern Power, and Westinghouse.
- In August 2024, NRIC completed the NRIC Collaboration Initiatives Annual Report (M2RC-24IN0202012). See INL/RPT-24-80063

Under the NRIC Collaboration Initiatives work package, NRIC made updates to the following collaboration tools—Siting Tool for Advanced Nuclear Development (STAND), Salesforce, and the Demonstration Resource Network. These updates include:

- A STAND system architecture update, as well as the expansion of the STAND database to include laboratory infrastructure for maritime and fusion.
- Within Salesforce, NRIC added additional fields for capturing developer information and demonstration readiness, created dashboards, developed new engagement questionnaire, and linked the platform to the Developer Resource Network.
- Within the Demonstration Resource Network, NRIC added more national laboratory testing and capability information and implemented a needed software update.
- The NRIC website was updated to be more user-friendly. These updates include:
  - Fact sheets on the NRIC testbeds and activities.
  - More publications being added to the NRIC website.
  - Increased visibility on events NRIC lead or participated in.
  - Additional drop-down options to the menus with more up-to-date information.

As part of the collaboration work package, NRIC hosted and attended several industry events. Some of these events are shown in Table 2

Table 2 Events and conferences with participation by NRIC staff.

Conference or Meeting	Dates	Location	Presenting/Attending	Name
American Nuclear Society (ANS) Conference: Utility Work Conference and Vendor Technology Expo	Aug 4-7, 2024	Marco Island, FL	Both	Jacob Rymer
North American Young Generation in Nuclear Conference	June 4–5, 2024	Charlotte, NC	Presenting	Sanjay Mukhi
ARPA-E Energy Innovation Summit	May 22–24, 2024	Dallas, TX	Attending	Sanjay Mukhi
Nuclear Energy University Program (NEUP): Open Architecture Meeting	May 15–16, 2024	Remotely	Attending	Samuel Reiss
Eielson Air Force Base Microreactor Pilot	May 9–10, 2024	Fairbanks, AK	Attending	Brad Tomer
Card 2024 Conference for Advanced Reactor Deployment	Mar 26–28, 2024	Charlotte, NC	Attending	Sanjay Mukhi
36th Annual Regulatory Information Conference (RIC)	Mar 12–14, 2024	Rockville, MD	Attending	Jacob Rymer Sanjay Mukhi
USNIC Advance Reactor Summit	Apr 16–17, 2024	Houston, TX	Presenting	Sanjay Mukhi
EPRI Supply Chain Workshop for Structural Components in Advanced Energy Systems	Apr 10–11, 2024	Dallas, TX	Presenting	Sanjay Mukhi
IAEA Conference	Mar 26, 2024	Virtual	Presenting	Luke Voss
ANS Winter Meeting	Nov 13–17, 2023	Washington, DC	Attending	Bradley Tomer Sanjay Mukhi
US NIC New Nuclear Capital 2023	Nov 6–8, 2023	New York, NY	Presenting	Sanjay Mukhi

In addition to the events listed in Table 2, NRIC completed various other speaking engagements in FY 2024, including regional public events; local, regional, and state environmental locations; and non-governmental sites with U.S. and international regulators, professors, students, and journalists.

6.3.3 Next Steps

As mentioned above, NRIC is reexamining and redefining its activities in this space. NRIC expects to continue to update its collaboration strategy in the FY 2025 NRIC Collaboration Initiatives Annual Report, as well as incorporating the NRIC gap assessment feedback.

6.4 Siting Tool for Advanced Nuclear Development

Project Start Date:	October 2020	Work Package Manager:	Matthew Bucknor Femi Omitaomu

6.4.1 Objectives

ANL, in partnership with INL, ORNL, and the University of Michigan, has developed STAND, which is a tool providing siting guidance based on energy policy, environmental justice, labor considerations, political will, and popular attitude, in addition to the recommendations in NRC Regulatory Guide 4.7, “General Site Suitability Criteria for Nuclear Power Plants Parameters.” A preference model is available within STAND to provide discrimination between multiple potential sites based on user preferences. As indicated in Figure 3, STAND offers vendors, utilities, and stakeholders a useful tool to evaluate siting for a variety of nuclear facilities in support of the DOE Advanced Reactor Demonstration Program (ARDP) and other DOE-NE initiatives.

ANL specific objectives under this work package include project coordination efforts, assisting in development and testing of STAND, and providing technical support for the ANL preference model. Efforts at ORNL include continuing to coordinate on STAND with ANL, INL, and the University of Michigan, as well as assisting vendors, utilities, and other stakeholders in the use of STAND and/or the addition of insights directly from the ORNL siting tool, Oak Ridge – Siting Analysis for Power Generation Expansion (OR-SAGE). Overall project direction and final decision-making is made by the NRIC technical project manager (TPM).

6.4.2 Progress and Accomplishments

The team continued STAND maintenance activities along with efforts to update data within the tool, add additional capabilities/data layers, and manage users. The team also continued activities to promote STAND and interface with users. As of June 2024, STAND had 529 registered users.

In September 2024, ORNL will prepare an annual report documenting its contribution to support, maintenance, and improvements for STAND (M4RC-24OR0203051).

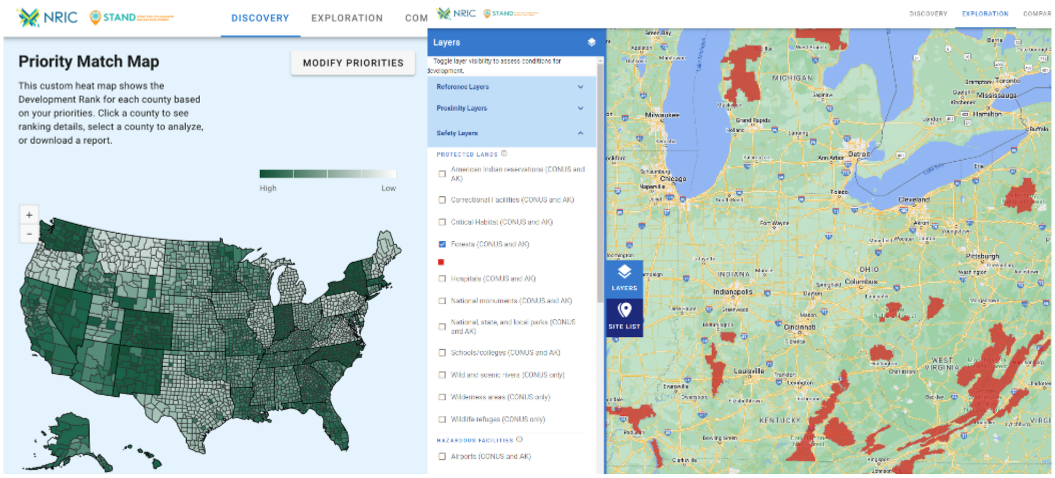


Figure 3 Images from the STAND tool.

6.4.3 Next Steps

Efforts on continued STAND deployment in FY 2025 will focus on sustained maintenance activities, support of the user base, and expanded tool capabilities. The team will also host new user training sessions as needed throughout FY 2025. Possible tool development activities include expanding STAND to include more data layers and metrics, and to be applicable to additional regions.

6.5 DOME Test Best Operation Support Equipment and Infrastructure

Project Start Date:	March 2021	Work Package Manager:	Chance Price

6.5.1 Objectives

The objectives of this work package are to provide the necessary equipment, infrastructure, requirements, analysis, and guidelines to facilitate the safe and affordable testing of advanced nuclear reactors in the DOME Test Bed to include fresh fuel storage, fresh fuel transportation at INL, fueling reactors, reactor supplemental shielding, irradiated fueled reactor removal from DOME, and defueling irradiated reactors.

The primary focus for FY 2024 is the completion of the preliminary design of reactor supplemental shielding, the DOME crane trade study, the fresh fuel handling and storage plan, the initial plan for the storage and disposal of irradiated reactor fuel at the Radioactive Scrap and Waste Facility (RSWF), and the preliminary reactor fueling support equipment recommendation, as well as initiating the final design and fabrication of the reactor supplemental shielding.

6.5.2 Progress

The following milestones associated with the DOME Test Bed Operation Support Equipment and Infrastructure work package were accomplished in FY 2024:

- In June 2024, the fresh fuel handling and storage plan for experimental reactor testing (M2RC-24IN0203012) was completed. See RPT-24-78543 “Fresh Fuel Handling and Storage Plan for Experimental Reactor Testing.”
- In June 2024, the initial plan for storage and disposal of irradiated reactor fuel at RSWF (M2RC-24IN0203013) was concluded. See NRIC PLN-7043.
- In June 2024, the preliminary reactor fueling support equipment recommendation report (M2RC-24IN0203014) was finalized. See RPT-24-78800, “Preliminary Reactor Fueling Support Equipment Recommendation.”
- In June 2024, a trade study and recommended crane option (gantry vs. polar) evaluation (M3RC-24IN0203016) was finished. See RPT-24-78418, “NRIC-DOME Crane Trade Study and Recommendation.”

6.5.3 Next Steps

In FY 2025, NRIC will continue to develop and procure the equipment required to support the safe testing of advanced nuclear microreactors in the DOME Test Bed.

6.6 NRIC-DOME Construction

Project Start Date:	October 2020	Work Package Manager:	Chance Price

6.6.1 Objectives

NRIC’s DOME project restores a portion of the capabilities of the Experimental Breeder Reactor-II (EBR-II) facility, which is located at MFC on the INL desert site and refurbishes it to host advanced reactor demonstrations and experimental reactors up to 20 megawatts thermal (MWth) fueled with high-assay low-enriched uranium (HALEU) while providing a safe path for these reactors to achieve initial criticality for the first time. By leveraging existing facilities that were originally constructed for nuclear work, DOME offers the following opportunities:

- Enabling testing and demonstration of reactor concepts by the private sector
- Validating advanced nuclear reactor concepts
- Resolving technical challenges of advanced nuclear reactor concepts
- Providing general R&D to improve innovative technologies
- Minimizing potential adverse impacts with existing programs
- Balancing research, development, and demonstration activities with the protection and preservation of human health and the environment, as well as compliance with applicable laws, regulations, and other requirements.

6.6.2 Progress

DOME construction initiated in October 2023 with the completion of subcontractor mobilization (M2RC-24IN0203031). In March 2024, NRIC issued a request for proposal (RFP) for the DOME Construction Commissioning Agent and received proposals in late April 2024. On May 14, 2024, NRIC awarded the commissioning agent subcontract to Northwest Engineering Services, Inc. (NWESI).

To demonstrate progress toward a functioning NRIC-DOME Test Bed, as observed in Figure 4, INL accomplished the following tasks in FY 2024:

- Demolition of the DOME containment concrete for equipment penetrations.
- Completion of the storm drains, conduit runs, backfill, installed the rebar reinforcement and concrete pour for the DOME equipment pad.
- Conclusion of the demolition of the control room, framing the walls, installation of the mechanical and electrical rough ins, and hanging of the sheetrock.

6.6.3 Next Steps

Construction will continue through FY 2025, with operational readiness expected to be achieved by Q3 of FY 2026.

Figure 4 DOME construction photos

6.7 NRIC-DOME Government-Furnished Equipment

Project Start Date:	October 2023	Work Package Manager:	Chance Price

6.7.1 Objectives

The EBR-II facility is being repurposed as the NRIC-DOME Test Bed. To help expedite the construction schedule, NRIC determined it would be beneficial to purchase certain equipment and components and provide these procured items to the subcontractor as government-furnished equipment (GFE). This objective of this work package is to complete the GFE procurement process that is required for the construction of the NRIC-DOME Test Bed.

Procured GFE hardware includes:

- Radiation monitors
- Electrical Penetration Assembly (EPA) – instrumentation and controls
- EPA – power
- Hatch
- Utility penetration assemblies
- Containment isolation valves
- Personnel door
- Pressure transmitter
- Temperature detectors
- Safety class (SC) heat removal system (HRS) expansion tanks
- SC duct bank
- Medium voltage (MV) transformer
- Low voltage switchboard
- MV switchboard (sectionalizer).

The primary objective of this work package is to complete the procurement of GFE to support DOME Test Bed construction.

6.7.2 Progress

All GFE items are on order, with one exception: the containment isolation valves. The team is working on two parallel paths with Valcor and Curtiss-Wright to determine the best option and identify which vendor can deliver the valves in time to support the DOME construction schedule.

6.7.3 Next Steps

In FY 2025, the DOME GFE work package will continue to work with potential vendors to get the containment isolation valves contract awarded and work with subcontractors/suppliers to ensure on-time delivery of each GFE item.

6.8 NRIC LOTUS Design and Construction

Project Start Date:	October 2020	Work Package Manager:	Jacob Rymer

6.8.1 Objectives

As observed in Figure 5, NRIC's LOTUS will reconfigure the Zero Power Physics Reactor (ZPPR) facility, which is located at MFC, to establish a test bed for experimental reactors up to 500 kilowatts thermal (KWth) and capable of utilizing fuels with greater than 20% fuel enrichment. The NRIC LOTUS Test Bed will provide a safe path for advanced reactor technologies to achieve criticality for the first time. By leveraging existing facilities that were originally constructed for nuclear work, LOTUS offers the following opportunities:

- Enabling experimentation of advanced nuclear technologies developed by the private sector
- Resolving technical challenges of advanced nuclear reactor concepts
- Providing general R&D to improve innovative technologies
- Minimizing potential adverse impacts with existing programs
- Balancing research, development, and experimentation activities with the protection and preservation of human health and the environment, and compliance with applicable laws, regulations, and other requirements.

LOTUS aims to accelerate the validation of modeling and proof of concepts for reactor designs of companies pursuing licensing within the nuclear power industry. At present, LOTUS will host the Molten Chloride Reactor Experiment (MCRE), which is designed as a molten-salt reactor concept with a fuel salt that will provide data for the validation of the much larger Molten-Salt Fast Reactor (MSFR) under development by Terra Power that may deliver up to 1,200 megawatts electrical (MWe). Validating the internal physics of this configuration is essential to commercializing this technology. The current design operations of the facility will provide a cell cooling system with a minimum capacity of 50 kilowatts thermal (KWth), which can be improved upon with supplemental upgrades.

6.8.2 Progress

In FY 2024, LOTUS did not have any approved work packages as the funding was provided for the preliminary and final design through DOE-NE-3. The following two milestones were attributed to the NRIC Operations work package:

- Provide comments for Preliminary Design (60%):
  - Completed May 20, 2024, through CCN 255984, Completion of DOE Level 2 Milestone (M2RC-24IN0201012), “Submit Review Comments to Enable Completion of LOTUS Preliminary Design Review (60%).”
- Provide comments for Final Design (90%):
  - In progress, scheduled to be completed by September 30, 2024.

NRIC received approval for critical decision (CD)-1 for LOTUS in June 2023 and issued the preliminary and final design agent contract in June 2023. The preliminary design review was held in January 2024, while the technical independent project review (TIPR) was completed in March 2024. The final design review process was initiated in June 2024.

The project team anticipates completing the final design documents and preliminary documented safety analysis (PDSA) by the conclusion of FY 2024. Figure 6 provides an artist's interpretation of the new NRIC LOTUS Test Bed.

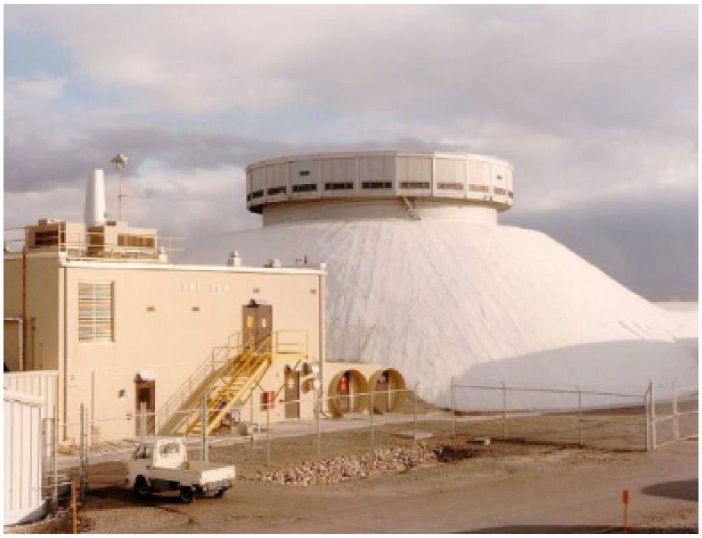


Figure 5 ZPPR prior to LOTUS redesign.

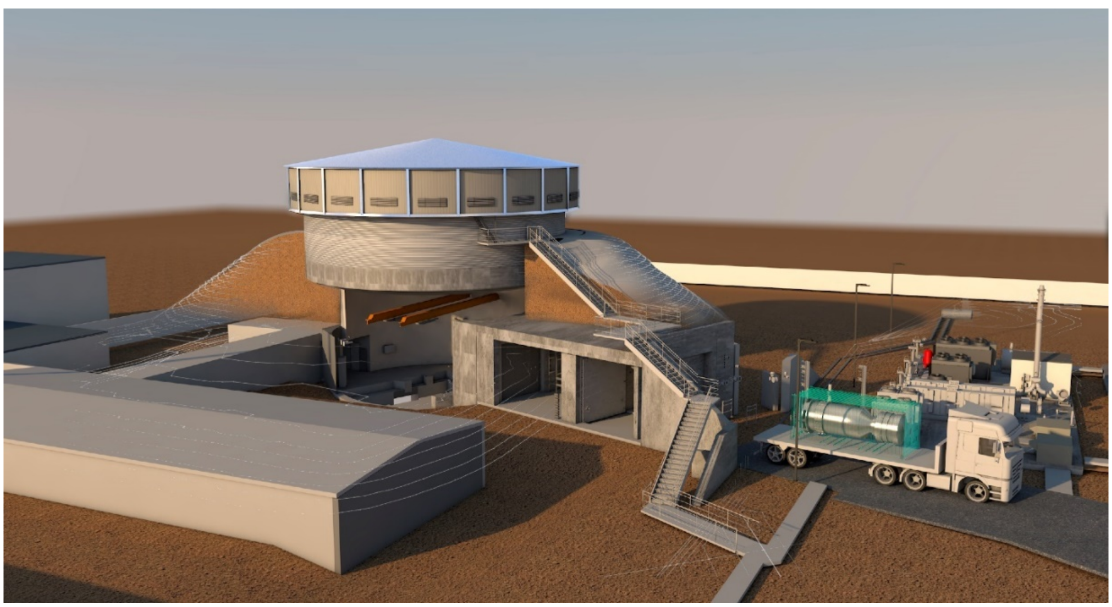


Figure 6 Rendered model of NRIC LOTUS Test Bed.

6.8.3 Next Steps

In FY 2025, LOTUS activities will focus on completing the project documents required by DOE O 413.3B project management process for CD-2/3, initiating the execution of construction of the test bed, and identifying long-lead items for procurement.

6.9 Front-End Engineering and Experiment Design for Testing Advanced Microreactors

Project Start Date:	June 2023	Work Package Manager:	Troy Burnett

6.9.1 Objectives

The objective of the Front-End Engineering and Experiment Design (FEEED) for advanced reactor testing in the DOME or other test beds is to begin the formal engineering and experiment design process for advanced reactor developers. To initiate the FEEED process, NRIC issued an RFP under which developers proposed the scope of work to complete FEEED for their advanced reactor. NRIC and DOE selected three developers to complete the FEEED process: Radiant, Ultra Safe Nuclear Corporation (USNC), and Westinghouse. Awards ranged between $1.2 million and $1.7 million and include both INL and developer costs associated with the work. A minimum of 20% cost share from the participant was required. Work completed during the FEEED process includes the safety documents, NEPA compliance documentation, conceptual design of the advanced test reactor, design for integration with the test bed, design of experiment, and an end-to-end estimate of the cost and schedule to complete design, fabrication, and testing.

This work package has supported industry integration requirement workshops with the demonstrators, as well as the development of key guidance materials and explanatory, exploratory, and analytical meetings to support experiment planning.

6.9.2 Progress

NRIC is nearing the completion of FEEED work for Radiant and Westinghouse. Westinghouse received approval of their Safety Design Strategy (SDS) and has completed and submitted the Preliminary Safety Design Report (PDSR) to DOE. Radiant has also received approval for the SDS and is preparing to submit the CSDR. USNC is working on its SDS and will be submitting it and the CSDR later this year.

By January 2024, NRIC had entered into agreements with all three FEEED awardees, which marked the completion of M2RC-24IN0203071. See CCN 255153, “DOME FEEED Study Contract Completion Memo,” M2RC-24IN0203071 – Final Selection of Qualified Vendors. With the submission of the Westinghouse PSDR, the NRIC Safety Design Report will be concluded, and M3RC-24IN0203074 will be completed. See CCN 256271, “DOME FEEED CSDR Completion Memo,” Conceptual Safety Design Report Submittal– Milestone Completion.

6.9.3 Next Steps

During the remainder of FY 2024, NRIC will continue with the submission of Westinghouse’s PSDR and Radiant’s CSDR. This will officially complete the submittal of one Safety Design Report, completing M3RC-24IN0203074. Following these submittals, developers will complete delivery of the remaining FEEED documents and officially complete the FEEED process by the end of FY 2024. Following successful completion of the FEEED process, the developers are expected to move into Detailed Engineering Design and Long-Lead Procurement (DDLLP), which is the next phase in the process for testing advanced reactors at DOME.

6.10 Advanced Construction Technologies Initiative

Project Start Date:	January 2022	Work Package Manager:	Luke Voss

6.10.1 Objectives

The NRIC ACTI is a cost-shared public-private partnership supporting a transformation in nuclear energy construction and deployment costs, thus enabling nuclear energy to make important contributions to the energy system of the future. This transformation is a critical component to increase the confidence of investors, energy system planners, policymakers, and ultimately, consumers in the capability of nuclear energy to meet future needs. It is, therefore, a critical element of the advanced nuclear energy system demonstration. Any development or demonstration project will consider regulatory requirements for commercial nuclear implementation and will incorporate strategies to include regulators in the demonstration of the technology. The first public-private partnership is with GE-Hitachi (GEH) to demonstrate construction technologies supporting a cylindrical build, such as the one that will be used for the BWRX-300, as observed in Figure 7. The ACTI Program is managed by NRIC. The project team that will demonstrate the cylindrical build will be led by GEH. The GEH team is funding 40% of the design costs, with DOE-NE responsible for the remaining 60%.

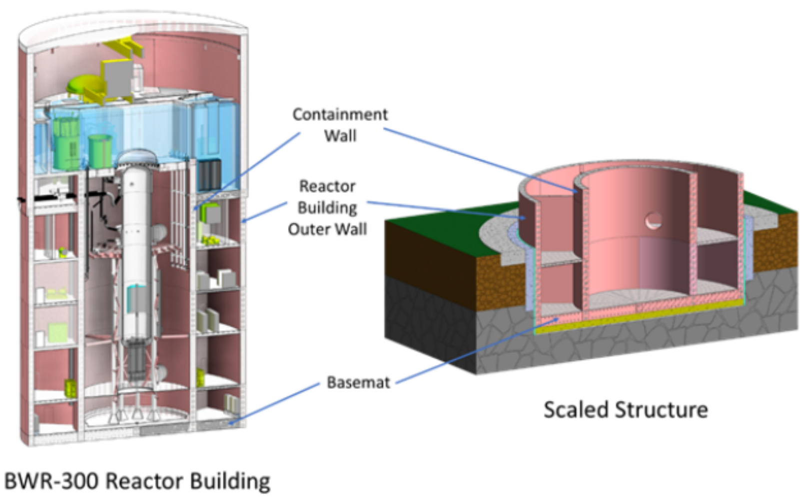


Figure 7 BWRX-300 reactor building and ACTI scaled structure

ACTI's success hinges on its collaborations. The GEH design team is made up of Purdue University and the University of North Carolina – Charlotte (UNCC), science centers such as the Electric Power Research Institute (EPRI), and leaders in nuclear construction like Black and Veatch, Modular Walling Systems Holdings Ltd (MWS), and Aecon Wachs, as well as utilities such as the Tennessee Valley Authority (TVA), Ontario Power Generation (OPG), and Duke Power. Representatives from both the NRC and the Canadian Nuclear Safety Commission (CNSC) have played a role in advising the design team. The team is an impressive group of leaders looking for ways to advance the construction of new nuclear reactors.

The goal of this first ACTI cost-shared public-private partnership is to demonstrate technologies that, when combined, could reduce the construction costs of building new reactors by more than 10% and significantly lower the associated scheduling risks and uncertainties. Use of these technologies allows work to go on in parallel, thus condensing the schedule, as shown in Figure 8.

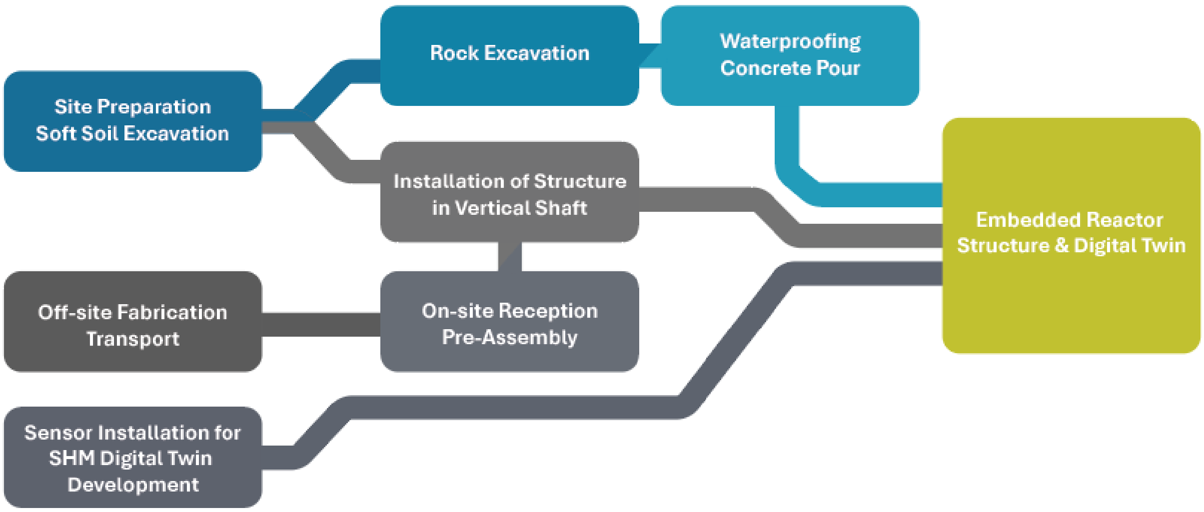


Figure 8 Process flow diagram of the overall construction and integration process.

The technologies highlighted by this initiative include:

- The Diaphragm Plate Steel Composite (DPSC), which is a next-generation steel-concrete composite module for Seismic Category 1 structures, including containments and novel techniques to integrate the modules into the basemat to avoid conventional structural attachment problems. The use of DPSC will reduce construction time and rework associated with welding rebar in high-strength concrete. The DPSC modules will be fabricated in-shop, reducing rework and improving the quality of the construction. Figure 9 shows a diagram of a DPSC module.

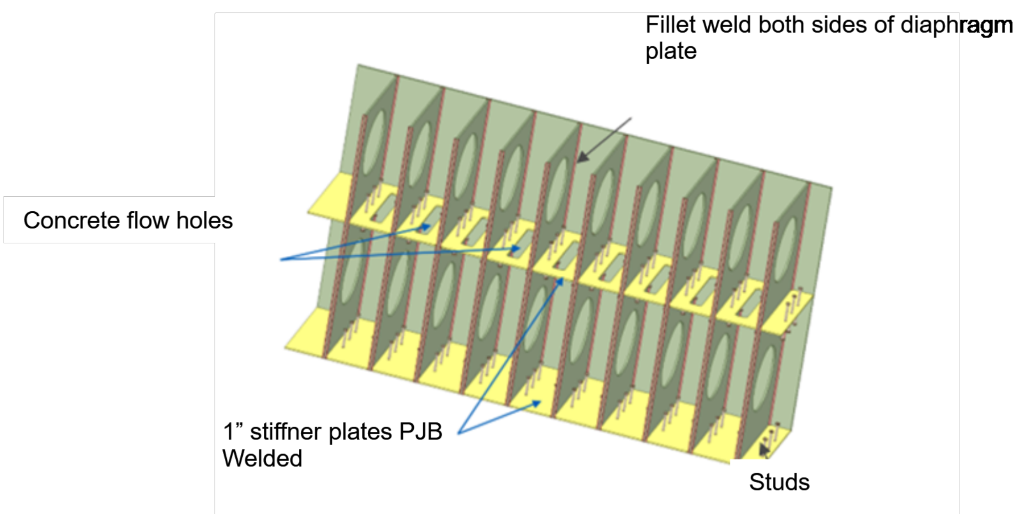


Figure 9 DPSC diagram

- Advanced condition and performance monitoring techniques for implementing construction and in-service surveillance programs to address 10 CFR 50.65, “Regulatory Inspection and Monitoring Requirements,” as part of the reliability integrity management plan.
- Digital twin replica of the structure to integrate sensor data, artificial intelligence (AI), machine-learning (ML), and data analytics.
- Advanced reactors that could benefit from these technologies include the General Electric (GE)-Vernova BWRX-300 and Power Reactor Innovative Small Module (PRISM) reactors, the TerraPower Traveling Wave Reactor and MCFR, the ARC ARC-100, and the DOE Versatile Test Reactor (VTR).

6.10.2 Progress and Accomplishments

The GEH ACTI project was broken up into two phases. Phase 1 included a detailed, site-specific design of a demonstration reactor containment building, utilizing the proposed technologies. To support the design, this first phase also included the fabrication and testing of steel-concrete composite specimens to validate the calculations, models, and assumptions used for the design of the containment structure using steel-concrete composites. Furthermore, included in this first phase was the development of an implementation plan for the proposed Phase 2 demonstration, as well as identifying the nondestructive examination (NDE) techniques that can be deployed on a concrete composite structure during construction. At the completion of Phase 1, GEH is expected to propose the demonstration structure design, project cost, and projected construction schedule to NRIC to potentially receive additional funding to move into Phase 2. The second phase of this project (if awarded) would be to construct a demonstration reactor building structure.

GEH began the ACTI project utilizing a steel/concrete composite walling system called SteelBricks™. However, as the project progressed, GEH identified several SteelBricks™-related construction issues that were projected to cause cost and schedule overruns during the demonstration (Phase 2) portion of the project. Significant weld volume was required for the full penetration welds to join each of the individual SteelBricks™ together. To address the construction limitations of SteelBricks™ and the challenges with full penetration welds in a SteelBricks™ system, the decision was made by an integrated focused team from project stakeholders to use a similar walling system design called diaphragm plate steel composite (DPSC) for the reactor building walling system. The DPSC design greatly reduces weld volume and helps solve the projected cost and schedule overruns for the demonstration portion of the project.

The DPSC system is composed of two continuous plates connected using diaphragm plates. Like the SteelBricks™ system, the DPSC plate is welded to the face plate using fillet welds. The fillet weld is designed to develop the capacity of the plates, similar to the full penetration weld in the SteelBricks™ system; however, the inspection and welding process (using automated robotic arms) is much easier to achieve than the full penetration weld. The inspection of the fillet weld in the DPSC diaphragm plate and the face plate is classified as a Category H weld and only requires visual inspection, which can be achieved by attaching a camera to the robotic welding arm, as opposed to extensive NDE required for the SteelBricks™ welds.

A DPSC module system, like SteelBricks™, consists of multiple components arranged and welded together to form a module. Each component consists of an individual steel element. The DPSC modules are spliced together to form structural walls, floors, or mat foundation sections. The DPSC system has a similar configuration to the SteelBricks™ system but without the full penetration welds used to connect the individual bricks. This system addresses the limitations of the SteelBricks™ system. The DPSC system has the following advantages:

- Major reduction in weld volume/NDE
- Strength and stiffness similar or equal to SteelBricks™
- Does not require bending/forming and post-forming heat treatment
- Simplified fit-up
- More cost-effective
- Some industry experience exists using this method for straight walls in AP1000.

6.10.3 Next Steps

As indicated in Figure 10, GEH is in the process of fabricating DPSC test specimens to send to Purdue University for structural load testing to validate DPSC performance against finite element (FE) models and confirm calculations used for analysis and design. This testing will assess and improve the constructability and feasibility of the DPSC system, as well as the welds used when applying it to actual construction projects. The testing will also develop relevant experimental results for accelerating regulatory review of reactor building containment designs using the DPSC system. A total of nine DPSC prototype specimens will be tested. The purpose of the testing is to subject the DPSC specimens to various loading scenarios to represent accidental pressure and loading conditions, accidental thermal conditions, thermal cycling, and seismic conditions.

Figure 10 Purdue testing rig

GEH is also working to finalize the design of the demonstration structure and provide a cost proposal to NRIC for the building and demonstrating of that structure using DPSC technology. Due to the funding levels for the Phase 2 demonstration, due to the funding levels, GEH has proposed a minimum viable structure that will demonstrate all key construction techniques, critical connections, concrete application, and other various aspects of using DPSC for a cylindrical reactor containment building. With additional funding and an extended project timeframe, a larger scale reactor building could be built to demonstrate this DPSC technology for an entire facility. Figure 11 shows a digital representation of the proposed minimum viable reactor building structure using a DPSC system with a basemat, containment building wall, outer reactor building wall, critical basemat to wall connections, second level mezzanine, and inner passageway walls.

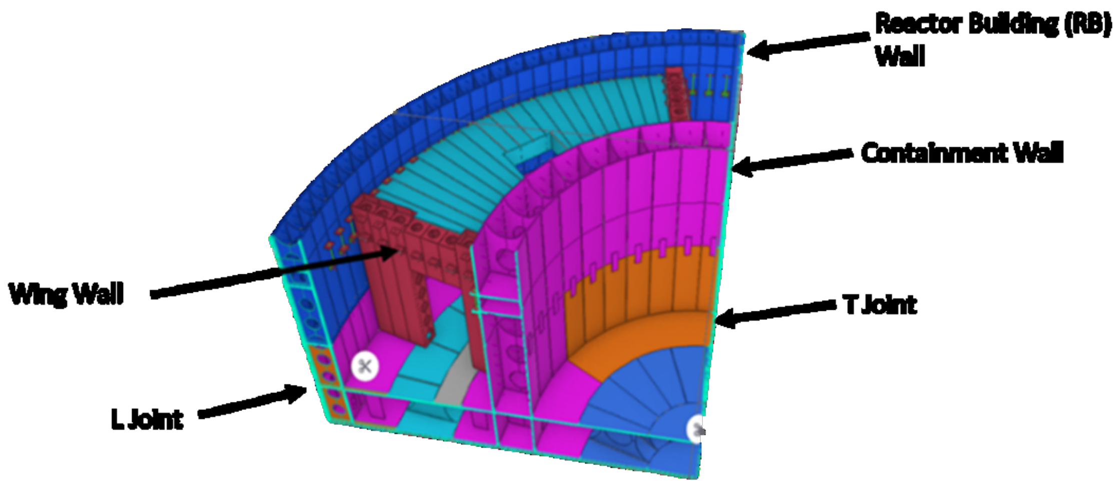


Figure 11 Digital representation of DPSC system demonstration structure

6.11 Digital Engineering

Project Start Date:	October 2021	Work Package Manager:	Peter Suyderhoud

6.11.1 Objectives

Digital engineering describes a holistic approach to the design of a complex system: moving from a document-based design process to a data-driven paradigm, integrating data stored in siloed engineering software platforms, developing digital replicas of real-life systems, and changing the culture of project teams to effectively deploy this technique. The U.S. Department of Defense (DoD) defines digital engineering as “an integrated digital approach that uses authoritative sources of system data and models as a continuum across disciplines to support lifecycle activities from concept through disposal.” Using robust information sources to design, engineer, build, operate, and maintain complex projects, this modern practice allows engineering teams to transfer legacy processes to new digital platforms. NRIC has continued to execute model-based systems engineering (MBSE) and software integration to support the creation of a “digital engineering ecosystem” incorporating disparate engineering domains. The software connections within the ecosystem are known as the digital thread, which will ultimately lead to the creation of a digital twin. NRIC defines “digital twin” as a complete digital replica of a physical asset, incorporating both predicted (simulated) and real-time data. Advancements in AI and ML have enabled digital twins to realize their full potential, synthesizing vast amounts of data to both facilitate the engineering, design, and analysis process and to assist operators in their decisions.

Under this work scope, NRIC’s Digital Engineering Team does not produce a specific physical product; rather, it provides the enabling mechanism that modernizes and optimizes engineering and management processes that help other NRIC areas of focus. This work also fosters collaboration with other nuclear energy-focused organizations throughout industry by providing access to the software platforms used for data-driven engineering at INL.

6.11.2 Progress and Accomplishments

The NRIC Digital Engineering Team has continued the roll-out of PTC Windchill, a Product Lifecycle Management (PLM) software application that helps design teams track all the data—documents, models, equipment—associated with a project. The PLM tool ensures robust configuration management practices are instilled from the inception through the design phase of nuclear energy projects conducted at INL. This centralized source of truth for engineering data provides access to the most up-to-date project information, facilitates design reviews, and tracks the version and state of deliverables (e.g., in work, in review, approved) throughout their lifecycles. The PLM tool, alongside INL's Deep Lynx data warehouse platform, forms the backbone of the NRIC Digital Engineering Ecosystem, as shown in Figure 12.

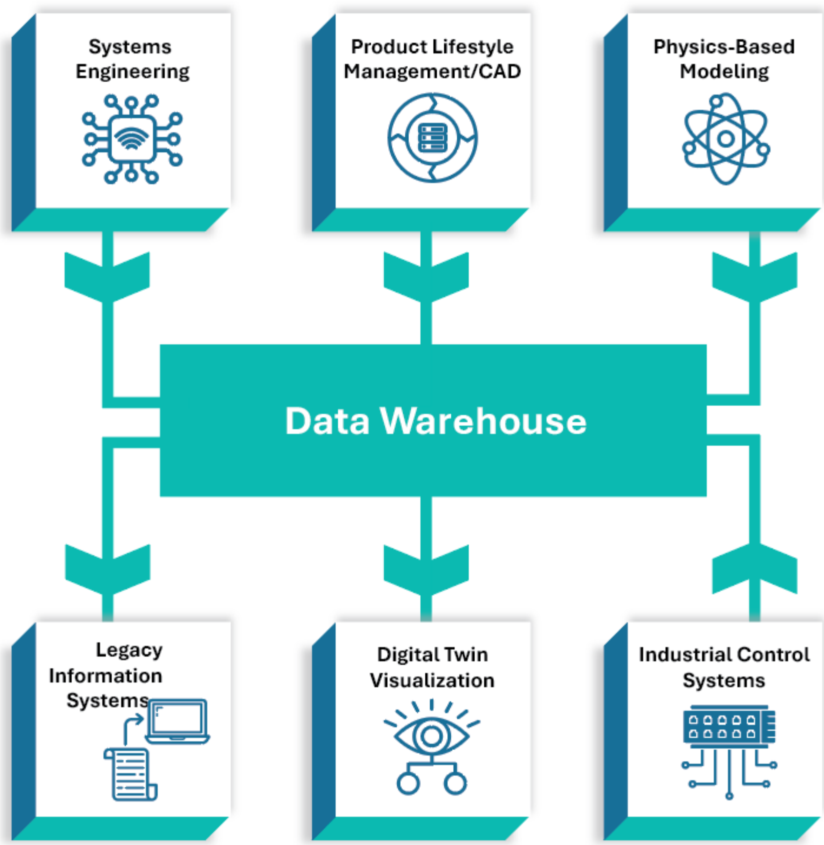


Figure 12 Data warehouse

Realizing that the PLM system is not the approved records storage system for INL, the NRIC Digital Engineering Team has been working to develop robust software infrastructure to sync the PLM system with INL's Asset Suite and Electronic Document Management System (EDMS), preventing manual rework associated with engineers loading documents and their properties into those systems. This capability will also support the turnover of final documentation from demonstrators seeking to utilize the NRIC test beds but needing to transmit their engineering outputs to INL for ownership.

Also in FY 2024, the NRIC Digital Engineering Team continued to make progress on developing the first nuclear facility digital twin centered on the DOME Test Bed. In order to accurately predict facility environmental parameters, a physical model of the test bed is required. Using Mathworks' Simulink product, paper-based engineering outputs like piping and instrumentation diagrams (P&IDs) and logic diagrams were transformed into executable models that can be tuned, altered, and simulated when needed (M4RC-IN0204014). The model can be run with different sets of parameters to optimize future design efforts, test various operating modes or conditions, and eventually accept real sensor data from the operating test bed. When coupled with ML algorithms, the models can be used to monitor operations and conduct predictive analysis in response to changes in operating conditions. In the future, this digital twin could interface with a digital twin of the microreactor experiment to create a "twin of twins."

A new capability that the NRIC Digital Engineering Team focused on in FY 2024 was the ability to convert data in one engineering domain automatically to the format required for downstream analysis activities. There are many instances throughout a project's lifecycle where a need for quick and accurate risk assessment of building designs arises. For example, an unexpected design change during construction may necessitate structural engineers to perform a seismic risk assessment on analytical models of the updated building design using high-fidelity structural analysis software. However, the efficiency of such workflows often depends upon the interoperability of architectural design software and structural analysis software. When the quality of this interoperability is lacking or even non-existent, the efficiency of virtual engineering workflows is hampered, which increases project costs. Therefore, NRIC has developed a capability to improve, automate, and generalize model data exchange between architectural building information modeling (BIM) software and structural analysis software (M4RC-24IN0204011). The goal is to help expedite and automate as much of the pre-processing step for creating analytical models in finite element analysis (FEA) software as reasonably as possible. The tool is currently capable of importing architectural BIM data of framed building structures, recognizing and extracting the aspects of the model that are required for structural analysis, adjusting the connectivity of frame members, and finally exporting to an analytical model stored in the industry foundation class (IFC) format, as shown in Figure 13.

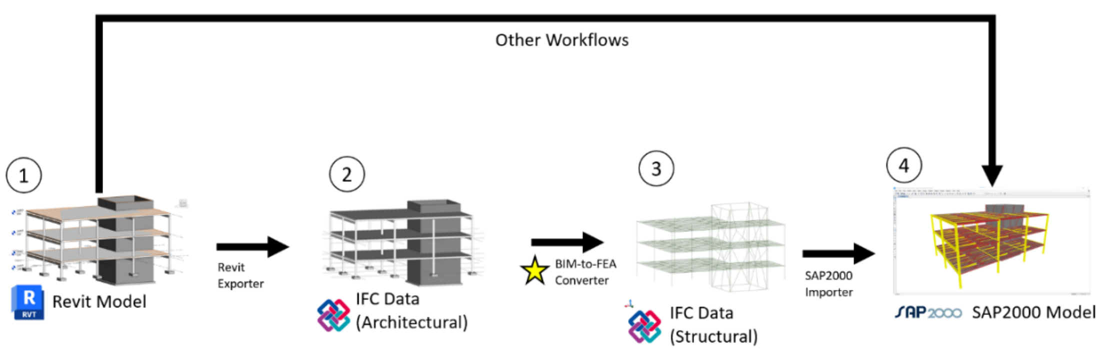


Figure 13 BIM-to-FEA Conversion Tool Workflow

Finally, the NRIC Digital Engineering Team has explored the use of AI in the engineering process. A prototype application was developed to convert engineering constraints such as requirements and informal sketches into three-dimensional (3D) models using probabilistic algorithms. This will obviate the need for projects to require drafting professionals and complex software to generate conceptual 3D models of new power plants. When coupled with the BIM-to-FEA capability discussed above, this will optimize the workflow associated with generating and analyzing a facility structure, allowing more value engineering and trade-off analysis for a new nuclear design.

6.11.3 Next Steps

Beginning in FY 2025, the NRIC Digital Engineering Team will continue progress towards the first nuclear facility digital twin using the DOME. Initially, the digital twin will provide user interaction within a mixed reality environment with existing design data. Once the facility is operational and begins to record real-time data, this information will be correlated with simulated facility models using INL-proven ML models to deliver insights and predictions to facility operators. Throughout its development, the digital twin will enable collaborator interaction with real test bed information and performance, streamlining future reactor demonstrations.

Concurrently, the NRIC Digital Engineering Team will capitalize on open-source tools within the AI domain to augment early engineering phases. Although MBSE provides huge benefits throughout the engineering life cycle, there is typically a manual conversion step required to transform its exclusively two-dimensional (2D), simple outputs into 3D models. Additionally, computer-aided drawings (CADs) typically require highly specialized engineers due to the complex nature of the drafting software. To eliminate this 3D-modeling barrier, the NRIC Digital Engineering Team will continue to develop software that automatically generates models of buildings and systems from rudimentary engineering inputs, such MBSE diagrams, dramatically decreasing the time required to produce conceptual designs.

Future development of the tool envisions the ability for efficient iterative risk assessment of generative building designs, all within a workflow utilizing open-source tools. One such open-source tool will be the Multiphysics Object Oriented Simulation Environment (MOOSE), an advanced FEA tool developed at INL. The conversion tool will also branch out from typical commercial building designs and aim to incorporate nuclear construction, such as the Revit model of the DOME project. The aim will be to convert both structural and non-structural components of nuclear facilities, such as curved concrete containment structures and piping systems, respectively.

6.12 NEPA, Siting Evaluation Activities, and Regulatory Risk Reduction

Project Start Date:	October 2021	Work Package Manager:	Jacob Rymer

6.12.1 Objectives

NRIC aligns its work within existing regulatory framework to accelerate the development and deployment of advanced nuclear technologies. To achieve this, it leverages NEPA knowledge and considerations, siting evaluations, and regulatory risk reduction to pursue the most advantageous path to fulfilling its mission.

To support the NRIC test beds, a NEPA analysis must be conducted to validate appropriate environmental requirements are being met for each experiment. To accelerate the NEPA analysis processes, NRIC has proposed that an Environmental Assessment (EA) be conducted for the operations of the DOME Test Bed that would allow multiple experiments to be conducted under a single EA.

Siting evaluation efforts have been incorporated into the STAND digital tool that provides developers, investors, and regulators with detailed information that is easy to input preferential criteria or filter and identify references.

Regulatory risk reduction encompasses regulatory items, including radiological, environmental, safety, and health criteria that must be completed for each advanced reactor experiment. NRIC has identified opportunities of applying digital tools to accelerate the development and review of existing regulatory submittal documents.

In addition, other activities supporting regulatory engagement include regular communication with NRC, DOE, and potential developers.

6.12.2 Progress and Accomplishments

NRIC has pursued two separate work packages focused on NEPA compliance: siting evaluations and regulatory risk reduction. These work packages and attributed milestone submittals include:

- RC-24IN020403, “NEPA and Siting Evaluation Activities:”
  - PEMP Notable Outcome 1.1A, “Submission of Draft National Environmental Policy Act Analysis for Operations of the National Reactor Innovation Center Demonstration of Microreactor Experiments Reactor Testbed”
  - M3RC-24IN0204031, “Complete Final Draft of Environmental Assessment (EA).”
- RC-24IN020404, “Regulatory and Economic Risk Reduction:”
  - M2RC-24IN0204042, “Complete Digital Authorization/Licensing Proposed Strategy.”

To accomplish the NEPA and Siting Evaluation Activities’ work package requirements, NRIC submitted a NEPA strategy to DOE-ID to complete a draft EA for DOE utilizing a Plant Parameter Envelope (PPE), which would accelerate the deployment of experiments within the DOME Test Bed by unburdening the developers of the environmental process(es) as long as their experiments matched the information captured within the site and engineered parameters. DOE-ID responded to the EA strategy with a signed Environmental Assessment Determination (EAD) on December 21, 2023. To meet the end of the fiscal year submittal deadlines, the project team working on the draft EA document proactively developed a draft EA prior to receiving the EAD. The draft EA was reviewed and re-evaluated for accuracy prior to being submitted to DOE-ID on July 18, 2024. The completion of this work is documented within CCN 256501, “Completion of DOE Level 3 Milestone (M3RC-24IN0204031), Complete Final Draft of Environmental Assessment (EA).”

To accomplish the NRIC Regulatory and Economic Risk Reduction’s work package requirements, NRIC worked with INL’s nuclear safety and digital engineering subject matter experts (SMEs) to develop a framework in which advanced reactor experiments may utilize digital tools to develop and improve reviews of documents that are a part of the Documented Safety Analysis (DSA) process. This framework is described in INL/RPT-24-78848, “Framework for a Digital Documented Safety Analysis,” which was published on June 21, 2024. NRIC is further developing and validating the digital DSA process through a pilot experiment that will provide necessary insight for the development team and will be concurrently reviewed by DOE-ID to identify reviewers needs and how to accelerate the review process.

Additional accomplishments from this year include INL/RPT-24-76187, “Startup Physics Testing of Advanced Reactors,” published in January 2024, and INL/RPT-24-78284, “DOE Authorization Plan for NRIC Test Beds,” published in June 2024. These reports provide insight into the startup physics analysis that must be developed for each reactor during the FEEED process and the expectations for the development of DOE authorization documents to establish the safety basis of an advanced reactor experiment in an NRIC test bed. Under the transportation PRA section, the PNNL team also completed the incorporation of maritime into PNNL-33524-2021, “TRISO Microreactor Offsite Transportation Probabilistic Risk Assessment.”

Another PNNL report that has not yet received input from the NRC is PNNL-31438-2023, “NEPA Roadmap for Advanced Reactor Prototype Deployment,” but has been available since September 2023.

6.12.3 Next Steps

FY 2025 will see continued work on leveraging DOE-authorized work for potential subsequent NRC licensing efforts, DOE and NRC coordination, development of an experiment to review the digital DOE authorization framework, discussion of digital applications for future NRC licensing pathways, and transportation analyses.

6.13 Irradiated Molten-Salt Capabilities

Project Start Date:	October 2023	Work Package Manager:	Carson Stronks

6.13.1 Objectives

The development and deployment of the NRIC MSTEC hotcell, as observed in Figure 14 and Figure 15, is necessary to assist in the advancement of the technical readiness level (TRL) of molten-salt reactors (MSRs). When completed, MSTEC will be the only facility in the world offering a comprehensive suite of characterization capabilities for irradiated fuel salts. Characterization of this type of material will significantly advance the deployment of advanced reactors.

The objectives of MSTEC are to qualify liquid-fuel salts, support industry and regulators such as the NRC, and facilitate the rapid deployment of commercial MSRs while minimizing the risks to stakeholders. Therefore, it is necessary to have infrastructure and equipment to measure the thermal, chemical, and physical properties of irradiated and unirradiated molten-salt systems—including fuel and coolant salts with prototypical concentrations of actinides, fission product, and corrosion-products.

Currently, the next generation of MSR designs are mostly theoretical. A large knowledge gap exists regarding the behavior of multicomponent salt systems under reactor conditions and how the behavior changes as a function of fuel burnup and irradiation exposure. It is equally important to understand how physical and mechanical properties of construction materials within an MSR change as a function of temperature, irradiation, and salt exposure. This work directly supports NRIC’s mission to demonstrate advanced nuclear energy designs in the near-term.

Collection of this data serves two interconnected primary purposes: (1) to inform accurate design of reactor components, operating procedures, limiting conditions, and predictive models relevant to advanced MSRs; and (2) to allow for qualification of the fuel and components of MSRs under NRC licensing requirements. In the long-term, the availability of such a capability would allow for ongoing monitoring of fuel salt samples taken from irradiation experiments, test reactors, and eventually commercial reactors to validate the important thermophysical properties over their operational lifetimes.

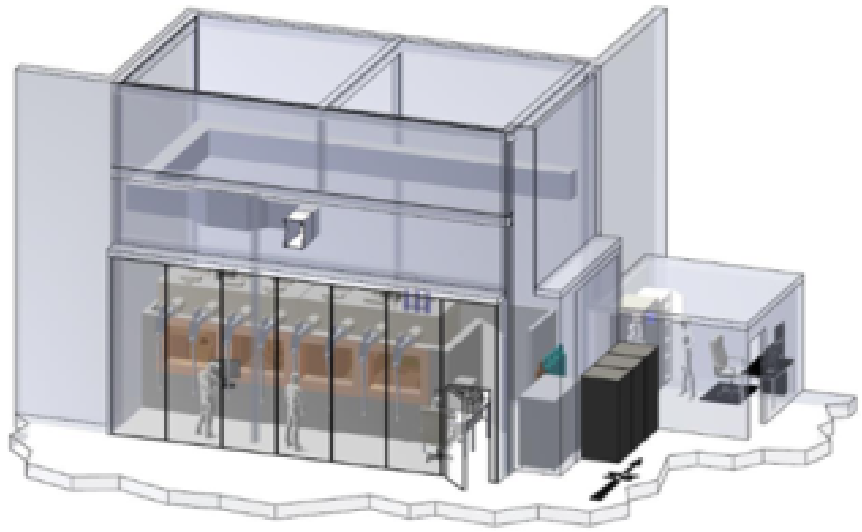


Figure 14 Model of the MSTEC hotcell

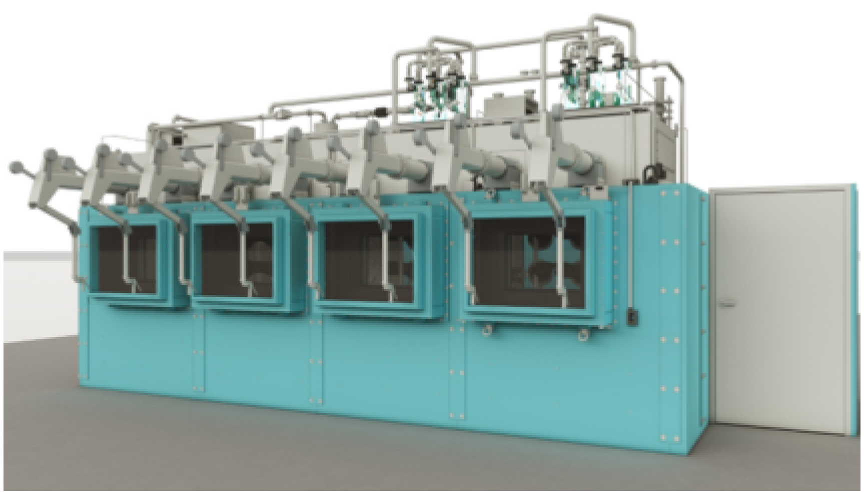


Figure 15 3D model of the MSTEC hotcell.

6.13.2 Progress and Accomplishments

MSTEC Phase 2 construction is ongoing and includes: (1) installation of the complete shielded cell in the Fuel Conditioning Facility (FCF); (2) fabrication and installation of a mezzanine over the shielded cell that will house the purification control systems and research hardware controls; (3) final tie-ins to all applicable utilities, such as the heating, ventilation, and air conditioning; tubing; piping; and electrical systems, from the equipment to the facility; and (4) final testing of all systems for final turnover to INL, as indicated in Figure 16.

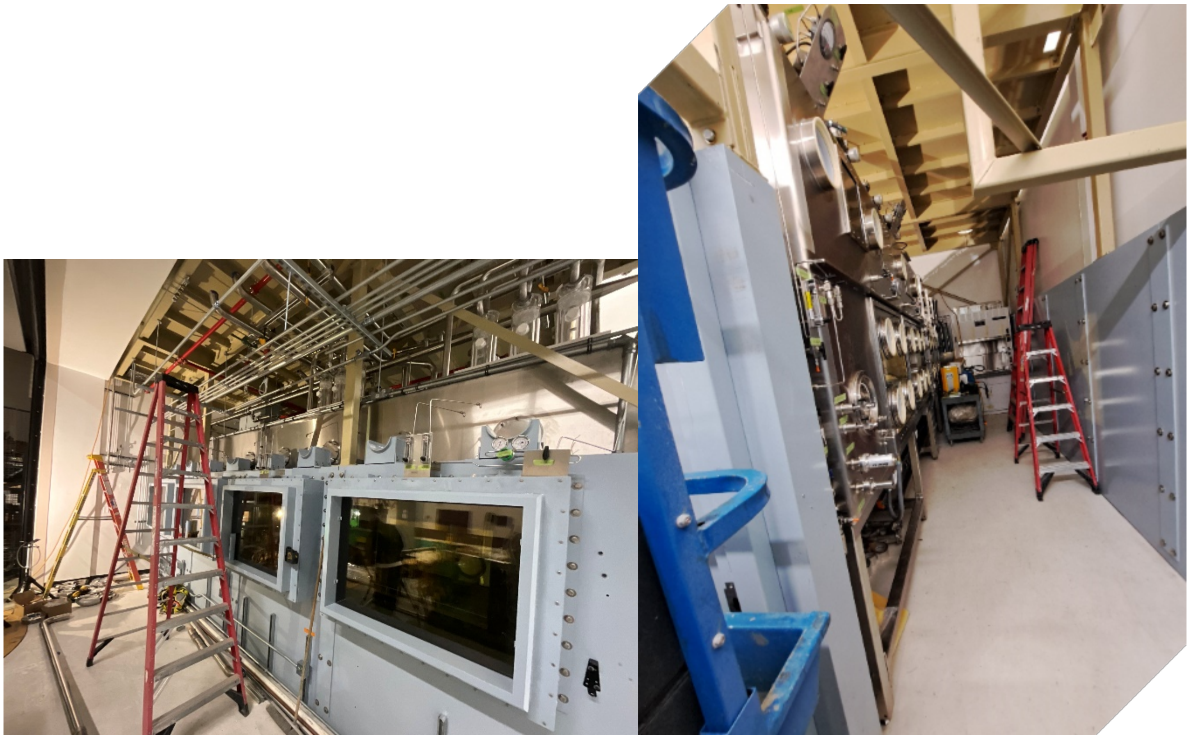


Figure 16 Photographs of MSTEC shield walls and glove box undergoing installation in FCF.

After construction is complete, INL will start installing the many pieces of equipment that go into the glove box and feed throughs to hook up the equipment that is going into the glovebox. They will also start installing the eight manipulators, as observed in Figure 17, on the glovebox in the FCF.

The INL MSTEC project team traveled to Extract Technology in Mauston, WI, the week of December 11, 2023, to oversee MSTEC factory acceptance test (FAT), as indicated in Figure 18 All steps of the INL-authored FAT procedure were executed during the visit and the operation of the MSTEC cell was successful. Included in the visit were the INL glovebox SME, MSTEC system engineer, MSTEC project engineer, MSTEC electrical engineer, MSTEC project manager and lead scientist, and the two primary MSTEC operators. The visit also served as the first major on-the-job training exercise for all visiting INL staff. Milestone M2RC-24IN0206054, “Complete INL Oversight of Factory Acceptance Test of MSTEC at Extract Technology Facility,” was completed successfully on January 29, 2024.

Figure 17 Photographs of manipulators at INL and a feed-through ready for installation.

Figure 18 Photograph of the MSTEC Project Team participating in the FAT at Extract Technology.

The shield walls and manipulators, as shown in Figure 19, were received at INL on January 15, 2024. These items had been shipped ahead of the glovebox to enable initiation of installation activities at the FCF. Delivery of the glovebox, fume hood, and all other ancillary equipment related to MSTEC was shipped within the next two weeks following completion of several minor action items from the FAT. The installation of the shield walls by DR Construction was initiated at FCF the week of January 29, 2024.

Figure 19 Photographs of MSTEC shield walls and manipulators (in wooden crates) in INL receiving warehouse.

6.13.3 Next Steps

In FY 2025, the following MSTEC activities are scheduled to be completed:

- Continued equipment installation in the glovebox
- Continued training and procedure development for MSTEC operations
- Completion and acceptance of SAR, TSR, and all other required safety documentation
- Conducting operational readiness reviews
- Beginning of MSTEC operation.

6.14 METL Operations, Testing, Maintenance, and Improvements

Project Start Date:	October 2020	Work Package Manager:	Chris Grandy (ANL)

6.14.1 Objectives

The METL work package includes the operations, testing, maintenance, and improvements for the METL facility and supporting infrastructure, which provides a platform for testing innovative systems and components in high-temperature liquid metals. METL is a key facility for fast reactor R&D infrastructure within the U.S and the DOE complex. METL operations and testing provides a versatile capability for U.S. industry needs regarding liquid metal technology development and fast reactor component testing in a prototypic environment.

This work will include coordination with the Advanced Reactor Technologies (ART) Program Fast Reactor R&D work package (as necessary) to continue the creation of a qualification area for METL test assemblies, including the continuation of testing for the 28-inch flexicask system and insertion of test articles into METL. The work will also include the development of the improved inductive level sensor for METL. It may include continuing longevity testing of heaters and wires along with other testing needed for METL.

Resources will be used by staff to implement and coordinate these efforts. Staff will operate and checkout METL equipment, systems, and supporting infrastructure on an ongoing basis.

The operation, testing, maintenance, and improvements for the METL facility supports the following objectives:

- Research, development, and demonstration of advanced innovative cost-reduction and performance-enhancing technologies for advanced fast reactor applications
- Development of advanced technologies for accident prevention and mitigation
- Development of sustained personnel, physical, and knowledge infrastructure for long-term research, development, and demonstration of fast spectrum systems
- Preservation and nurturing of the domestic knowledge base and U.S. professional expertise to facilitate science-based R&D
- Reestablishment and maintenance of U.S. technology leadership for advanced fast reactor technology.

6.14.2 Progress and Accomplishments

The METL facility has been operational since September 19, 2018. Funding for its operations from NRIC started in April 2022. In FY 2024, the following were observed:

- METL was maintained in a hot molten state for 24 hours a day, seven days a week.
- The METL team performed periodic sodium purification runs in order to maintain sodium purity in METL. During these purification runs, the cold trap was observed to be reaching the end of its life. The cold trap is currently operated at 170 C, but an external customer requested operation at only 150 C. However, while trying to cold trap down to 150 C, flow began to be lost. We have procured a new cold trap (identical to the installed one), as well as a new and improved cold trap stand, and are in the process of fabricating new piping segments to be installed within the new cold trap.

- The METL team supported Gear Test Assembly (GTA) operations, which completed Test Campaign 7 and 8. For Test Campaign 7, the test article operated for 14.4 hours of testing, but testing was stopped due to bearing failure. The GTA has been removed from the METL Test Vessel 1, processed through the carbonation process, and dismantled, as indicated in Figure 20.

Figure 20 THETA fully installed in Test Vessel 4 (notice Test Vessel 6 to the right of THETA).

- The METL team supported the operations of the Thermal-Hydraulic Experimental Test Article (THETA). In FY 2023, THETA was refurbished to install thermal insulation around the THETA core barrel and intermediate heat exchanger. In FY 2024, THETA's secondary system was installed on the METL mezzanine and THETA was made fully operational to reject the 38 kW of heat to the atmosphere in the highbay, as indicated in Figure 21.

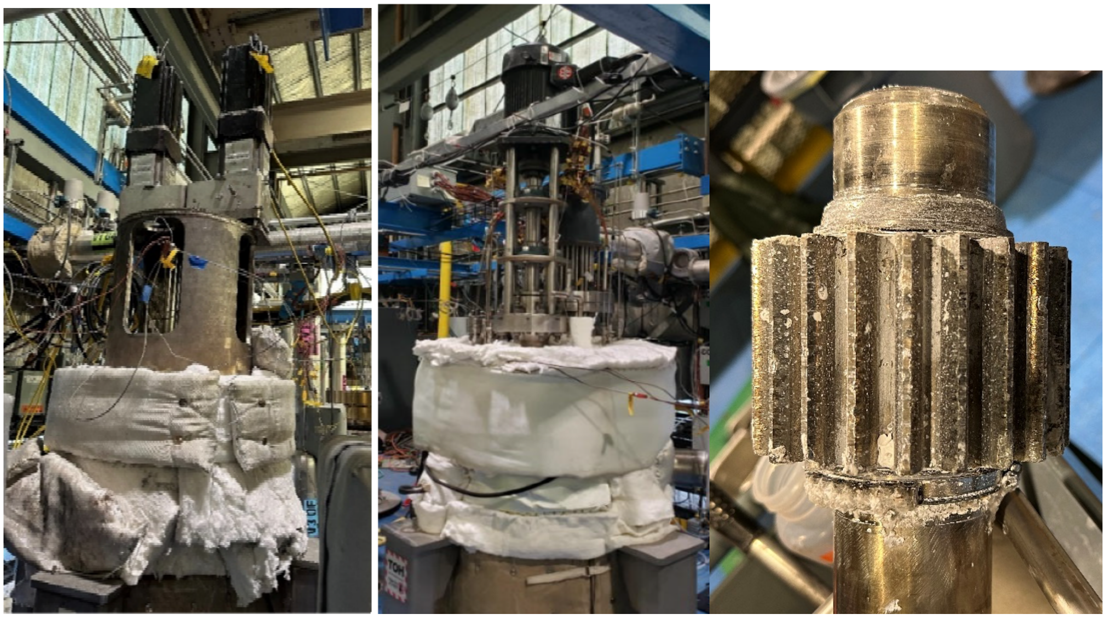


Figure 21 . (Left) GTA installed in Test Vessel 1. (Right) Image of tested gears.

- The METL team installed an off-the-shelf structural health monitoring system on the piping system for Test Vessel 6. This new system will allow monitoring of this piping system, as well as a demonstration of the high-temperature structural health monitoring system.
- The METL team developed a sample basket, as observed in Figure 22, that then was fabricated for use. This basket allows for the investigation of the compatibility of the material samples with high-temperature sodium. The basket has a part that is submerged in sodium and a part that can hold components in the vapor space. The sample basket is designed for installation in an 18-in. METL test vessel.
- The METL Experimenters Guide was published. This guide provides information that supports innovators in their quest to design experiments to go into METL. This guide is located on the METL website.
- The METL team supported the installation of Test Vessel 6. This Level 2 milestone work included the installation of piping systems to provide sodium to the test vessel from the main loop and returning sodium to the main loop. In addition, the installation of heaters on the installed piping system was 90% completed. A level detector was removed from the dump tank in preparation for connecting the Vessel 6 drain line to the dump tank. As of July 19, 2024, METL has been drained and the dump tank is cooling down to ambient conditions in preparation for making the final drain line connection to the dump tank. That work will be followed by weld radiography, the completion of the heat and instrument installation, the insulation of the piping and the vessel, and then the bakeout of the system prior to filling with sodium, as observed in Figure 23.

Figure 22 Sample basket.

Figure 23 Test Vessel 6

- The METL team designed a wet vapor nitrogen (WVN) system that will be used to augment the moist carbon dioxide sodium cleaning system. Currently, test articles removed from a METL test vessel are cleaned with moist carbon dioxide for about a week or two to convert residual sodium on the test article to sodium bicarbonate. This process does not completely clean a test article. In order to react with more residual sodium, we are installing a WVN system that will allow for more sodium to be reacted from a test article before it is removed from the cleaning tank. The parts for the WVN system have been procured as of the writing of this report and are being installed.
- While at the NRIC Program Meeting held at INL on April 23, 2024, the METL team gave a presentation on the status of this work, which was completed in FY 2023 and FY 2024.
- In October 2023, the METL team provided tours to personnel from NA-211, International Nuclear Safety. The GTA and THETA experiments were discussed along with the overall METL facility.
- In December 2023, the METL team provided tour to several INL employees, including Jess Gehin, Erin Searcy, Monica Regalbuto, Youssef Ballout, Eric Whiting, and Brad Tomer.
- The METL team has started to support an Advanced Sensors and Instrumentation (ASI) Program activity related to the demonstration of the Parameter Free Reasoning Operator for Automated Identification and Diagnosis (PRO-AID) program with a specific focus on cold trap and plugging meter performance. A meeting was held with Rick Vilim on May 2, 2023, to discuss this project. Since this meeting, Derek Kultgen has provided access to the METL data focused on the METL purification and diagnostic system. Kultgen provided the team with a plot of generated transient data as an example of what the PRO-AID team can expect. The goal of this work is to have this computer program detect anomalies within the purification and diagnostic systems. A demonstration of this capability was provided to those attending the ASI Program Meeting in September 2023, as shown in Figure
- The Fast Reactor Program was invited to the ASI Program Meeting to provide a presentation that covered three areas: (1) ART Fast Reactor Program Sensor Development, (2) Testing Infrastructure, and (3) Fast Reactor Sensor Needs. The approximately 20-minute presentation was given on November 2023 and discussed METL, THETA, and some of the other test articles, as well as current areas of collaboration with the ASI program.
- The METL team is collaborating with various NEUP awardees in demonstration of various sensor technologies, such as flow monitoring, structural health monitoring, and impurity monitoring. The goal is to deploy all of these sensors at METL once fully developed.

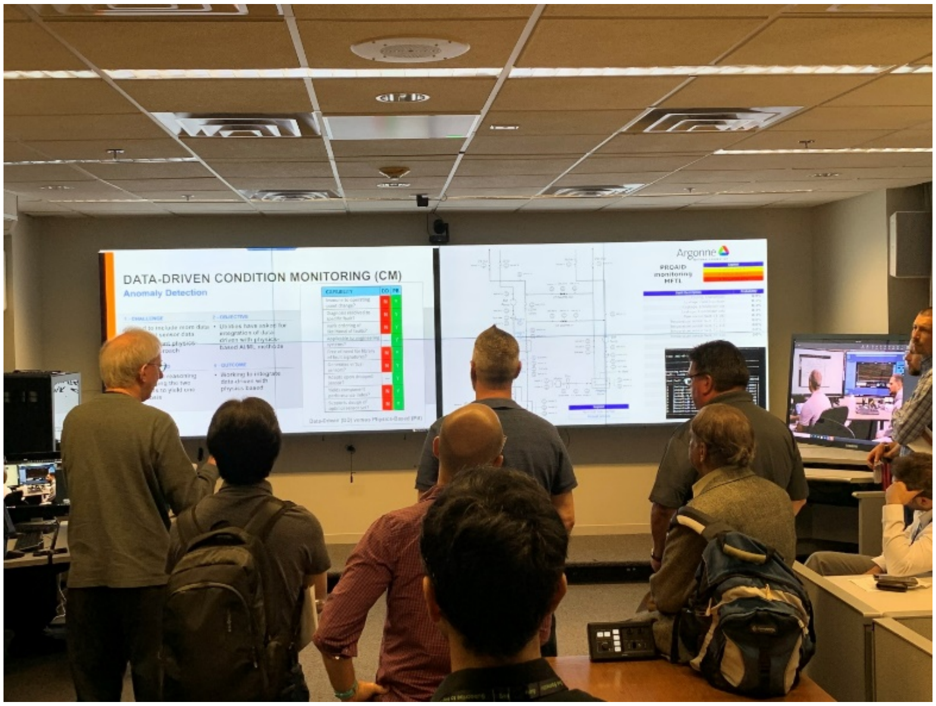


Figure 24 Demonstration of PRO-AID on METL at the ASI Program Meeting in September 2023.

6.14.3 Next Steps

The METL team will continue to operate, maintain, and improve the facility in support of system and component testing in sodium through the following efforts:

- Testing of gears and bearings in sodium via the GTA.
- THETA testing to support the validation of thermal-hydraulic codes.
- Preparation for the testing of a vendor test article and a flow sensor test article.
- Commissioning of the new WVN system for conversion of residual sodium to sodium hydroxide.
- Preparations for the removal and installation of a new cold trap into METL. The current cold trap appears to be getting to its end of life because flow is lost when the cold trap is adjusted down to 150°C. Replacing the cold trap will be the first time METL has replaced its existing cold trap in over 5.5 years of service. Once the old cold trap is replaced and METL is brought back online, the old cold trap will be characterized, and a new (potentially larger) cold trap will be designed and fabricated.

6.15 Virtual Test Bed

Project Start Date:	October 2020	Work Package Manager:	Lise Charlot

6.15.1 Objectives

Many advanced reactor concepts under development will require extensive experimentation and analysis campaigns before they are ready for deployment. NRIC is tasked with accelerating the deployment of these designs by providing both physical and virtual infrastructure for component testing and development. The VTB represents the virtual arm of this effort in that it provides a computational environment for M&S efforts in support of nuclear reactor pilot demonstrations. The VTB also supports NEAMS tools used to confirm, verify, and evaluate industry-relevant designs. M&S tools and valuation methodologies will be a central focus of this project to encourage design review activities. This would support private-sector innovators in meeting nuclear technology development needs.

More specifically, the VTB establishes a venue to create simulations of advanced reactor concepts and showcases example use cases. These models have a wide variety of applications, ranging from confirmatory analysis to regulatory safety validation. The project emphasizes the use of advanced, multidimensional, and coupled Multiphysics NEAMS codes that are under development at the National Laboratories. The VTB also coordinates necessary code development and reactor analysis of reactor concepts needed to support potential demonstrations. This effort intends to create non-proprietary, open-source reactor core reference simulations that will be used to promote broader public engagement and validation efforts. These tasks will provide the basis to develop a framework to evaluate design concepts, including a safety review and feasibility assessment. In addition, cross-cutting improvements will be made to NEAMS codes and frameworks, where necessary, for simulating reactors of interest. This effort will provide a starting point to evaluate nuclear demonstration projects, allowing NRIC to be responsive to stakeholder requests.

6.15.2 Progress and Accomplishments

- The VTB team, comprised of staff from INL and ANL, added 15 advanced reactor simulation use cases in FY 2024, for a total of 50.
- The team deployed continuous integration on the INL High Performance Computing (HPC) platform for large transient or high-fidelity computational fluid dynamics (CFD) simulations.
- The team developed an initial model of the DOME shield that can be coupled with any reactor model to evaluate the resulting temperature in the shield accounting for neutron and gamma heating.
- The VTB team held engagements with several stakeholders this year. VTB models are referenced in an NRC report on the V&V of NEAMS tools, and held its own special session at ANS conferences, highlighting M&S efforts hosted on the VTB.
- The project is using the Google Analytics tool on the VTB website to track unique visitors and their locations, among other data. Over the period from June 2023 to June 2024, the VTB saw over 3,000 unique visitors.
- The team has been collaborating with the Digital Engineering Team to integrate VTB models to system-level simulations and digital twins.

6.15.3 Next Steps

The VTB team strives to maintain the quality and usefulness of the repository and aims to provide that benefit in FY 2025. Additional models of interest will be added to expand the repository, increasing its effectiveness to the advanced reactor development community. Beyond traditional M&S, the team intends to include framework models that assist reactor developers in accomplishing their projects, including requirements models, product breakdown structure models, and ontology models.

6.16 HFEF-15 Cask Modifications

Project Start Date:	October 2020	Work Package Manager:	Curtis Nielsen

6.16.1 Objectives

This project will design, fabricate, inspect, and install physical modifications to the Hot Fuel Examination Facility (HFEF)-15 shipping cask to support its use for large-format experiments in the Transient Reactor Test (TREAT) facility at MFC. Procedures to use the cask will also be updated. At the conclusion of these tasks, engineering-led readiness activities will occur to verify the HFEF-15 cask processes and procedures adequately address safety and operational requirements.

The HFEF-15 cask, as presented in Figure 25 has been used to transfer the TREAT Mk-IIIC sodium loop cartridge between the HFEF and the TREAT facility. While the HFEF-15 cask is currently in use, incorporating the mechanical aspects and the hazards unique to shipping a large-format experiment, such as the modern TREAT Mk-IIIR sodium loop cartridge, requires physical and process modifications. These will allow the installation, transport, and removal of the modern TREAT Mk-IIIR sodium loop cartridge and other large-format experiments.

6.16.2 Progress and Accomplishments

In FY 2024, the project team completed the remaining design activities, procured all fabricated items, disassembled the cask to remove old components, and installed the new components. The team completed all draft drawings ahead of schedule to complete the Level 3 milestone (M3RC-24IN0206043).

Figure 25 The disassembled and cleaned HFEF-15 cask body.

6.16.3 Next Steps

The project will complete closeout activities by the end of FY 2024, highlighted by the final deliverable of the project, a project letter signifying that the cask can now accept large-format experiments. Figure 25 shows the new HFEF-15 cask.

Figure 26 The HFEF-15 cask fully assembled using new components.

6.17 Maritime Applications of Nuclear Energy Studies

Project Start Date:	October 2020	Work Package Lead/Manager	Sanjay Mukhi Marvin Fielding

6.17.1 Objectives

Marine power represents a potential market for advanced nuclear energy that several advanced reactor innovators are pursuing. NRIC manages a working group called the Maritime Nuclear Application Group (MNAG), which grew to over 130 members in FY 2024 and has identified a growing interest for floating nuclear power and nuclear propulsion of large ocean-going vessels as part of the global drive to zero emissions. It is now widely recognized in the sector that international climate goals of reaching zero emissions for shipping will not be attainable without deploying advanced nuclear-powered ships. This interest is international, and investors are entering the sector to support and facilitate the development of advanced nuclear solutions for deployment at sea. NRIC's maritime efforts are exploratory, identifying key challenges and opportunities through expert and stakeholder consultation and literature review. NRIC's activities are designed to raise awareness, foster collaboration, and identify paths forward to enable commercial maritime use of nuclear energy.

6.17.2 Progress and Accomplishments

From July 2023 to July 2024, the following items were accomplished in this task:

- NRIC held a quarterly MNAG meeting in October 2023, with a recap of the American Bureau of Shipping (ABS) Global forum, an update of the ABS Task 2, a recap of the nuclear caucus, a recap of the Core Power DC Summit, and presentations from the four MNAG working groups. Approximately 42 people attended the virtual meeting.
- In December 2023, NRIC completed a testbed gap analysis report for maritime applications (M2RC-24IN0207011). The report included the findings of an information needs request from industry to understand perceived maritime testing needs, as well as a similar request of the National Laboratories and universities to understand maritime testing capabilities.
- In conjunction with ABS, NRIC completed Task 3 of the ABS Industry Funding Opportunity Announcements (iFOA) award by submitting a Readiness Report for DOE Support of Maritime-related Demonstration Projects of Advanced Nuclear Technology for DOE review in February 2024. This report builds on the gap assessment that was completed in December and identifies the need for a ship motion test facility.
- NRIC began work on two reports in January 2024. These reports are, "The Economic, Social, and Environmental Impacts of Maritime Nuclear Applications," and the "Engineering Requirements and Cost Estimate for A Ship Motion Test Facility." Work progressed through the first drafts of each of these reports and NRIC gave a brief of early findings to DOE in May 2024. Two reports were completed and submitted to DOE on July 11, 2024, RPT-24-79176 Ship Motion Testing Needs Evaluation, and RPT-24-79165 Engineering Requirements and Capital Cost Estimation for a Ship Motion Test Facility. Submission of these reports marked early completion of milestone M3RC-24IN0207013: Complete a Maritime Nuclear Test Platform Engineering Requirements and Cost Estimation analysis. Submission of The Economic, Social, and Environmental Impacts of Maritime Nuclear Applications report will culminate in the completion of another milestone due September 30, 2024: (1) M3RC-24IN0207012, "Complete MNAG White Paper: Maritime Nuclear Economics Considerations".

- NRIC conducted a quarterly MNAG meeting in February 2024, which provided an update from ABS on the progress of Tasks 3 and 4 of the iFOA award, an NRIC review of the MNAG Regulatory Landscape report, a progress report from MPR Associates on the Ship Motion Test Facility report, and a progress report from MPR on the Economics White Paper. NRIC conducted an interactive poll seeking input from attendees on topics for future quarterly meetings. The top suggestions were public acceptance, siting, insurance, build first plant, and regulatory approach. Fifty-one MNAG members attended the virtual meeting.
- NRIC hosted several meetings over the past year to introduce potential industry partners to the work that NRIC and MNAG are doing and discuss the potential applications for nuclear technology and opportunities for collaboration.
- NRIC hosted an MNAG quarterly meeting on June 11 with presentations on insurance for nuclear and non-nuclear-maritime hazards, a regulatory approach from a security perspective, and public acceptance of nuclear technology for maritime applications.
- DOE and NRIC presented a seminar to the NRC in June on NRIC’s work in the maritime sector.

6.17.3 Next Steps

The “Economics, Social, and Environmental Impacts of Maritime Nuclear Applications” report will be finalized in the fourth quarter of FY 2024.

ABS and NRIC will finalize the Task 4 deliverable, “Overcoming Barriers to Nuclear-Maritime Demonstrations.”

Provide pre-conceptual planning and support for a DOE determination of mission need for a Ship Motion Test Facility.

6.18 In-Cell Thermal Creep Frames for Demonstration Project Preparations

Project Start Date:	June 2021	Work Package Manager:	Marvin Fielding

6.18.1 Objectives

The objective of developing in-cell thermal creep frame capabilities is to establish the necessary infrastructure and technical experience to provide materials testing of neutron-irradiated materials at applicable high-temperature conditions for advanced nuclear reactor developers and the nuclear industry.

Several advanced reactor concepts will have core operating temperatures greater than 500°C, resulting in thermally driven processes, such as creep, that contribute significantly more to material behavior and degradation than compared to light water reactor conditions. Therefore, the long-term mechanical behavior of irradiated candidate structural materials must be assessed at the higher temperatures to determine the geometric and mechanical integrity of in-core components during both steady-state and off-normal conditions.

As neutron damage still plays a significant role in a component's lifetime, it is important to understand the interplay between the processes for radiation damage and thermal degradation that affect structural materials. This requires the use of hotcell facilities, which are extremely limited in physical space and maneuverability, to safely conduct tests. This space limitation excludes the use of traditional creep frames and large specimen geometries. To address this, the feasibility of using smaller creep frames and subsized specimens must be explored. In addition, aligning of new testing frame capabilities with sample geometries that are typically irradiated within capsules at test reactor facilities (such as the INL's Advanced Test Reactor [ATR]) will accelerate the testing process and help address the demands for performance data under reactor relevant conditions. These conditions are integral in enabling materials qualification for licensing processes and development.

Therefore, NRIC has prioritized the development of thermal creep testing infrastructure at INL, using smaller specimens to accelerate the demonstration and deployment of advanced reactor concepts.

6.18.2 Progress and Accomplishments

Creep is a very slow deformation process, requiring the testing of multiple samples simultaneously. Standard creep testing approaches are not feasible due to hotcell space restrictions. NRIC provided funding for the design, fabrication, and qualification of three compact thermal creep frames to support materials development, qualification, and licensing for advanced reactor materials. The compact size of the creep frames will facilitate installation in a hotcell, where testing irradiated smaller samples can occur. The creep frames were developed in response to a need for in-cell testing of irradiated samples, a capability not available in any other DOE laboratory.

The Thermal Creep Frame schedule and cost estimate for the project through facility turnover was completed in March 2023, M4RC-23IN0206072 :Thermal Creep Frame Schedule & Cost Estimate. As-built drawings and creep frames qualification were completed in FY 2023 M3RC-23IN0206074: In-cell Thermal Creep Frames Installation. It is anticipated that the creep frames will be installed in the Sample Preparation Lab (SPL), which will become operational in FY 2026. NRIC anticipates that Kairos will be the first user of the creep frames to test and qualify materials in its advanced reactor program.

The Irradiated Fuels and Materials organization in NS&T is currently using the creep frames for small specimen testing on additively manufactured material for the DOE-NE Advanced Materials and Manufacturing Technologies (AMMT) Program. This testing is expected to continue into FY 2025.

NRIC investigated alternate locations for hosting the creep frames including PNNL and ORNL to accelerate testing for the first user. Those labs needed additional information which was not available to determine when and where they might be able to deploy the creep frames. At this same time, the first potential user paused their testing program. After considering the logistics of moving the creep frames to another lab, the delayed need for test data, and the on-going need for AMMT program testing, NRIC concluded that it would be advantageous to keep the creep frames at INL.

6.18.3 Next Steps

No funding nor associated activities are planned for FY 2025. Activities related to Creep Frames will resume in FY 2026 upon the completion of the SPL facility which include:

- Determine whether the sub-sized irradiated samples that will be loaded in the creep frames can be contact handled, or if they require remote handling.
- Make minor adjustments to the creep frames, if necessary, to better accommodate sample handling and loading requirements.

7. APPENDIX A

NRIC ORGANIZATION CHART