INL/RPT-23-74476

National Reactor Innovation Center Annual Report FY 2023

September 2023

AnnMarie Marshall
Author
Brad Tomer
Approver

NRIC | INL Idaho National Laboratory

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

DISCLAIMER

REVISION LOG

Document ID	Date	Affected Pages	Description
LTD-20-59965	09/28/2020	All	Initial Issuance.
RPT-22-68908	09/15/2022	All	Annual Update
RPT-23-74476	08/30/2023	All	Annual Update.

Page intentionally left blank:

ACTING DIRECTOR'S MESSAGE

It is my privilege to present this year's annual report for the National Reactor Innovation Center (NRIC). Now rounding out our fourth year of operation, NRIC is poised for successfully delivering our most foundational promise: to accelerate the testing and demonstration of advanced nuclear technology by providing access to national laboratory assets and expertise. Some specific goals include the following:

- Establish and maintain four new experimental facility capabilities:
  - MSTEC – 2025
  - METL – Operational
  - HeCTF – Operational
  - Creep Frames – 2026
- Construct and operationalize two advanced reactor test beds (DOME and LOTUS) for integrated technology demonstrations and experimentation – 2028
- Complete minimum of two advanced nuclear technology tests – 2030
  - Advanced Construction Technology – 2025
  - Advanced microreactor test in DOME or LOTUS – 2027 and 2029

NRIC's success stems from our outcome-driven approach to accelerating the demonstration and deployment of advanced nuclear energy. The nation's greenhouse gas abatement commitments present a renewed sense of urgency for NRIC to rapidly meet the congressional mandates set forth in the Nuclear Energy Innovation Capabilities Act (NEICA).

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 U.S. Department of Energy (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 2023 (FY 2023), which emphasized the following:

- NRIC made significant progress toward constructing the two test beds, including awarding NRIC-DOME construction subcontract, and initiating NRIC-LOTUS preliminary and final design. In addition, NRIC drafted an end-to-end user guide for testing advanced reactors in the DOME, which will greatly facilitate accurate cost estimating and scheduling future tests. Further, NRIC took a major step forward in establishing tests in the DOME by awarding multiple cost-shared Front-End Engineering and Experiment Design (FEEED) subcontracts to our industrial partners.

- NRIC partnered with General Electric Hitachi and Purdue University complete the testing of modular wall systems under Advanced Construction Technology Initiative. This testing yielded very encouraging results and sets NRIC up for success in the demonstration phase of this project.

Additionally, NRIC continued to drive successful outcomes, for example:

- The talented and dedicated core team grew and sustained the skills and diverse perspectives to support the unique and evolving needs of innovators.
- NRIC's digital efforts took leaps forward in both the Virtual Test Bed and the Digital Engineering portion of the program.
- Industry benefited from the NRIC Resource Team's assistance in areas related to performing preliminary analyses, refining scopes, and accessing key resources and tools through the DOE national laboratory system.
- Finally, NRIC improved vital tools to inspire stakeholders and the public, including our siting tools, website, webinar series, workshops, and regular speaking engagements.

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 2023 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

CONTENTS

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 Operation 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 Reactors
MSTEC	Molten Salt Thermophysical Examination Capability
NAMRC	Nuclear Advanced Manufacturing Research Centre
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 Sates
UNCC	University of North Carolina Charlotte
USNC	Ultra Safe Nuclear Corporation
V&V	Verification and Validation
VTB	Virtual Test Bed
ZPPR	Zero Power Physics Reactor

National Reactor Innovation Center Annual Report FY 2023

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 the U.S. private sector, national laboratories, government agencies, and regulators to provide access to capabilities, facilities, nuclear development subject matter experts, and tools essential to the demonstration of new reactor technologies and to address key barriers to entry and success.

NRIC's vision is, through NRIC support, an industry capable of deploying multiple advanced nuclear technologies by 2030 which, when deployed, will substantially reduce carbon emissions worldwide. To that end, NRIC's goal is to accelerate the demonstration and deployment of advanced nuclear technology by providing access to national laboratory assets and expertise, establishing four new experimental facility capabilities and two large reactor test beds for integrated technology demonstrations and experimentation by 2028, and completing two advanced nuclear technology tests by 2030.

Achieving this mission and 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); the DOE-Nuclear Energy (NE) program that grants access to technical, regulatory, and financial support for commercializing nuclear energy. NRIC builds upon these new reactor concepts and technology successes to effectively strengthen U.S. nuclear leadership.

2. NRIC AND DOE NATIONAL LABORATORIES

NRIC's headquarters is located at Idaho National Laboratory (INL), 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 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 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 that makes use of our essential research strengths. NRIC's Demonstration Resource Network Tool, which launched in Fiscal Year (FY) 2021 and has been updated each year, showcases national laboratory capabilities across the country. These can support innovators in their demonstration efforts. 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), the Nevada National Security Site (NNSS), and Lawrence Livermore National Laboratory (LLNL). NRIC looks to strengthen and expand these partnerships in FY 2024.

Figure 1. NRIC Providing Capabilities for Reactor Concepts.

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 2024.

Additionally, 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.

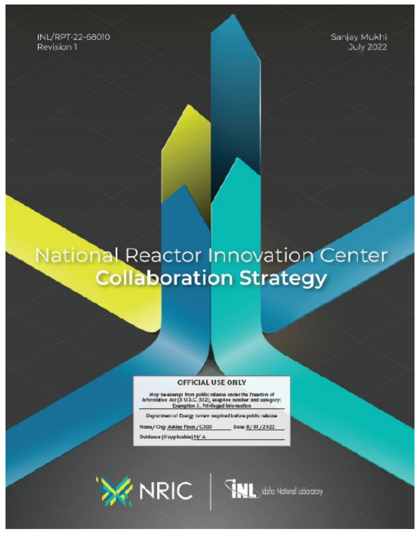


Figure 2. NRIC Collaboration Strategy.

4. FUNDING

The FY 2023 congressional appropriation for DOE provided $90 million (which includes $20 million for the Laboratory for Operation and Testing in the United States [LOTUS] as a capital line item) for NRIC to support testing, demonstration, and performance assessment to accelerate deployment of advanced reactors. The FY 2024 presidential request for NRIC was $34 million with language to support spending up to $32 million in capital expense on support for the design of test beds. The FY 2024 House of Representatives mark was $65 million in addition to the $32 million line item for capital expense to support the design of test beds.

To realize the NRIC mission of two operating advanced reactor demonstration facilities by the end FY 2027 and to prepare for subsequent commercial reactor demonstration projects post-FY 2027, the NRIC program will require $340 million over the next four years.

Table 1. NRIC-Initiated Projects Funding Table FY 2023.

Work Package Title	Control Account/ Work Package	FY 2023 Total Funding ($)
Program Management		
NRIC Program Management at INL	RC-23IN0101	2,536,374
NRIC Operations		
NRIC Operations	RC-23IN0201	8,799,849
Stakeholder Engagement		
Stakeholder Engagement	RC-23IN020201	1,052,619
NRIC Resource Team	RC-23PN020202; RC-23IN020203; RC-23OR020204; RC-23AN020205	1,121,015
Siting Tool for Advanced Nuclear Development – ANL	RC-23AN020303	110,707
Demonstration Reactor Siting and Capabilities Support – ORNL	RC-23OR020304	67,959
Demonstration Reactor Infrastructure		
Demonstration of Microreactor Experiments (DOME)	RC-23IN020305; RC-23IN020306; RC-23IN020307; RC-23IN020308; RC-23IN020309	42,685,289
NRIC DOME Test Bed Operation Support Equipment and Infrastructure	RC-23IN020302	7,734,151
Laboratory for Operation and Testing in the United States (LOTUS)	RC-23IN020310; RC-23IN020311; RC-23IN020312; RC-23IN020313	20,196,841
Front-End Engineering and Experiment Design (FEEED) for Testing Advanced Microreactors	RC-23IN020314	4,500,000
Regulatory and Economic Risk Reduction		
Advanced Construction Technology Initiative (ACTI)	RC-23IN020401; RC-23IN020403	24,258,737
Development and Demonstration of Digital Engineering Systems	RC-23IN020402	507,727

Work Package Title	Control Account/ Work Package	FY 2023 Total Funding ($)
Demonstration Reactor Siting Environmental and Regulatory Support – PNNL	RC-23PN020404	45,000
National Environmental Policy Act (NEPA) and Siting Evaluation Activities	RC-23IN020405	321,044
Regulatory Risk Reduction	RC-23IN020406	764,358
Tristructural Isotropic (TRISO) Microreactor Offsite Transportation Probabilistic Risk Assessment Development	RC-23IN020407; RC-23PN020408	172,473
Engineering Analysis and Evaluation		
INL Siting Preparation Studies	RC-23IN020501	346,304
NNSS Demonstration Reactor Support Activities	RC-23NN020502	27,080
Experimental Infrastructure		
Molten Salt Thermophysical Examination Capability (MSTEC)	RC-23IN020601; RC-23IN020605	2,535,953
Mechanisms Engineering Test Loop (METL) Operations, Testing, Maintenance, and Improvements	RC-23AN020602	4,782,582
Virtual Test Beds (VTB)	RC-23IN020603; RC-23AN020604	1,014,634
Helium-Component Test Facilities (HeCTF)	RC-23IN020606	3,461
In-Cell Thermal Creep Frames Installation	RC-23IN020607	499,628
Hot Fuel Examination Facility (HFEF)-15 Cask Modifications	RC-23IN020608	2,000,000
Integrated Energy Systems and Nonelectric Applications		
Maritime Applications of Nuclear Energy Studies	RC-23IN020702	500,000

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 demonstration 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 2023, NRIC continued work on a set of projects developed in the previous FY 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 2023, 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

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 overall performance of the NRIC program. Strategic support to NRIC leadership in developing and improving the NRIC's overall strategic plan as well as specific strategies and collaborations with other programs, agencies, and nuclear energy demonstration efforts. High level objectives include the following:

- Establish and update a systematic approach to operations of NRIC.
- Grow the NRIC organization in a way that it can be effective, agile, and scalable, including hiring necessary staff to support the program's foreseeable needs.
- Strengthen and develop program coordination with other national laboratories, DOE programs, and potential partners.
- Establish processes that enable innovators to access facilities, sites, materials, and expertise to demonstrate advanced reactors.

Progress

Milestones accomplished in FY 2023 include:

- In July 2023, NRIC completed its updated Strategy and Execution Plan (INL/RPT-23-73785) based on the evolving needs of innovators and changes in advanced reactor demonstration activities.
- In September 2023, NRIC completed its FY 2023 Annual Report (INL/RPT-23-74476), detailing all major NRIC activities, projects, and accomplishments for FY 2023, and the NRIC Collaboration Execution Plan (INL/RPT-23-74516).

Next Steps

In FY 2024, 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 2020	**Work Package Manager:**	Jack Britt

Objectives

Support the INL NRIC staff 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; engineering to support NRIC's project scoping and startup, scheduling, budgeting, and controls for the program; and internships. They also develop planning and execute industry, stakeholder, and other public engagement for NRIC.

This 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, public outreach, and project management. The objective is for NRIC to maintain an aggressive schedule to demonstrate advanced nuclear reactors while responsibly managing technology risk, project risk, and the complex interfaces among private-sector collaborators as well as nuclear reactor systems.

Progress

Despite shortages in the labor market, NRIC made significant progress in recruiting staff to support project execution. NRIC identified and hired a new department manager, three technical program managers, a new configuration management coordinator, a replacement risk manager, and a replacement administrative assistant. In addition, NRIC identified two project managers who are now matrixed to NRIC through the INL Program Management Office.

The labor market is tight and competitive, resulting in NRIC losing several employees to promotions and higher pay elsewhere. The former NRIC director took a position elsewhere in INL, and the NRIC director position is in the process of being filled by INL leadership. NRIC has one vacant technical program manager position.

Figure 3. NRIC Organization Chart, September 2023

NRIC held its annual review with DOE Headquarters (DOE-HQ), DOE Idaho Operations Office (DOE-ID), NRC, and other stakeholders. For the past few years, the NRIC program review has been smaller scale and held virtually due to COVID restrictions. In May 2023, NRIC held its annual review in person at INL. Over 100 participants registered to attend, with 70 attending in person. Multiple representatives were in attendance from DOE-HQ, DOE-ID, and NRC. Representatives from several of our industry collaborators were in attendance, including representatives from: TerraPower, Westinghouse, Radiant, X-Energy, Nano Nuclear, Advanced Reactor Concept (ARC), Nuclear Energy Institute, Flibe, Terrestrial USA, Oklo, Ultra Safe Nuclear Corporation (USNC), BWXT, General Electric Hitachi Nuclear Americas LLC (GEH), and Boston Government Services. Four different national laboratories were represented: INL, ANL, PNNL, Sandia. Several universities participated: Virginia Tech, University of North Carolina Charlotte (UNCC), University of Michigan, University of Alaska, University of Wisconsin, and Purdue University.

Figure 4. NRIC Participants in the NRIC Program Review, May 2023.

Milestones associated with the Operations work package accomplished in FY 2023 include the following:

- In December 2022, NRIC submitted a draft application and agreement process for reactor developers to test in the DOME (M3RC-23IN201013). This application and agreement process was finalized in July 2023 (M2RC-23IN0201014).
- In January 2023, NRIC completed a DOME operating cost estimate for FY 2024 planning (M3RC-23IN0201015)
- In June 2023, NRIC initiated training of Fuel Conditioning Facility (FCF) operators who will be operating the MSTEC experimental facility.
- In August 2023, NRIC prepared and submitted a memo that detailed a year end summary of all our experimental support activities (M4RC-23IN0201032) and completed a year end summary of ACTI management and coordination activities as well as a Phase 1 summary (M4RC-23IN0201023 and M4RC-23IN0201024).
- In September 2023, NRIC completed a revision of the NRI DOME Test Bed User Guide based on final design (M2RC-23IN0201012). Additionally, NRIC completed the draft DOME Operator Testing Plan (M3RC-23IN0201052).

Next Steps

To continue the significant progress achieved in FY 2023, additional staff is needed to address increased workload. NRIC is currently in the process of recruiting for hire in early FY 2024 the following positions:

- NRIC Director
- Technical Program Manager

This work package will continue to provide funding support for the necessary personnel and subcontracts to provide administrative assistance and program operations for NRIC. In FY 2024 the scope of this work package will be adjusted to include programmatic oversight for experimental and infrastructure programs as well as for LOTUS preliminary and final design.

6.3 Stakeholder Engagement

Project Start Date:	October 2020	Work Package Manager:	Stephanie Weir

Objectives

From its inception, NRIC defined 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, the significant increase in the need for stakeholder engagement activities (due to increasing public interest, legislative activities within states, and federal activities) and the desire for NRIC to narrow its focus, NRIC is in the process of reexamining and redefining its activities in this space.

NRIC expects to update its stakeholder engagement strategy in FY 2024. NRIC’s current stakeholder engagement program is built on three pillars:

- Regional Stakeholder Engagement: Engagement with Idaho and Intermountain West stakeholders relevant to NRIC’s activities at INL.
- Support to Innovators: Project management support from NRIC’s team for innovators as well as organizations at the community, regional, and state level.
- Stakeholder Engagement Initiative – Making Voices Count: Cross-disciplinary research into modern stakeholder engagement best practices used by other sectors, including renewables, mining, waste siting, and public health. Findings to be published and shared within the NRIC network.

By engaging with innovators and industry as well as the community, 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. Effective local stakeholder engagement in communities may have a significant impact on a project’s success, especially in the nuclear energy sector. NRIC is keenly aware of how nuclear energy in previous decades posed a challenge to the public trust. NRIC’s stakeholder engagement team posits its strategies and implementation plans in accordance with Executive Order 14008, “Tackling the Climate Crisis at Home and Abroad,” as well as with DOE's response to the Justice40 initiative. 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, but stakes a firm claim on a future that is transparent, inclusive, and just.

Progress

Milestones associated with the Stakeholder work package accomplished in FY 2023 include:

In August 2023, NRIC published INL/RPT-23-74110, “Annual Report on NRIC Stakeholder Engagement Activities to Support Advanced Reactor Demonstration Efforts” (M3RC-23IN0202013).

In September 2023, per CCN 254377, NRIC completed the beta-version of a community-focused site analysis tool (M2RC-23IN0202012).

As part of the stakeholder work package, NRIC hosted and attended several industry events some of which are included below:

- Hosted NRIC-Developers Best Practices Workshop (May 15, 2023)
- Gave presentations at the American Nuclear Society (ANS) Winter meeting in December 2022.
- Gave presentations at, attended, and sponsored Energy Communities Alliance's (ECA) Forum: *ECA Nuclear Development Forum: Building Capacity & Opportunity*, which took place between May 17 through 19, 2023, in Paducah, Kentucky.
- Completed various other speaking engagements including regional public events; regulators; local, regional, and state environmental organizations; non-government organizations; and U.S. and international regulators, professors, students, and journalists.

Next Steps

As mentioned above, NRIC is reexamining and redefining its activities in this space. NRIC expects to update its stakeholder engagement strategy in FY 2024.

6.4 Resource Teams

Project Start Date:	October 2020	**Work Package Manager:**	Sam Reiss

Objectives

The NRIC Resource Team's mission is to support further development of qualified nuclear demonstration projects by providing limited direct-funded technical and project planning support to nuclear project innovators. The NRIC Resource Team mission aligns with NRIC's mission to accelerate the commercialization of new reactor concepts and technologies, effectively advancing the U.S. in nuclear leadership.

Progress

Milestones associated with the Resource Team's work package accomplished in FY 2023 include:

In August 2023, Issued INL/RPT-23-74320, NRIC Resource Team Annual Report. In September 2023, PNNL, ORNL, and ANL submitted Annual Resource Team Reports summarizing the activities throughout the year (M4RC-23PN0202022, M4RC-23OR0202042, and M4RC-23AN0202052).

Next Steps

As NRIC and the advanced nuclear industry have evolved, NRIC has evaluated that early-stage engagement with the national laboratories should be through GAIN, and NRIC resources are better spent on development of infrastructure and capabilities for reactor demonstration. Thus, the Resource Team program will end and not be available in FY 2024. Funding from this program will be applied to other NRIC key initiatives.

6.5 Siting Tool for Advanced Nuclear Development

Project Start Date:	October 2020	**Work Package Manager:**	Matthew Bucknor and Randy Belles

Objectives

ANL, in partnership with INL, ORNL, and the University of Michigan, has developed a Siting Tool for Advanced Nuclear Development (STAND). STAND provides siting guidance based on energy policy, environmental justice, labor considerations, political will, popular attitude, and on 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. 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 assisting in development and testing of STAND and providing technical support for the Argonne preference model. ORNL will continue to coordinate on STAND with ANL, INL, and the University of Michigan and assist vendors, utilities, and other stakeholders in the use of STAND or to add insight directly from the ORNL siting tool Oak Ridge – Siting Analysis for Power Generation Expansion (OR-SAGE). Assistance will be directed by the NRIC technical lead, acting as the gatekeeper.

Progress and Accomplishments

The team continued STAND maintenance activities along with efforts to update data within the tool and manage users. Efforts were initiated to develop information sheets to highlight select topics and capabilities of STAND. The team also continued activities to promote STAND and interface with users at events such as the 2022 ANS Winter Meeting, where team members participated in an NRIC panel and a question-and-answer session.

In September 2023, ANL and ORNL prepared an annual reports documenting Argonne's and ORNL's support, maintenance, and improvements for the STAND Tool (M4RC-23AN0203032 and M4RC-23OR0203042).

Next Steps

FY 2024 STAND activities will focus on continued maintenance activities and support of the user base. The team will also host new user training sessions as needed throughout the fiscal year. Possible tool development activities include expanding STAND to include more data and metrics, and to be applicable to additional regions.

6.6 DOME Test Bed Operation Support Equipment and Infrastructure

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

Objectives

The objectives of this work package are to provide the necessary equipment, infrastructure, requirements, analysis, and guidelines for demonstrator reactor shielding designs and to support the irradiated fuel management and defueling options for testing in the DOME test bed. These requirements will be provided to reactor demonstrators to inform their reactor shielding and core design for testing in DOME. The test bed shielding requirements will include a shielding enclosure to reduce cell activation and supplemental shielding for non-reactor equipment.

The primary focus for FY 2023 will be design of shielding and setting up a procurement to fabricate shielding as well as some fueling and reactor removal-equipment development. NRIC will finalize the shielding conceptual design and develop the procurement strategy for modular or removable shielding for testing reactors in DOME. After the conceptual shielding design is finalized, NRIC will develop the performance baseline and expression of interest (EOI) for final shielding design and fabrication. This scope will facilitate safe, secure, affordable testing and material management to meet INLs requirements for testing of advanced reactors.

Progress

Milestones associated with the DOME Test Bed Operation Support Equipment and Infrastructure work package accomplished in FY 2023 include:

- In March 2023, NRIC finalized the procurement strategy for modular shielding for testing reactors in DOME (M2RC-23IN0203024).
- In August 2023, NRIC issued the design-build EOI for DOME (M2RC-23IN0203025) and completed the initial robotics plan in support of DOME Testbed Operations (M3RC-23IN0203026).
- In September 2023, NRIC drafted a report to detail the identification and evaluation options for fueling reactors (M3RC-23IN0203027).

Next Steps

For the DOME operational support equipment and infrastructure work package, in Q2 FY2024 NRIC will complete the preliminary design report for Reactor Supplemental Shielding (RSS) for testing of high-temperature gas reactors (HTGRs). In Q3 FY2024, NRIC will issue the preliminary reactor fueling support equipment recommendation report, release the fresh fuel process plan for DOME experimental reactor fueling, issue the preliminary storage and disposal of irradiated reactor and fuel at Radioactive Scrap and Waste Facility (RSWF) Process Plant, and complete a trade study and selection of crane options (gantry or polar crane). In Q4 FY2024, NRIC will complete the final design report for RSS for HTGRs.

6.7 NRIC DOME

Project Start Date:	October 2020	**Work Package Manager:**	Phil Schoonover and Chance Price

Objectives

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

- Enable testing and demonstration of reactor concepts by the private sector.
- Validate advanced nuclear reactor concepts.
- Resolve technical challenges of advanced nuclear reactor concepts.
- Provide general R&D to improve innovative technologies.
- Minimize potential adverse impacts with existing programs.
- Balance research, development, and demonstration activities with the protection and preservation of human health and the environment and compliance with applicable laws, regulations, and other requirements.

In FY 2023, several work packages are associated with the DOME project and those include the following:

- DOME Project Data and Documentation
- DOME Construction Integration Support
- DOME Construction
- DOME Government Furnished Equipment
- DOME Planning for Construction.

Progress

NRIC issued a request for proposal (RFP) for DOME construction in November 2022 (M3RC-23IN0203072), with a response date set for early January 2023. At the bidder's request, the response date was extended due to the bidder's inability to get sufficient responses from sub-tier suppliers who provide the needed equipment. NRIC received the DOME construction proposals in March 2023 in response to the RFP. The proposals received exceeded the RFP schedule limits and were significantly over the Class 3 estimates developed for the program.

NRIC used INL's reconciliation process to investigate the discrepancies and developed and executed a plan to reduce costs and significantly improve the schedule. NRIC performed value engineering of the proposals to allow equivalent equipment from alternate suppliers to be specified, potentially reducing the schedule overrun by 50 weeks, as compared to the more than 100 weeks proposed by the bidders. These components were then moved to the DOME Schedule X list, which is for long-lead procurement items, to allow NRIC to provide long-lead electrical components as government furnished equipment (GFE), thereby saving five months, and reducing the overall lead time by approximately 50 weeks.

Using the GFE process and issuing a best and final offer after removing those items from the bidder's scope, NRIC received amended proposals from the constructors on May 17, 2023. The best and final offer proposals are expected to significantly reduce the overall cost because large program management costs would otherwise be incurred while subcontractors wait on long-lead electrical components.

The milestone to submit construction subcontract award package to DOE-ID for approval (assuming at least one of the received bids is deemed responsive) was completed by submittal of the award recommendation package to DOE-ID on July 19, 2023, and with DOE-ID approval, INL awarded the construction subcontract on July 31, 2023. This was two months earlier than the milestone commitment, exceeding expectations, and allowing for the kickoff and initiation of construction to begin prior to the end of FY 2023 also exceeding expectations.

The digital twin developed (M3RC-23IN0203062) will support a multi-physics modeling and simulation (M&S) capability for the DOME and will connect and support a combined simulation capability with the installed experimenter's reactor. This capability will allow for expedited installation and commissioning operations as well as M&S of the reactor test plans prior to the physical asset's arrival on site.

To demonstrate progress toward a functioning NRIC-DOME test bed, INL accomplished the following additional asks in FY 2023:

- Obtained firm interface agreements to store incoming fresh fuel at the Chemical Processing Plant (CPP)-651 and with the Radioactive Scrap and Waste Facility for the storage of irradiated fuel and the irradiated advanced reactors to support DOME advanced reactor experiments. These agreements provide INL, NRIC, and developers with reliable locations for detailed planning.
- NRIC initiated the demolition and removal of large concrete pads and leveling of the DOME floor providing an unobstructed DOME surface area for developer advanced reactors and balance of plant equipment layout and design.
- In December 2022, NRIC developed the GFE Procurement Package (M2RC-23IN0203082). Also in December, NRIC provided an updated FY 2023 cost estimate (M3RC-23IN203053).
- In March 2023, NRIC finalized the NRIC DOME Preliminary Design Safety Analysis (M3RC-23IN0203052) and initiated purchase orders for DOME GFE (M2RC-23IN0203083).
- In July 2023, NRIC submitted the DOME construction subcontract award package to DOE-ID for approval (M2RC-23IN0203073). The construction contract was then signed in August and construction began in September 2023.

Figure 5. EBR-II DOME before partial demolition.

Figure 6. Computer Render of the DOME 3D Digital Twin.

Next Steps

For the DOME work package, construction on the facility will begin in Q1 FY 2024 through Q4 FY 2025, with operational readiness being achieved by Q3 of FY 2026.

6.8 NRIC LOTUS

Project Start Date:	October 2020	**Work Package Manager:**	Phil Schoonover and Jacob Rymer

Objectives

NRIC's LOTUS will reconfigure the Zero Power Physics Reactor (ZPPR), which is currently located at INL's MFC, to establish a test bed for experimental reactors up to 500 KWth, capable of utilizing fuels with greater than 20% enrichment. The NRIC LOTUS test bed will provide a safe path for reactors to achieve initial criticality for the first time. By leveraging existing facilities that were originally constructed for nuclear work, LOTUS offers opportunities for the following:

- Enable testing and demonstration of reactor concepts by the private sector.
- Validate advanced nuclear reactor concepts.
- Resolve technical challenges of advanced nuclear reactor concepts.
- Provide general R&D to improve innovative technologies.
- Minimize potential adverse impacts with existing programs.
- Balance research, development, and demonstration 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 validation of modeling and proof concepts for reactor designs for companies pursuing integration into the nuclear power industry. At present, the facility will provide the infrastructure for the Molten Chloride Reactor Experiment (MCRE). The MCRE design supports molten salt core and fuel design validation for the much larger Molten Salt Fast Reactor under development by Terra Power that may deliver up to 1,200 MW of electricity. Validating the internal physics of this configuration is essential to commercializing this technology for deployment. The current design operations of the facility will provide a cell cooling system with a minimum capacity of 50 KWth which can be improved upon with supplemental upgrades.

In FY 2023, several work packages were associated with the LOTUS project:

- LOUTS Planning Package for Construction
- LOTUS Preliminary and Final Design
- LOTUS Developing Requirements, Guidelines, and Conceptual Design for Operational Infrastructure Support Equipment
- LOTUS Project Data/Documents.

Progress

The LOTUS submitted draft documentation in support of critical decision (CD)-1 for LOTUS in March 2023 (M3RC-IN0203142), completed the revised LOTUS shielding analysis, design guidelines, and requirements report in March 2023 (M3RC-23IN0203122), and received approval of the Conceptual Safety Design Report (CSDR) in April 2023.

The project received approval for CD-1 from DOE on June 1, 2023. This authorized the following key documents and plans:

- Preliminary Project Execution Plan
- Acquisition Strategy
- Conceptual Design
- Functional and Operational Requirements
- Code of Record (COR)
- NEPA and Environmental Compliance Permitting
- Risk Management Plan and Risk Register
- CSDR
- Cost Estimate
- Schedule
- Project Data Sheet.

In addition to the documents listed above, the project team has also received approval of the design authority for the project and have initiated the preliminary and final engineering design process through awarding the engineering design to Enercon Federal Services. The project has held a kickoff and alignment meeting with Enercon on July 18, 2023.

The project team has also scheduled a physical walk down of the existing facility with the engineering design agent subcontractor set for August 15, 2023, and a potential interface review with the MCRE advanced reactor developer team. The project team is also reviewing trade studies and reports on disposition pathways for irradiated materials to be removed from the LOTUS test bed. Going forward this line-item project will follow the 413.3B project management process with regards to the design and development of the facility.

In September 2023, NRIC completed the summary report on irradiated fuel handling and management for LOTUS (M3RC-23IN0203123).

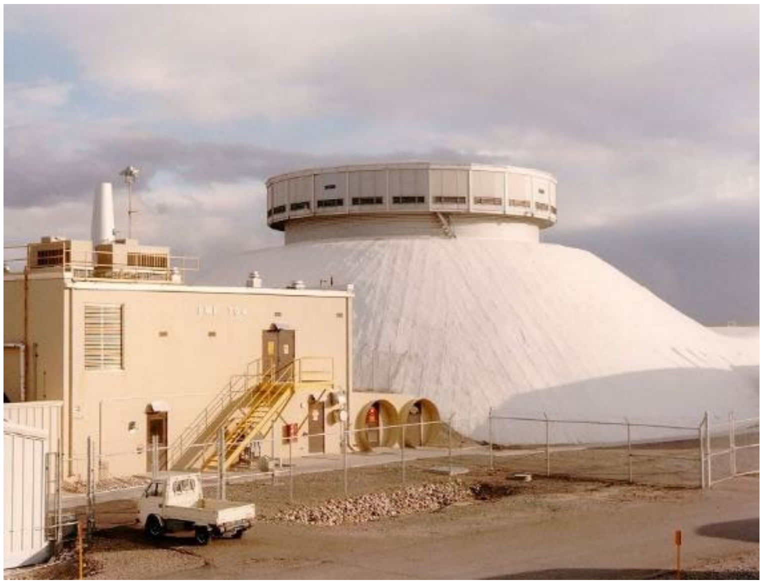


Figure 7. ZPPR Prior to LOTUS Redesign.

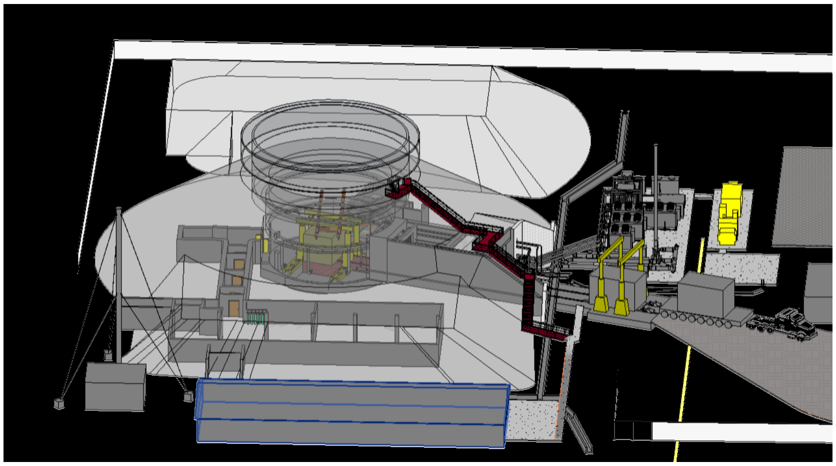


Figure 8. Digital Twin of LOTUS Design with New Access Tunnel.

Next Steps

In FY 2024, LOTUS activities will focus on completing preliminary and final design. Timely development of design documentation and authorization to proceed to construction are critical in meeting identified capability gaps. The project will evaluate opportunities to accelerate CD-2/3 development activities.

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

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

Objectives

Initiate and complete Front-End Engineering and Experiment Design (FEEED) for advanced reactor testing in the DOME or other test bed. To initiate the FEEED process, NRIC will issue an RFP under which developers can propose the scope of work to complete FEEED for their advanced reactor. NRIC and DOE will select up to four reactor developers to complete the FEEED process. Awards will be between $1 million and $1.5 million and include both INL and developer costs associated with the work. A minimum of 20% cost share from the participant is required. NRIC will award the resulting subcontracts and then the teams will complete the FEEED process. This includes 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.

This work package supports industry integration requirements workshops with demonstrators as well as development of key guidance materials and explanatory, exploratory, and analytical meetings to support experiment planning. It allows for design of custom modifications for users if needed and allows for full test campaign planning, scheduling, and cost estimating for specific competitively selected demonstration projects.

Progress

NRIC completed the first official DOME User Guide, which describes the end-to-end process for collaborating with NRIC, INL, and DOE to safely conduct new reactor testing in the DOME. The user guide was released to DOE-HQ following approval from DOE-ID. It provides a roadmap for the developers and NRIC's support teams in performing the groundbreaking process of installing, authorizing, testing, removing, and dispositioning of multiple advanced reactors in quick succession, using the same purpose-built DOME facility. The user guide will enable more precise planning and cost estimations and will facilitate higher quality advanced reactor testing with lower schedule and cost risk. It can also be modified to provide an end-to-end process to deploy microreactors outside of the DOME and will facilitate faster commercial deployments.

In FY 2023, NRIC collaborated with multiple advanced reactor developers who have shown interest in using the NRIC-DOME and leveraging the expertise NRIC has assembled. The industry response to the DOME has exceeded expectations and capacity and is now oversubscribed in requests for use. NRIC has established an RFP process to evaluate the initial readiness and level of maturity of each developer in support of their future testing needs through a detailed FEEED process. Follow-on programs will prioritize and schedule the developers for available testing time slots in the DOME. NRIC has advanced the DOME at an expedited rate to make it available for developer use as early as possible and has exceeded expectations in delivering on our FY 2023 Notable Outcome.

In January 2023, INL delivered a DOME plan and schedule to DOE. This plan laid out all steps to have the DOME available for installation of the first demonstration test reactor by September of 2026.

On June 8, 2023, INL issued an EOI for reactor developers to enter FEEED. The FEEED phase is intended to evaluate the actual state of maturity of the developer's design and the developer's current state of readiness to engage in an experimental program. The primary outcomes of FEEED are the completion of an end-to-end program plan, Class 4 or better cost estimate, and a contractual agreement for work to be performed at INL. Twelve responses were received and evaluated with seven meeting the requirements to be invited to the next stage. In July 2023, an RFP was sent to each of the seven qualifying respondents (M3RC-23IN0203152). In August 2023 proposals were received and evaluated. The first subcontract to enter FEEED was awarded September 2023 (M2RC-23IN0203153).

Next Steps

In FY 2024, NRIC anticipates signing remaining FEEED contracts and completing the FEEED process with the selected vendors. If additional funding is received, an additional EOI and RFP may be issued towards the end of FY 2024 and will be worked in FY 2025.

6.10 Advanced Construction Technologies Initiative

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

Objectives

NRIC ACTI is a cost-shared public-private partnership. It supports a transformation in nuclear energy construction and deployment costs, 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. ACTI will demonstrate construction technologies that support a cylindrical build such as was used for the BWRX-300 (as shown in Figure 9). The ACTI Team will be led by GEH. The GEH team is funding 30% of the design costs, with DOE-NE responsible for the remaining 70%.

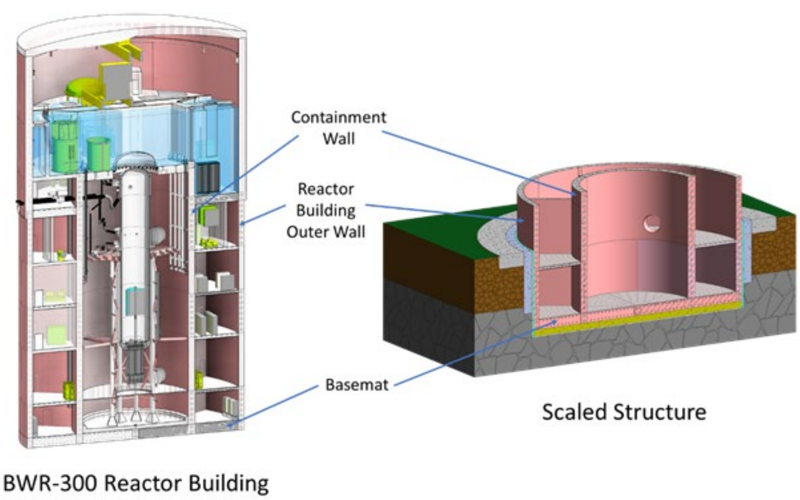


Figure 9. BWRX-300 Reactor Building and ACT Scaled Structure.

ACTIs success is hinged on its collaborations. The design team is made up of universities (Purdue and UNCC), science centers (Electric Power Research Institute [EPRI] and Nuclear Advanced Manufacturing Research Centre [NAMRC]), leaders in nuclear construction (Black and Veatch, Modular Walling Systems Holdings Ltd [MWS], and Caunton Engineering), along with Utilities (the Tennessee Valley Authority [TVA], Ontario Power Generation [OPG], and Duke Power). Representatives from both the NRC and 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 cost-shared public-private partnership in ACTI 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 10.

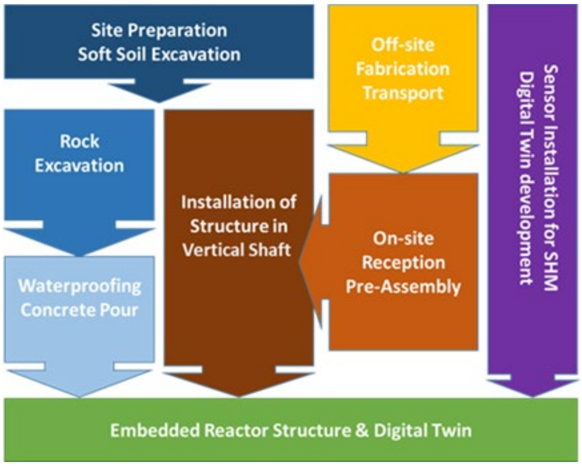


Figure 10. Process Flow Diagram of the Overall Construction and Integration Process.

The technologies highlighted by this initiative are as follows:

- Steel Bricks™, licensed by MWS, next generation steel-concrete composite modules 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 Steel Bricks™ will reduce construction time and rework associated with welding rebar in high-strength concrete. The Steel Brick™ modules will be fabricated in shop, reducing rework and improving the quality of the construction. Figure 11 shows the Steel Brick™ modules before being placed in the shaft.

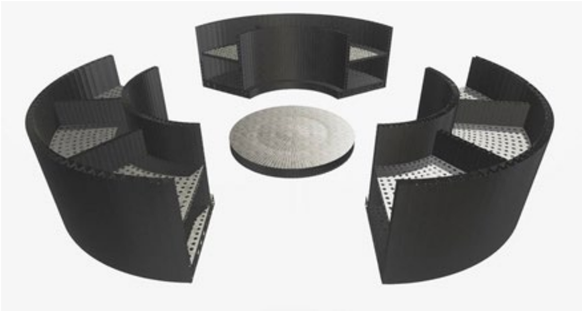


Figure 11. Modules Prior to Placement in the Shaft.

- 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, machine learning, and data analytics.
- Vertical-shaft construction techniques leverage best practices from the tunneling industry to lower construction costs and schedule durations associated with installation, inspections, and testing of safety-related engineered backfill.

Advanced reactors that could benefit from these technologies include GEH's BWRX-300 and Power Reactor Innovative Small Module (PRISM) reactors, TerraPower's Traveling Wave Reactor and MCFR, ARCs' ARC-100, and DOE's Versatile Test Reactor.

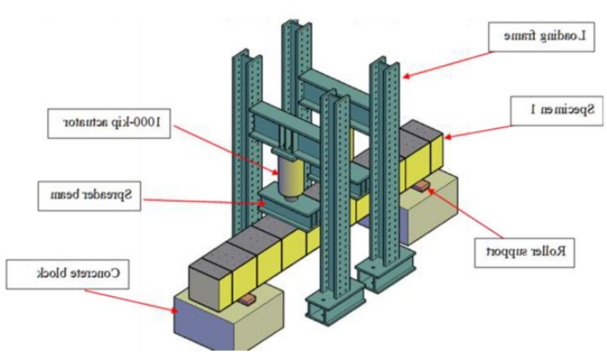
Progress and Accomplishments

In January 2023, ACTI completed the Nuclear Reactors and Construction Standards Report. (M2RC-23IN0204032)

ACTI completed its Phase 1 90% design review in March 2022. During the review, the updated Construction Plan, Demonstration Testing Plan, and Decommissioning Plan were presented. A list of expected permits, impact assessments, and needed reviews and approvals were submitted. A video preview of the mini-digital twin design was presented at the 60% design review and completed for the 90% design. The digital twin design was led by UNCC with a team from EPRI, NAMRC in the UK, and Purdue University. (M2RC-23IN0204034)

The ACTI project successfully completed performance testing of prototype Steel Bricks™ at Purdue University's Bowen Laboratory. These Steel Bricks™ are a key component to the ACTI project and will be used in the reactor containment construction during the demonstration portion of the project. The objective of the Steel Bricks™ testing was to confirm their performance under and beyond design-basis loading conditions. Under all the testing scenarios and loading conditions, each specimen performance met or exceeded the design criteria. The test results confirm the conservatism and applicability of the design equations being used for various parts of the structure. The Steel Bricks™ will help facilitate deployment of future reactors by allowing developers of small modular reactor to prefabricate their reactor containment structure, thus saving time and money during the design and construction phases of the reactor development process. (M4RC-23IN0204033) The Steel Bricks™ project is one of several technologies that could significantly lower the construction costs of building containment facilities for new small modular reactors and reduce scheduling risks and the uncertainties associated with them.

According to researchers at Purdue, the small-scale demonstration "outperformed expectations." In all testing scenarios and loading conditions, specimen performance met or exceeded the design criteria. Test results confirm the conservatism and applicability of the design equations being used for various parts of the structure. The data collected during the prototype tests will be used to support licensing of the modules for use in future reactor containment construction. Representatives from the NRC were in attendance as well to witness testing. NRC involvement is a key aspect of the ACTI project to streamline the licensing process for future developers of small modular reactors. The NRC rotational candidate with NRIC presented an overview of NRIC focusing on his work on ACT to the NRC Commissioners. Stakeholders from the CNSC also attended the testing.



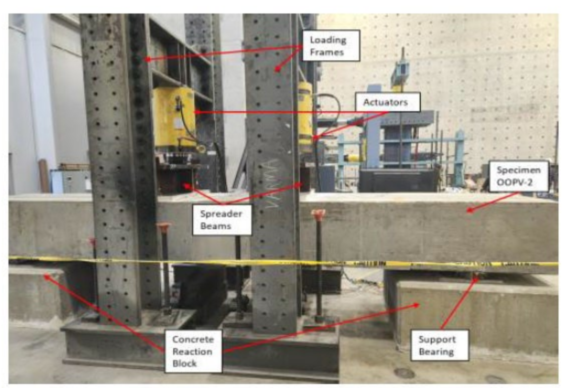


Figure 12. Out of Plane shear test setup

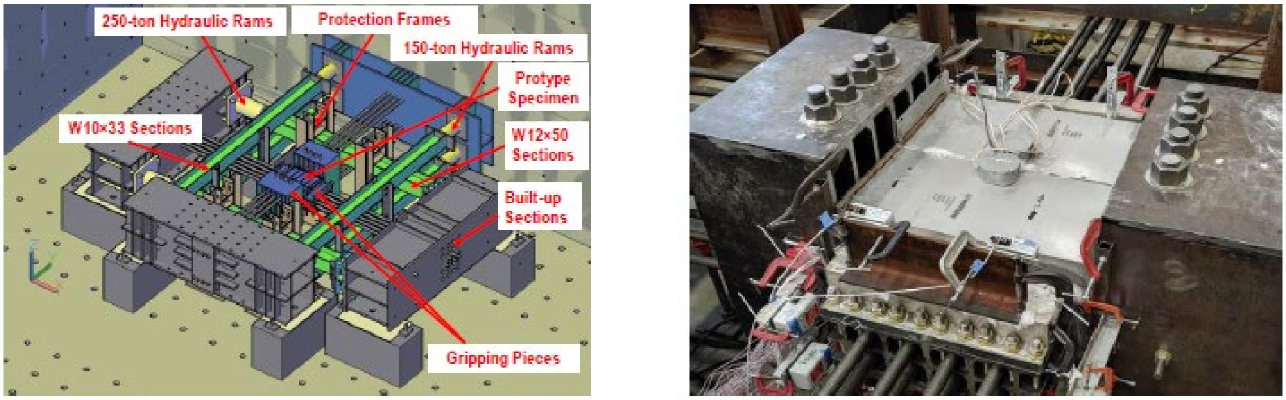


Figure 13. Bi-Axial Tension Test Setup

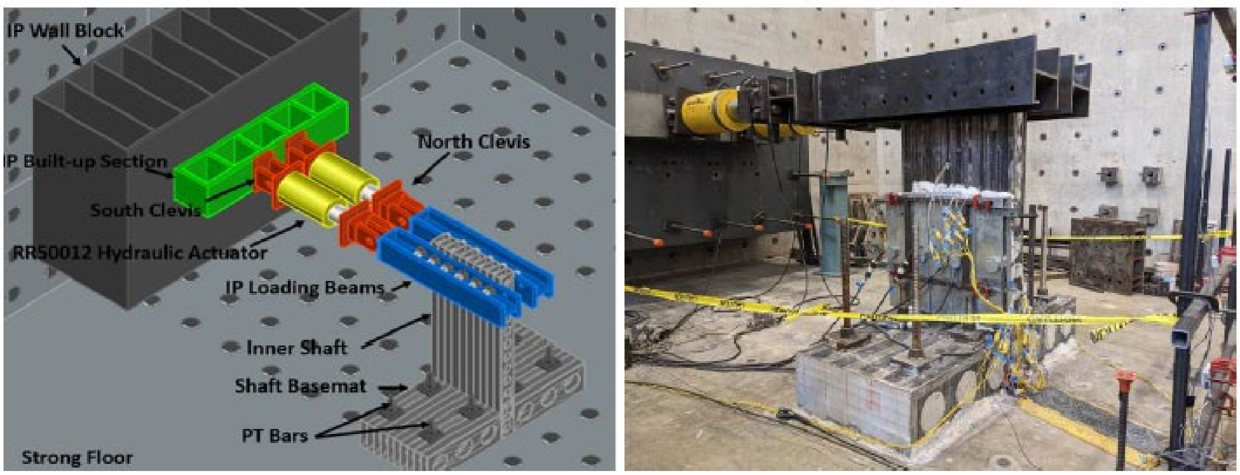


Figure 14. In-Plane Shear Test Setup

Next Steps

NRIC is working with GEH on the completion of Phase I activities and deliverables, which includes a final design review and a Phase II proposal. Once GEH completes Phase I of the project, NRIC will evaluate GEH's proposal for Phase II. Upon a successful Phase II proposal review and with DOE approval, GEH would be awarded the contract to move to Phase II of the ACTI project. During Phase II, GEH would begin activities to construct the demonstration structure at the demonstration site.

6.11 Digital Engineering

Project Start Date:	October 2021	Work Package Manager:	Christopher Ritter

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, and changing the culture of project teams to effectively deploy this technique. This work scope supports economic risk reduction for NRIC. NASA data shows the project cost generally correlates with expenditure on systems and digital engineering. The U.S. 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 digital information to design, engineer, build, operate, and maintain complex projects, digital engineering allows engineering teams to transfer legacy processes to new digital platforms that will enable an integrated development of new models and data sharing. NRIC has continued to execute model-based systems engineering (MBSE) and software integration to support the creation of a “Digital Engineering Ecosystem” that incorporates 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 to support operator 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.

Progress and Accomplishments

In January 2023, NRIC Digital Engineering deployed and configured a Product Lifecycle Management (PLM) tool for NRIC use on projects being executed at INL (M3RC-23IN0204022). The PLM tool ensures that 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 life cycles. The PLM tool, alongside INL’s Deep Lynx data warehouse platform, forms the backbone of the NRIC Digital Engineering Ecosystem, shown in the figure below.

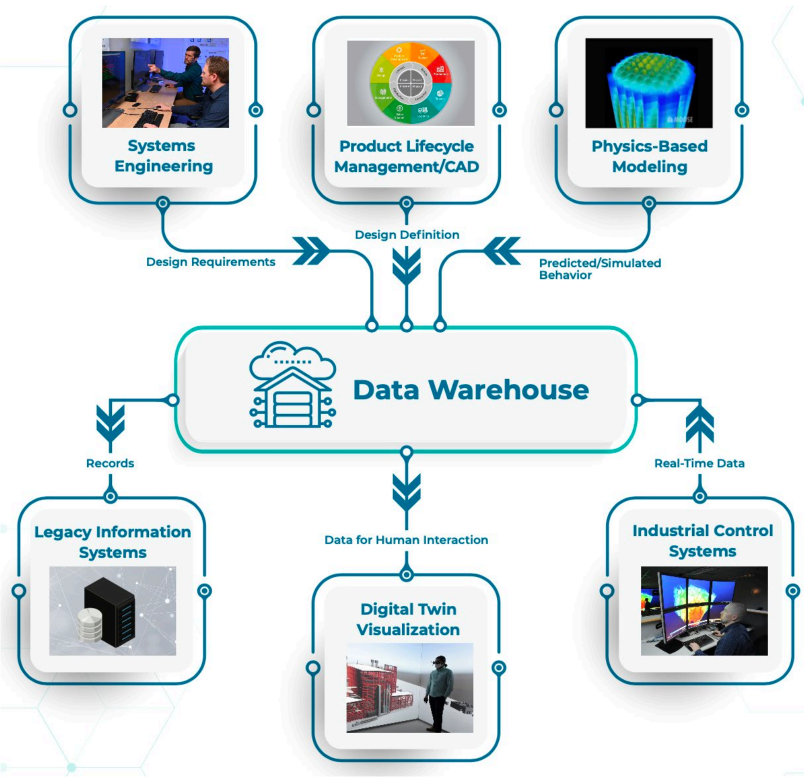


Figure 15. NRIC Digital Engineering Ecosystem

Also in early 2023, NRIC digital engineering developed a software "adapter" that extracted, transformed, and loaded schedule data from INL's production instance of Oracle Primavera P6 into the NRIC Digital Engineering Ecosystem (M3RC-23IN0204023). This software facilitates the reuse of schedule activities in downstream applications such as construction management and building information modeling tools. Using mixed-reality hardware such as the Microsoft Hololens, engineers and construction personnel can walk through a real construction site overlaid with virtual computer-aided drawing (CAD) models, interact with each object, and discover when each is scheduled to be delivered to the site and installed.

In March of 2023, NRIC Digital Engineering deployed and configured a verification and validation (V&V) software platform (M4RC-23IN0204024). V&V is a core tenet of systems engineering where engineers first verify that each detailed technical design input requirement is met in the design definition and then validate that the completed asset works as intended and meets all stakeholder needs. Methods of V&V include events such as engineering output review, M&S, site acceptance testing, and startup and commissioning testing. The V&V database provides direct linkage to the NRIC requirements management platform, aligning with the data-driven philosophy of digital engineering. The links between requirements and verification events provides "forward" traceability that all requirements will be or have been satisfied by objective design evidence (i.e., drawings, specifications, analysis, field tests). Backwards traceability also ensures that planned field testing has justification within the design requirements set.

To conclude the year, NRIC Digital Engineering delivered software used to extract, transform, and load data stored within the PLM system to the central data warehouse (M3RC-23IN0204025). Additional software then transfers this information to legacy INL systems such as the electronic document management system and Asset Suite, an asset management platform. This obviates the need for manual rework within the existing INL engineering process associated with loading documents and drawings into these outdated systems.

Next Steps

Next fiscal year, NRIC Digital Engineering 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 machine learning 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, NRIC Digital Engineering will capitalize on open-source tools within the artificial intelligence domain to augment early engineering phases. Although model-based systems engineering provides huge benefits throughout the engineering life cycle, there is typically a manual conversion step required to transform its exclusively two-dimensional, simple outputs into three-dimensional (3D) models. Additionally, CAD typically requires highly specialized engineers due to the complex nature of the drafting software. To eliminate the barrier to 3D modeling, NRIC Digital Engineering will demonstrate software that automatically generates models of buildings and systems from rudimentary engineering inputs such as functional requirements or process flow diagrams, dramatically decreasing the time required to produce conceptual designs.

6.12 NEPA, Siting Evaluation Activities, and Regulatory Risk Reduction

Project Start Date:	October 2021	Work Package Manager:	Stephanie Weir

Objectives

NRIC has prepared and presented a NEPA strategy for DOME testbed operations to DOE-ID; DOE-ID will evaluate the strategy and determine whether an Environmental Assessment (EA) is an appropriate path forward. This work package is predicated on DOE-ID's deciding to pursue an EA; if so, an EA would be pursued to evaluate the potential impacts of a surrogate reactor plan for the DOME test bed, using a proposed plant-parameter envelope approach.

Activities that support regulatory engagement include engagements with NRC, DOE, and potential reactor demonstrators. This work package also includes preliminary work on the development of a strategy to leverage work supporting DOE authorization and demonstrations at DOE sites in potential subsequent NRC licensing efforts, work related to DOE and NRC coordination under the DOE/NRC memorandum of understanding, preliminary work on developing a high-level strategy for a potential digital DOE authorization or NRC licensing pathway, transportation analyses, and work supporting reactor startup physics testing.

Progress and Accomplishments

In September 2023, NRIC completed the Regulatory Risk Reduction Activities Annual Report (M3RC-23IN0204061) and PNNL completed revisions to the NEPA Roadmap for Advanced Reactor Prototype Deployment (M3RC-23PN0204042).

Next Steps

Next year will see continued work on leveraging DOE-authorized work for potential subsequent NRC licensing efforts, DOE and NRC coordination, potential digital DOE authorization or NRC licensing pathways, transportation analyses, and reactor startup physics testing.

6.13 TRISO Microreactor Offsite Transportation Probabilistic Risk Assessment

Project Start Date:	January 2022	**Work Package Manager:**	Stacie Strain and Harold Adkins

Objectives

The project objective is to produce a parametric study addressing the modelling uncertainty for factors associated with the release of radiological material for use in calculating the radiological dose consequences of an accident involving transportation of a TRISO fueled microreactor. The factors include fractions of material-at-risk released from the TRISO fuel during normal operations that reside in the core, reactor structure, and primary circuit. Ultimately, conservative estimates of airborne release fractions and respirable fractions created during transportation accident conditions are the objective of the analysis.

The study addresses the impact that uncertainty in the values of these fractions and other key assumptions have on the radiological dose consequences of transportation accidents. The purpose of the study is to (1) gain generalizable information about the values to use for release-related factors that could be used in a dose consequence analysis for a transportation accident involving a TRISO fueled microreactor, (2) provide insights about how the uncertainty associated with the release-related values used in a dose consequence analyses impacts the estimated radiological dose, and (3) generate insights about future analyses and tests that could be performed to address the modelling uncertainties that have the greatest demonstrated impact on estimating the radiological dose consequences.

Key sections of the report describe the radiological dose consequences methodology that will be used in the parametric study and following analysis, including the following:

- Description of TRISO fueled microreactor transportation accident scenarios selected for investigation in the parametric study.
- Baseline and sensitivity studies selected for the parametric study and the bases for their selection.
- Presentation of results and insights from the parametric study that may influence testing and further data collection.

Progress and Accomplishments

In November 2022, NRIC finalized the parametric study of factors that affect calculated dose from the TRISO Fueled Microreactor Transportation Accident Report (M3RC-23IN0204072).

Next Steps

No further activities are expected related to this work scope. This work package will be closed in FY 2023.

6.14 Siting Preparation and Demonstration Studies

Project Start Date:	February 2022	**Work Package Manager:**	Alison Conner

Objectives

NRIC partners with industry to enable the testing and demonstration of reactor concepts. Multiple reactor test projects are anticipated through the DOE ARDP, as well as independent of the ARDP. Some partners are considering INL locations. The objectives of this work package are to complete activities necessary to enhance site characterization and viability of preferred advanced reactor testing and demonstration sites at INL.

Progress and Accomplishments

In April 2023, INL/RPT-23-72144, "National Reactor Innovation Center (NRIC) Infrastructure Integration Plan," was published (M4RC-23IN0205013). This plan serves as a roadmap for integrating future test reactors at INL's desert site into core infrastructure and services required for reactor operations. It represents an overview of the most likely infrastructure and services required by some or all the test reactors as well as what infrastructure and services exist at the site that have the potential to support and enable NRIC test reactors. Completion of this work provides future test reactor projects with INL infrastructure information available at the site. It may also enable INL's Net Zero goals.

In July 2023, INL/RPT-22-68838, Revision 1, "National Reactor Innovation Center (NRIC) Grid Connection Roadmap," was published (M4RC-23IN0205012). This report defines the roadmap for establishing the necessary electrical infrastructure at INL to fully support connection of NRIC demonstration reactors and identifies the reactors currently forecasted for installation at INL. The roadmap leverages this information, and, with this revision, provides an integrated timeline to support detailed planning and execution of system improvements as well as a list of risks that will need to be managed as the program moves forward.

Next Steps

No further activities are expected related to this work scope. This work package will be closed in FY 2023.

6.15 Irradiated Molten-Salt Capabilities

Project Start Date:	October 2020	**Work Package Manager:**	Sam Reiss

Objectives

Deployment of the NRIC MSTEC is necessary to assist in the advancement of technical readiness level 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, to support industry and regulators (such as the NRC), and to 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 U.S. 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.

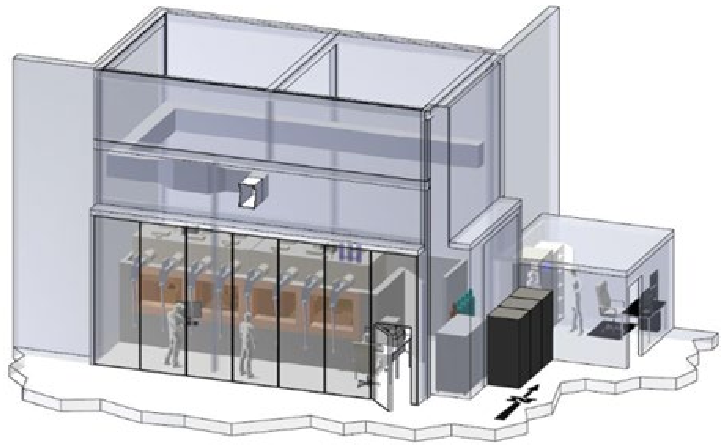


Figure 16. 3D Model of the MSTEC Hotcell.

Figure 17. 3D Model of the MSTEC Hotcell.

Progress and Accomplishments

In FY 2023, under NRIC leadership, MSTEC is on schedule. Additionally, construction work was completed in the FCF location that will house MSTEC.

NRIC completed Phase 1 (room construction) for the MSTEC hotcell; the room is ready to house the hotcell. This work was completed on schedule, despite its being performed in a legacy nuclear facility where facility layout drawings were done by hand over 30 years ago and did not match the actual facility configuration. Mezzanine construction and installation of the hotcell will be Phase 2 scope carried out in FY 2024. Currently, hotcell construction is two months behind schedule on a multi-year contract at Walker Barrier. (M2RC-23IN0206054)

The completed Phase 1 facility modifications included: (a) installing new electrical equipment to route power to MSTEC, (b) routing facility argon, instrument air, and chilling water to the location of MSTEC, (c) removing the south wall of the Intermediate Bulk Container (IBC) Wash Station and removing a structural column, (d) reinforcing the room structure to compensate for column removal, (e) installing a roll-up door and man door in place of the south wall, (f) installing additional suspect exhaust ductwork, and (g) grouting the wash station drains and adding floor-leveling grout. A photograph of the completed, fully prepared MSTEC room is shown in Figure 18.

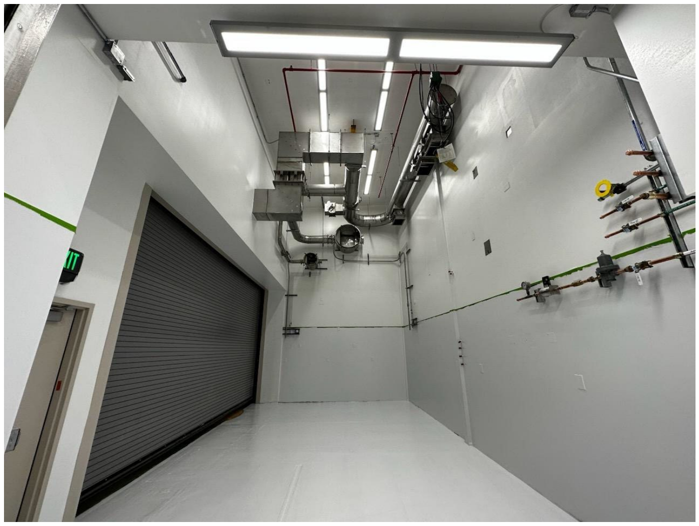


Figure 18. Photograph of the MSTEC room following completion of facility modifications.

Progress in FY 2023 sets the stage for completion of MSTEC construction in FY 2024. This program is critical for MSR developers as the INL will have the only facility capable of physically testing, qualifying, and validating irradiated fuel salts. The MSTEC cell is in high demand; two contracts have been signed by outside organizations to use the facility when completed. In addition, the MCRE ARDP project plans to use the facility as well.

Two additional milestones, M4RC-23IN0206012, Complete incorporation of Safety Analysis Report (SAR) revision comments from DOE-ID, and M3RC-23IN0206053, Complete on-site inspection of MSTEC shielded cell fabrication at Walker Barrier were both completed on time.

The SAR is required for the operation of MSTEC and was initially submitted to DOE-ID on September 8, 2022. Comments were received and integrated in February 2023. The MSTEC SAR and technical safety requirements (TSR) revisions were submitted to the DOE-ID for review and are now in the process of incorporating a fire hazard assessment (FHA).

On-site inspection of the MSTEC hotcell at Walker Barrier in Wisconsin was completed May 2023 which is the final step prior to factory acceptance testing and receipt of the hotcell. Four INL staff visited Walker Barrier for a preliminary factory acceptance test of MSTEC, including the glovebox, shielding, manipulators, purification control system, and leaded glass shielding. Pictures from the pre-factory acceptance test are shown in Figure 19.

Two FCF nuclear operators have been designated as lead operators for MSTEC by the FCF Nuclear Facility Manager. In May 2023, the operators finalized a detailed matrix of all research and operational activities related to MSTEC that must be performed in FCF. The matrix includes all procedures and qualifications that must be developed or modified for MSTEC.

Figure 19. MSTEC glovebox at Walker Barrier (top left), Shielding (top right), purification gas panel (bottom center).

Next Steps

In FY 2024, the following MSTEC projects should be completed:

- Receive and install the hotcell and analytical equipment in the hotcell.
- Continue training and procedure development for MSTEC operations.
- Completion and acceptance of SAR, TSR, and all other required safety documentation.
- Conduct the DOE operational readiness review.
- Begin operation of MSTEC.

6.16 METL Operations, Testing, Maintenance, and Improvements

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

Objectives

Operations, testing, and maintenance of, and improvements to, the DOE METL facility and supporting infrastructure that 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 DOE complex. METL operations and testing provides a versatile capability for U.S. industry' need for 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 continuing testing of 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 on-going basis.

Operation, testing, maintenance of, and improvements to, the METL facility supports the following objectives:

- Research, develop, and demonstrate advanced, innovative cost reduction and performance that enhance technologies for advanced fast reactor applications.
- Develop advanced technologies for accident prevention and mitigation.
- Develop sustained personnel, physical, and knowledge infrastructure for long-term research, development, and demonstration for fast spectrum systems.
- Preserve and nurture the domestic knowledge base and U.S. professional expertise to facilitate science-based R&D.
- Re-establish and maintain U.S. technology leadership for advanced fast reactor technology.

Progress and Accomplishments

The METL facility has been operational since September 19, 2018, and funding for its operations from NRIC started in April 2022. In FY 2023, METL accomplished the following:

- In February 2023, METL completed METL Inductive Level Produce Development (M3RC-23AN0206023).
- The METL team provided a tour to Aaron Goldner, a staffer from the Senate Energy and Water Appropriations Subcommittee and Jared Hatch, DOE's Office of Chief Financial officer, along with other senior leaders at ANL (April 14, 2023).

- Teddy Kent and Jordan Rein attended the International Congress on Advanced in Nuclear Power Plants (ICAPP) meeting in Korea, where Teddy Kent's presentation on the gear testing in METL won best paper for that track.
- The METL team supported the operations of the Gear Test Assembly (GTA), which completes Test Campaign 6. It operated for 1,300 hours of testing without failure of gears or bearings in the test article. The GTA has been removed from the METL Test Vessel 1, processed through the carbonation process, and dismantled (see Figure 20).
- The METL team supported the operations of the Thermal Hydraulic Experimental Test Article (THETA). THETA was removed from Test Vessel 4, cleaned, dismantled, and reinstalled into Test Vessel 4 (see Figure 20). This work was performed to install thermal insulation around the THETA core barrel and intermediate heat exchanger.
- In May 2023, the METL team provided tours (with detailed discussions) of the METL facility, THETA experiment, and GTA to Dr. Yasir Arafat (INL MARVEL Project Manager), Mark Nelson (Managing Director of Radiant Energy Group), and Matt Loszak (Chief Executive Officer of Aalo Company).
- 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 on May 2, 2023, to discuss this project with Rick Vilim. Since this meeting, Derek Kultgen has provided access to the METL data focused on the METL purification and diagnostic system. Derek had a meeting with the team to plan the METL Application Programming Interface (API). A "how-to" document was generated explaining the use of the API and providing examples. The API, along with investments made to METLs networking infrastructure, enabled the PRO-AID team to rapidly develop their integration with a real-world facility. Note, during conversations with many clients, access to real-time data is always a top concern. As demonstrated with the METL/PRO-AID collaboration, METL's services were able to provide integration with third-party systems immediately after IT security steps were implemented. The intuitive nature of the API nearly eliminates any learning curve. Information on the piping and instrumentation diagram has been provided to the team, together with information on the sensors and heater. 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.

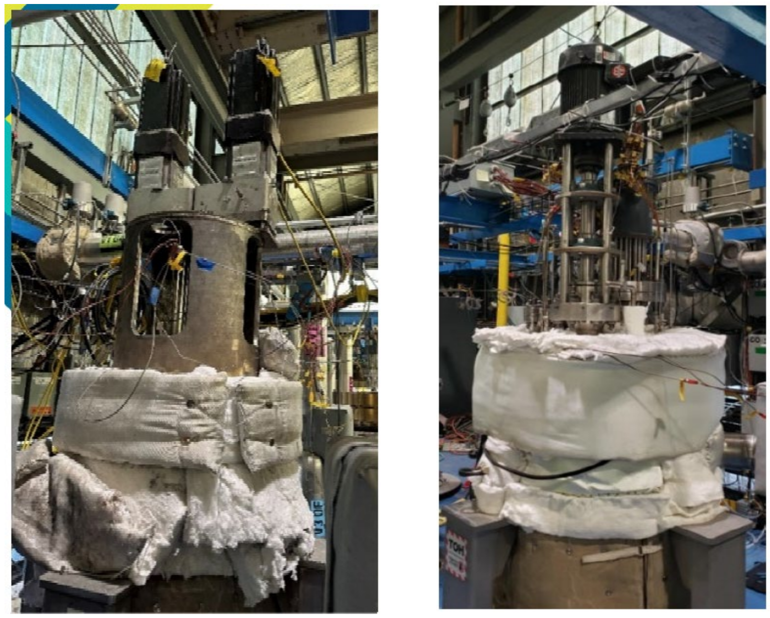


Figure 20. (Left) GTA installed in Test Vessel 1 and (Right) THETA Test article reinstalled in Test Vessel 4

In addition, METL completed the following milestones in FY 2023:

Completed the business operating plan in July 2023 (M2RC-23AN0206024) as well as the METL Facility Annual Operations and Testing Report in September 2023 (M2RC-23AN0206022).

Next Steps

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

- 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.

6.17 Virtual Test Beds

Project Start Date:	October 2020	**Work Package Manager:**	Abdalla Abou-Jaoude

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 testing and development of components. 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. 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 multi-physics NEAMS codes that are under development at 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.

Progress and Accomplishments

- The VTB team, comprised of staff from INL and ANL, added 19 advanced reactor simulation use cases in FY 2023, for a total of 35, and added two tutorials/trainings.
- The team instituted a tagging system in the repository that enables users to find models of interest more quickly. The tagging system provides the application of metadata to each model allowing users to filter the set of models.
- The team developed two new simulation use cases relevant to NRIC's DOME and LOTUS test beds: a gas-cooled microreactor and a low-power MSR.
- The VTB team held engagements with several stakeholders this year, including the NRC, Westinghouse Nuclear, TerraPower, and Southern Company, and held its own special session at ANS conferences, highlighting M&S efforts hosted on the VTB.
- The VTB helped remove risk from the MCRE ARDP confirmatory analysis by building the foundation for an MSR test case for the LOTUS test bed.

- The VTB collaborates with other DOE campaigns: NEAMS on uploading new models to the repository and setting up a training on fuel performance simulation and setting up the ART program on a training for pebble bed reactor simulation.
- The project employed the Google Analytics tool on the VTB website to track unique visitors, their location, among other data. Over the period from June 24 to July 7, 2023, the VTB saw over 600 unique visitors.

Next Steps

The VTB team strives to maintain the quality and usefulness of the repository and aims to provide that benefit in FY 2024. 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.

6.18 Helium Component Test Facility

Project Start Date:	June 2021	**Work Package Manager:**	Luke Voss

Objectives

Gas-cooled reactors have been proposed to support several funded reactor demonstration projects. It can be difficult to work with most inert gaseous coolants that are low-molecular mass fluids such as helium, argon, and nitrogen.

Testing high-temperature gas-cooled reactor (HTGR) components in a prototypic helium environment is essential to support HTGR demonstration and commercialization. X-Energy, USNC, BWXT, and Radiant have expressed interest in a helium-component test facility (HeCTF), capable of high-pressure, high-temperature operations. This work package has led to the construction of the HeCTF, which can be used by industry to support the development and component qualification of gas-cooled reactors.

This HeCTF can be used to support the testing of components such as heat exchangers, pumps, piping, and components in a non-irradiated environment. The HeCTF fills a capability gap for helium-component testing and supports the development of microreactor and larger-scale HTGR concepts that can be demonstrated within this decade.

Progress and Accomplishments

The first customer component demonstration occurred in October 2022. An air-to-helium heat exchanger was successfully demonstrated at temperature and pressure to test its performance. The data from the testing was provided to the customer to help guide future design decisions.

The HeCTF project close out was completed in February 2023 (M3RC-23IN0206062).

Next Steps

With the testbed now operational, several companies have expressed interest in using the testbed. The most interest has been expressed by USNC. They have components that need testing at parameters within the range of the HeCTF. Several meetings have been held to discuss the parameters of the testbed and to understand the needs of the test. NRIC anticipates further collaboration and scoping with USNC toward a potential component demonstration at the end of next fiscal year.

6.19 In-Cell Thermal Creep Frames for Demonstration Project Preparations

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

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.

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). As-built drawings and creep frames qualification were completed in FY 2023 (M3RC-23IN0206074). It is anticipated that the creep frames will be installed in the Sample Preparation Lab (SPL), which will become operational in FY 2026. The creep frames may be used in a temporary test setup for early testing prior to that time. Kairos will be the first user of the creep frames to test and qualify materials in its advanced reactor program.

Next Steps

No funding nor associated activities are planned for FY 2024. Activities related to Creep Frames will resume in FY 2026 upon the completion of the SPL facility.

6.20 HFEF-15 Cask Modifications

Project Start Date:	October 2020	**Work Package Manager:**	Greg Core

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. Procedures to use the cask will also be updated. At the conclusion of these tasks, readiness activities, including management self-assessments will occur to verify that the HFEF-15 cask processes and procedures adequately address safety and operational requirements.

The HFEF-15 cask was historically 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 modifications will allow the installation, transport, and removal of the modern TREAT Mk-IIIR sodium loop cartridge and other large format experiments.

Progress and Accomplishments

The project team has completed the preliminary design of one-third of the necessary modifications and has completed conceptual design of the remaining modifications. The team is on track to complete all draft drawings by the end of FY 2023 (M2RC-23IN0206082). These drawings will be used to solicit fabrication bids from vendors in the first quarter of FY 2024.

Next Steps

The project will complete design, procurement, and installation of all modifications in FY 2024. The HFEF-15 cask is expected to be ready to accept large format experiments by the end of FY 2024.

6.21 Maritime Applications of Nuclear Energy Studies

Project Start Date:	October 2020	**Work Package Manager:**	Sanjay Mukhi

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 includes more than 60 participating organizations and has identified a growing interest for 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.

Progress and Accomplishments

In FY 2023, the following was accomplished:

- NRIC held a quarterly meeting in May 2023, which provided a briefing from Prodigy Energy on their work with Nuscale for maritime applications for small modular reactors (SMRs), a review of the report on the intergovernmental panel on climate change by the American Bureau of Shipping (ABS), and an overview of the DOE Liftoff Report.
- MNAG completed the first draft of a licensing and regulatory landscape white paper, which will be reviewed in quarter four of FY 2023. More information on MNAG is available at https://nric.inl.gov/maritime/.
- NRIC, in conjunction with ABS, has completed the first draft of the Phase 2 report required in the Industry Funding Opportunity Announcements (iFOA) award: Accelerating Commercial Maritime Demonstration Projects for Advanced Nuclear Reactor Technologies. The Phase 2 report covers technoeconomic analyses, regulatory gaps, and suitable technology for maritime applications.
- NRIC and ABS conducted, over the past quarter, a series of interviews of federal agencies to understand and catalog regulatory issues facing maritime applications of advanced nuclear reactors. The final draft of the Phase 2 report is expected to be completed in the fall.
- Programmatically, NRIC established a contract with MPR Associates to assist with maritime demonstration requirements.
- In September 2023, PNNL built upon the framework developed in PNNL-33524, to include maritime transport considerations for potential internal applications (M3RC-23PN0204082) and NRIC completed a white paper on the review of the regulatory and licensing landscape (M3RC-23IN0207023).

Next Steps

Upon completing the testing platform gap analysis, NRIC will address the ABS Task 3 award, which aims to identify current maritime testing opportunities across the national laboratory enterprise and identify areas for further development to support the maritime nuclear industry. Additionally, NRIC will support ABS's effort on Task 4, which will provide an advisory note to the maritime community on the process for testing and demonstrating maritime nuclear applications.

Through the MNAG, further development of the four recently established working groups will be conducted to provide awareness on key research and identify recommendations related to R&D, regulations, economics, insurance, and environmental and other public interests for maritime nuclear applications.

Based on industry, national laboratory, and university feedback, NRIC will identify functional engineering requirements for a maritime testing and demonstration platform to support the maritime nuclear industry. These functional engineering requirements will form the basis for initial cost estimates that will be provided to DOE for a determination on establishing such a platform.