



# ACCELERATING MICROREACTOR DEVELOPMENT AND DEPLOYMENT THROUGH JOINT PUBLIC TEST BEDS AND PRIVATE ADVANCED REACTOR DEVELOPMENT

*Changing the World's Energy Future*

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# **ACCELERATING MICROREACTOR DEVELOPMENT AND DEPLOYMENT THROUGH JOINT PUBLIC TEST BEDS AND PRIVATE ADVANCED REACTOR DEVELOPMENT**

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## **Abstract**

The United States Department of Energy (DOE) has funded the National Reactor Innovation Center (NRIC) to accelerate the development and commercialization of small modular reactors and other advanced reactor technologies. As part of this effort NRIC is building test beds at the Idaho National Laboratory (INL) to facilitate public-private partnerships for the development and testing of advanced nuclear reactors. One test bed will provide a location for high-assay low enriched uranium (HALEU) fueled reactors and a second test bed for highly enriched uranium (HEU) fueled reactors. These test beds fill an infrastructure gap and alleviate the financial and operational burdens associated with industry providing their own test facilities. Therefore, this approach not only accelerates technological innovation and reduces time-to-market for advanced nuclear reactors but also underscores the DOE's commitment to fostering an ecosystem where nuclear energy will thrive as a clean, reliable, and efficient source of power. The Demonstration of Microreactor Experiments (DOME) and Laboratory for Operations and Testing in the United States (LOTUS) have planned availability in 2026, and 2027 respectively.

### **1. INTRODUCTION**

The need for carbon-free power and grid flexibility has driven rapid investment to develop advanced nuclear technologies in recent years. This is because new advanced reactors can address the clean and flexible energy needs across a broad range of applications, including grid power providers, power for space missions, cogeneration with hydrogen, and energy storage. The DOE seeks to accelerate the development of next generation nuclear energy technology to achieve timely de-carbonization and grid flexibility mission objectives. For instance, the DOE is working to address testing infrastructure gaps such that the industry can overcome financial and regulatory challenges associated with accelerating technology development.

The Nuclear Energy Innovation Capabilities Act (NEICA) of 2017 [1] aims to enable research and development of a wide variety of advanced nuclear energy technologies by private and public institutions. NEICA authorized NRIC in 2019 to accelerate development of advanced nuclear energy technologies. NRIC and DOE will collaborate with public and private-sector developers to design and test advanced reactor systems to accelerate commercial deployment. This national investment in test infrastructure and capabilities is imperative for establishing a timely and cost-effective path for licensing and commercializing new nuclear energy systems.

### **2. PROGRAM MISSION**

NRIC aims to accelerate nuclear technology development through expanding the utility and reach of national lab capabilities and resources [2]. NRIC is working to provide facility and test program infrastructure

for developers to achieve technology readiness and prepare robust licensing cases for the deployment of next generation of nuclear reactors.

The Idaho National Laboratory (INL) plays a key role in this objective by providing reactor test beds, materials and fuels testing capability, permitting and regulatory expertise, and contracting support for private industry. Research and demonstration tests conducted at the test beds will reduce risk by progressing the technical readiness for first of a kind nuclear reactor systems. This testing will provide a strong licensing case with the Nuclear Regulatory Commission (NRC) and other regulatory agencies.

## 2.1. Benefits

NRIC mission activities will have the following benefits.

- Overcome financial and technological barriers to nuclear innovation
- Provide infrastructure that commercial industry can use for testing advanced reactor systems
- Expand industry knowledge and expertise on nuclear technologies
- Improve accessibility to DOE to support private industry and government agencies

## 3. PROGRAM DESCRIPTION

The staff and facilities at INL are central to achieving NRIC's mission. INL is the nation's lead nuclear energy research laboratory tasked by DOE with the responsibility of leading and conducting nuclear energy research, development, and demonstration in support of meeting nation's energy supply, environmental, and energy security needs.

The Demonstration of Microreactor Experiments (DOME) and Laboratory for Operation and Testing in the United States (LOTUS) test beds at the Materials and Fuels Complex (MFC) will be key infrastructure for testing reactor systems. Additionally, the MFC hosts facilities, capabilities, and instruments for fabricating, handling, testing, and characterizing nuclear fuel and radioactive materials. Additionally, MFC work covers engineering, operations, maintenance, research, and production.

NRIC is leading the test bed program to build the DOME and LOTUS test beds at the INL and the associated ecosystem of support for private industry to research their reactor systems.

Developers partnering with NRIC and DOE to utilize the test beds are industry innovators of advanced nuclear reactor systems, looking to progress the technical maturity of their unique technologies. Developer technologies may range from microreactors for space applications, small modular reactors (SMRs), all the way to advanced reactors integrated with thermal energy storage capabilities. NRIC will work developer projects based on technical viability and the needs of the program. Private industry may enter a cooperative partnership agreement with NRIC to execute projects. Once the developer, NRIC, and INL have entered an agreement, they will collaborate through the entirety of the project lifecycle starting with front end engineering and experimental design (FEEED, or the conceptual design phase) through design, construction, commissioning, testing, and removal and disposal.

## 4. TEST BEDS

MFC at INL has two facilities that are undergoing refurbishment to support NRIC's reactor system test mission [3]. These will become the DOME and LOTUS test beds. The facilities under construction for the creation of DOME and LOTUS were previously de-commissioned research facilities, that provide basic infrastructure that can be leveraged. These facilities, once modified for advanced nuclear testing, will maintain robust safety authorization bases for the successful execution and quick turnaround of reactor testing. Developers' reactor testing programs are built around the use of these test beds to support development of their reactor technologies. Each test bed will accommodate one developer system at a time. Once a developer has completed testing, their system will be removed from the test bed to make room for the next developer.

### 4.1. DOME

The DOME program ecosystem includes the facility, equipment, infrastructure, processes, procedures, and developer's reactor systems. The DOME program will leverage existing Experimental Breeder Reactor-II (EBR-II) infrastructure shown in Figure 1 by refurbishing the facility to meet the needs of nuclear microreactor

demonstration testing. The DOME test bed will be available to start testing reactor systems in the late 2020's.

The DOME facility will be a hazard category 2 facility [4] providing safety class confinement to support testing of up to 20 MWth reactor systems. The DOME facility will be equipped to accommodate high-assay low enriched uranium (HALEU, <20% enrichment) and low-enriched uranium (LEU, <5% enrichment) fueled reactor systems. Table 1 below provides a summary of the size and capabilities of the DOME test bed.

There is also fuel storage, radiation waste management, and post irradiation fuel testing available through other support facilities at INL near the DOME test bed.

The DOME program includes design documents, guidance, processes, and procedures that are available for developers who want to use the test bed. This program includes a user guide, operations training plans, and environmental assessments for testing (plant parameter envelope). Radiant, Ultra Safe Nuclear Corporation, and Westinghouse are developers that were selected through a competitive process to enter the Front-end Engineering and Experiment Design phase [5] and are progressing through the design process to test at the DOME facility within this program infrastructure.

*Table 1. DOME Test Bed Capabilities*

Capability	Detail
Floor Space for Reactor Experiments	65.75 ft diameter × 37.5 ft height
Hatch Opening	15 ft width x 17 ft height
Penetrations	Large and small wall penetrations for process use
Control Room	Space for developer control room in connecting building or pad outside
Utilities	Heating, ventilation, cooling, electrical service, fire suppression, compressed air and water access
Shielding	Reactor Supplemental Shielding (RSS)
Equipment	46 ft tall polar crane inside, forklift, rigging equipment, decontamination equipment, etc.



*Figure. 1. DOME Test Bed*

#### **4.2. LOTUS**

While DOME will support the testing of low enriched uranium fuel (HALEU and LEU) reactor systems, LOTUS will support testing of high-enriched uranium fuel reactor systems. INL's Zero Power Physics Reactor (ZPPR) facility at MFC will be repurposed to become the LOTUS test bed. Figure 2 below provides a rendering of the LOTUS test bed. The LOTUS test bed is projected to support reactor testing in the 2020's. Today, LOTUS is undergoing final design, after which the safety basis will be established.

The LOTUS test bed will also be a hazards category 2 facility with elevated security posture for radiological confinement. The cell for testing is planned to provide containment for up to 500 KWth reactor systems. Table 2 below provides a summary of the size and capabilities of the LOTUS test bed.

Table 2. LOTUS Test Bed Capabilities

Capability	Detail
Test cell geometry	30 ft diameter, 16 ft 11 in recessed pit area
Entry Tunnel	13 ft x 13 ft pathway
Utilities	Reactor and cell heat removal, argon cover gas, electrical service
Equipment	Polar crane



Figure 3. LOTUS Test Bed

### 5.1. Reactor System Engineering Design Support

NRIC's strategy to accelerate nuclear technology advancement incorporates collaboration with private industry beginning with design and continuing through construction, testing, removal, and finally disposal of the reactor systems tested at DOME and LOTUS. INL will engage with industry to support the engineering design and development of these systems. INL staff have the requisite experience to provide this unparalleled value. INL core competencies in support of engineering work are:

- Nuclear fuels fabrication
- Fuel characterization
- Materials characterization of radiation damage in cladding and reactor components
- Fuel recycling and nuclear material management
- Transient irradiation testing
- Radioanalytical chemistry
- Space nuclear power
- Reactor safety in design integration, authorization and licensing
- Test bed engineering and advanced microreactor support
- Focused basic research
- Isotope production
- Nuclear non-proliferation and nuclear forensics.

In collaborating to develop reactor systems to test in the DOME and LOTUS test beds, INL will provide DOME and LOTUS engineering and design basis information, engineering expectations, and frequent reviews of engineering deliverables as they are completed by the developer. INL will also support the developer in tracking schedule, costs, and strategic planning to ensure engineering work is completed resulting in a feasible design with a robust safety basis.

### 5.2. Nuclear Safety

Nuclear safety is paramount in the vision, mission, and values of NRIC's test bed programs. Designing safe nuclear reactor systems includes navigating and implementing the DOE's nuclear safety design standards. INL staff have extensive experience in developing safety basis and authorization documents in support of compliance with DOE regulatory requirements.

Bridging the gap between development engineering and the regulatory expectations for implementing critical safety concepts is a major benefit provided to developers by the Program. For example, safety analysis and documentation are needed to achieve authorization from the DOE for fueling, operating, and decommissioning of reactor systems. The DOME and LOTUS test bed operation will be regulated by DOE. INL will provide the interface with the DOE and submit all documentation on behalf of the developer to DOE for approval.

DOE authorization expectations include a safety-in-design approach with important design milestones and activities. INL will engage with developers to ensure early integration of safety concepts and approaches.

### **5.3. Management of Test Beds, Onsite Work, and Testing**

INL staff will manage and execute work at MFC. INL maintains a user facility model for ensuring operations are compliant with nuclear safety requirements and scientific equipment is maintained. INL performs operations and maintenance (O&M) for the test beds and is responsible for the safe operation of the facility and management of its infrastructure, processes, and workflow.

The INL user engagement model ensures there are staff to operate, engineer, maintain, and support mission execution in test beds at INL. INL O&M activities include preventative and corrective maintenance, revitalisation and refurbishment, and construction of new support infrastructure for safe operation. INL will maintain the test bed design and engineering documentation to provide as input to design development of reactor test systems; which will identify key interfaces between the existing facility and new equipment and systems.

The test beds are intended to be adaptable to ensure usability by developers and enable successful testing of a large variety of technologies and systems. Early in the design of developer reactor systems to be tested in the NRIC test beds, INL will receive feedback from the developers on the modifications they require to accommodate their reactor systems. INL will implement approved changes and follow established engineering change processes to ensure the test bed safety basis is maintained.

Installation, testing, and removal of the reactor systems will also be managed by INL. Training for work performed specific to the reactor system will be developed in collaboration between the developer and INL throughout the design process. Generally, the developer will be responsible for providing subject matter expertise and originating documentation for onsite work, while INL will execute the work.

## **6. CONCLUSION**

NRIC is targeting infrastructure gaps standing in the way of deploying advanced nuclear technologies and is committed to filling these gaps to accelerate development. The development of the DOME and LOTUS test beds, the test bed program ecosystem, and subject matter expertise provided by NRIC are critical to microreactor deployment and commercialization. Without them, developers would have to expend capital on testing infrastructure instead of technology advancement to build their own test beds to achieve technical readiness necessary for licensing. Developers should seek out NRIC for the opportunity to expedite the testing of their unique advanced nuclear technologies.

## **REFERENCES**

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