INL/RPT-22-68412

Candidacy Renewal Report for ICERR Designation

July 2022

Submitted to the IAEA as a request for ICERR designation renewal by Idaho National Laboratory and Oak Ridge National Laboratory

Idaho National Laboratory INL

Oak Ridge National Laboratory
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

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EXECUTIVE SUMMARY

The International Atomic Energy Agency (IAEA) has established a designation for an International Centre based on Research Reactors (ICERR). The intention of this designation is to provide a vehicle for IAEA member states to access international research-reactor and ancillary nuclear research and development infrastructure.

The U.S. Department of Energy (DOE) has made a commitment to world leadership in the development of advanced nuclear energy, science, and technology. To this end, DOE has established programs and initiatives to enhance this leadership role.

ICERR designation constitutes an important step in achieving the DOE vision. DOE, represented by Idaho National Laboratory (INL) and Oak Ridge National Laboratory (ORNL), is submitting this application for re-designation as an IAEA ICERR.

Both INL and ORNL have a decades-long and storied history that supports nuclear research, development, and deployment both nationally and internationally. Both have a history of safe and efficient nuclear operations and have demonstrated a track record of international collaboration and cooperation.

INL and ORNL are home to two primary and two secondary research reactors. The primary reactors are

- Advanced Test Reactor at INL
- High-Flux Isotope Reactor at ORNL.

Secondary reactors include:

- Neutron Radiography Reactor at INL
- Transient Reactor Test (TREAT) Facility at INL
- INL Advanced Test Reactor: Critical Facility (ATRC).

ICERR designation will also include numerous ancillary facilities at both laboratories, including the following:

- Multiple post-irradiation examination facilities at both INL and ORNL
- Radiochemistry hot-cell facilities at ORNL
- INL nuclear-fuel-fabrication and materials-science facilities
- INL and ORNL radiological and nuclear analytical capabilities.

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FIGURES

TABLES

ACRONYMS

AECOM	Architecture, Engineering Consulting Operations, and Maintenance
ATR	Advanced Test Reactor
ATRC	Advanced Test Reactor: Critical Facility
BEA	Battelle Energy Alliance
BWX	Babcock and Wilcox Technologies, Inc.
CAS	Central Alarm System
DOE	Department of Energy
EPRI	Electric Power Research Institute
FEG	field emission gun
FIB	focused ion beam
GAIN	Gateway for Accelerated Innovation in Nuclear
HFEF	Hot Fuels Examination Facility
HFIR	High Flux Isotope Reactor
IAEA	International Atomic Energy Agency
ICERR	International Centre based on Research Reactor
ICP-MS	inductively coupled plasma mass spectroscopy
ICPP	Idaho Chemical Processing Plant
IFEL	Irradiated Fuels Examination Laboratory
IMCL	Irradiated Materials Characterization Laboratory
IMET	Irradiated Material Examination and Testing Facility
INL	Idaho National Laboratory
INTEC	Idaho Nuclear Technology & Engineering Center
ITER	International Thermonuclear Experimental Reactor
JICS	The Joint Institute for Computational Sciences
LAMDA	Low Activation Materials Development and Analysis Laboratory
MSCF	Material Security and Consolidation Facility
NASA	National Aeronautics and Space Administration
NE	(DOE) Office of Nuclear Energy
NSUF	Nuclear Science User Facilities

ORNL	Oak Ridge National Laboratory
RD&D	research, development, and demonstration
RDD&D	research, development, demonstration, and deployment
REDC	Radiochemical Engineering Development Center
SEM	scanning electron microscopy
SFTP	Spent Fuel Treatment Program
SPL	Sample Preparation Laboratory
SSPA	Shielded Sample Preparation Area
TEM	transmission electron microscopy
ToR	Terms of Reference
TREAT	Transient Reactor Test Facility
ZPPR	Zero Power Physics Reactor

Candidacy Renewal Report for ICERR Designation

1. PURPOSE

This report details the candidacy renewal of Idaho National Laboratory (INL) and Oak Ridge National Laboratory (ORNL) to be designated for inclusion in the International Centre based on Research Reactors (ICERR). In doing so, they seek to continue to make available to member states of the International Atomic Energy Agency (IAEA) their sizable research-reactor capabilities and surrounding infrastructure and depth of experience in order to facilitate the adoption or expansion of peaceful nuclear applications.

1.1 Background

In 1942 the United States Army Corp of Engineers acquired 60,000 acres in the Oak Ridge, Tennessee area, and began construction of uranium enrichment facilities for the United States Army as part of the Manhattan Project. A portion of that land was established as the Clinton Laboratories (also named X-10), and later renamed to Oak Ridge National Laboratory. In 1943, the world's second self-sustaining nuclear reactor, called the Clinton Pile or X-10 Graphite Reactor was constructed and operated at the Clinton Laboratories as a plutonium enrichment demonstration. After the war was over and wartime security restrictions relaxed, Oak Ridge scientists participated in an organized effort to turn nuclear research from exclusively militaristic uses to peaceful harnessing of power and, most importantly, to civilian control of research.[a] This resulted in the construction and operation of 13 unique research reactors at ORNL, including the High Flux Isotope Reactor (HFIR), which remains in operation today, as well as the first school for nuclear operations and hazard analysis, the Oak Ridge School of Reactor Technology. In its first fifteen years, the school trained almost 1,000 nuclear operators.

The post-war changes were instrumental in the creation of the INL which, from its origin as the National Reactor Testing Station, was purposed to test nuclear reactor designs and irradiate nuclear fuels and materials. Reactors designed at Oak Ridge and the University of Chicago were realized on an expansive and unpopulated desert site located some 30 miles from the cities of Blackfoot and Idaho Falls, Idaho. At INL, the first Experimental Breeder Reactor (EBR-I) was used to create electrical power from nuclear reactions, and an early Materials Test Reactor (MTR) was constructed, to be followed, in later decades, by the Engineering Test Reactor and the Advanced Test Reactor (ATR), which remains one of the pre-eminent test reactors in the world.[b] In total, 52 research reactors were built for experimentation at the Idaho Site.

INL and ORNL host both regional and international scholars and scientists for training and advanced research into fields including fuel development and testing, fuels and materials characterization, and isotope research and production. Through the Nuclear Science User Facilities (NSUF) program, experimenters from outside of INL and ORNL have access to the ATR, HFIR, and their supporting infrastructure for experiments requiring intense irradiation examination of hot fuels and materials.

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a. *Swords to Plowshares: A Short History of Oak Ridge National Laboratory*, Oak Ridge National Laboratory. pp. 1–4.

b. Stacy, Susan M., *Proving the Principle: A History of the Idaho National Engineering and Environmental Laboratory, 1949-1999*, Idaho Operations Office of the Department of Energy, 1995, pp. 25–27, 36–53.

1.2 Idaho National Laboratory Overview

As the U.S. Department of Energy (DOE) Office of Nuclear Energy (NE) national nuclear laboratory, INL serves a unique role in civilian nuclear energy research. INL has historical preeminence in reactor and fuel-cycle technology research, development, and demonstration (RD&D) going back to the 1950s and stewardship over a majority of the DOE infrastructure for nuclear-energy development. INL assists DOE-NE by leading, coordinating, and participating in research, development, and demonstration performed by national laboratories, U.S. universities, and collaborating international research institutions. To this end, DOE has established programs and initiatives to enhance this leadership role. As an example of this commitment, DOE has established the Gateway for Accelerated Innovation in Nuclear (GAIN) initiative. The intent of GAIN is to accelerate deployment of advanced nuclear energy technology and reduce risks associated with licensing and demonstration of this technology. The Idaho National Laboratory (INL), along with its partner laboratories Oak Ridge National Laboratory (ORNL) and Argonne National Laboratory, is leading the GAIN initiative for DOE. ICERR designation is an important step in achieving the DOE vision.

Battelle Energy Alliance, LLC (BEA) has managed and operated the Idaho National Laboratory since 2005. During this time INL has made substantial progress supporting the advancement of nuclear energy technology. INL's mission is to discover, demonstrate, and secure innovative nuclear-energy solutions, other clean-energy options, and critical infrastructure. INL's five S&T initiatives work toward a low-carbon energy future built on a foundation of nuclear energy:

- **Nuclear Reactor Sustainment and Expanded Deployment**. INL develops and demonstrates advanced technology to improve the performance of both existing and future carbon-free, reliable nuclear energy systems that are vital to a clean energy future.
- **Integrated Fuel Cycle Solutions**. INL advances effective and integrated fuel cycle solutions to sustain the current reactor fleet and enable its expansion and replacement with advanced reactors. Leveraging its expert staff, historical fuel cycle expertise, and specialized infrastructure, INL creates solutions to make special nuclear material (SNM) available for fuel fabrication.
- **Integrated Energy Systems**. INL leads the discovery and demonstration of innovative technologies to advance the integration of energy generation, storage, and delivery needed for a low-carbon future.
- **Advanced Design and Manufacturing for Extreme Environments**. INL accelerates discoveries to improve the performance of materials for harsh and extreme environments, including advanced nuclear reactors, defense systems, and space applications, while reducing costs and production time.
- **Secure and Resilient Cyber-Physical Systems**. INL leverages its world-class R&D capabilities and unique assets to solve complex challenges to the security and resilience of our infrastructure, including growing threats and vulnerabilities and increased coupling and control of cyber-physical systems and their interdependencies.

INL is a multi-program laboratory. Many competencies that arise from expertise or infrastructure were initially developed for the nuclear-energy mission. Besides advancing nuclear energy, INL mission areas now encompass enabling clean energy deployment and securing and modernizing critical infrastructure. These mission areas are built on a foundation of thirteen existing and two emerging core capabilities, and support a broad customer base that includes the DOE, other federal agencies, universities, and industry. INL also serves a unique role in the U.S. Intermountain West region as a technical resource and advisor on local and regional issues related to the future direction of energy production and distribution. The INL mission areas and outcomes are depicted in Figure 1. Also shown in the figure are the five science and technology initiatives that INL focuses on.

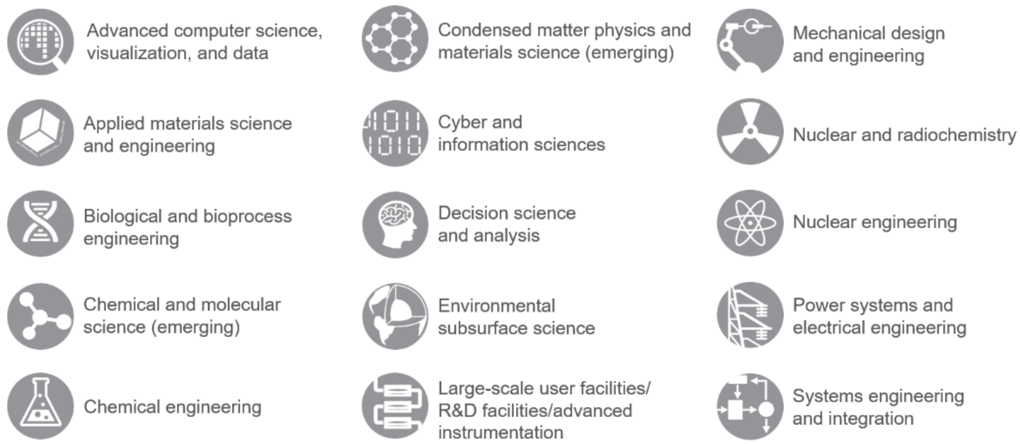


Figure 1. INL's thirteen existing and two emerging core capabilities support the fundamental science required to create deployable technology solutions.

1.2.1 INL at a Glance

Location: Idaho Falls, Idaho

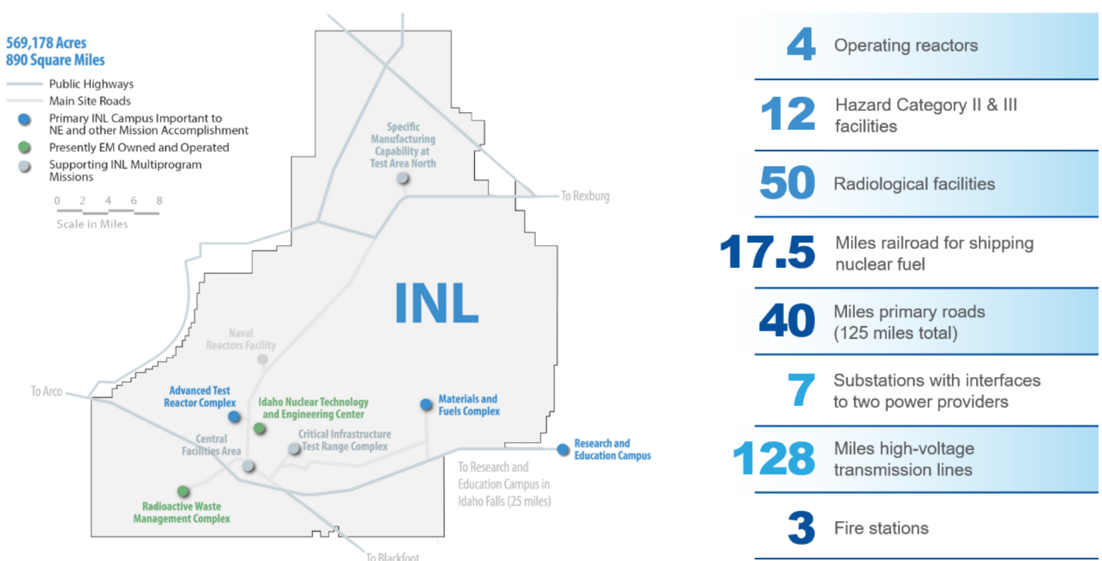
Type: Multi-program laboratory

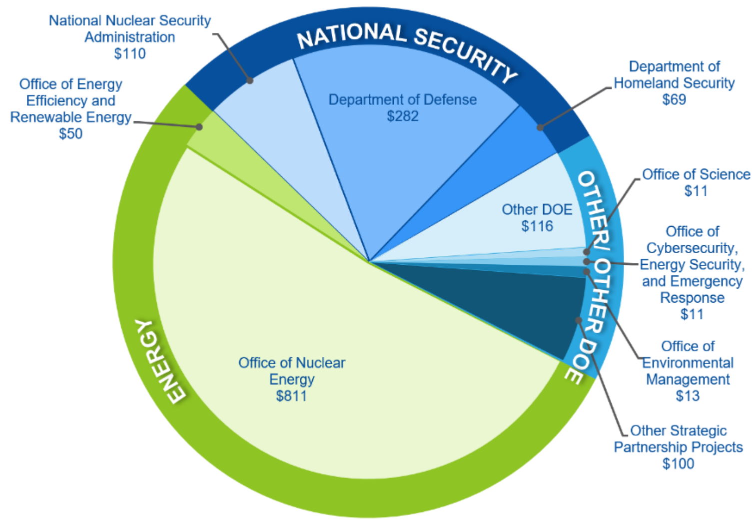
Contractor: Battelle Energy Alliance, LLC (BEA)

Responsible DOE Field Office: Idaho Falls Office

Website: https://www.inl.gov/

INL Site: INL resembles a "well characterized city/region," where energy and security questions can be addressed at scale, and it includes the following:





FY21 business volume by source ($M)

FY21 business volume

DOE/NNSA Costs: $1,121M
SPP (Non-DOE/Non-DHS): $377M
CRADA: $5M
DHS Costs: $69M
Total: $1,572M

FY21 human capital

5,734 full-time equivalent employees
42 joint appointments
95 postdoctoral researchers
289 undergraduate interns
182 graduate interns
26 graduate fellows
21 visiting scientists
1,142 facility users

1.2.2 INL Management Team

Operating since 1949, INL is the nation’s leading RD&D center for nuclear energy, including nuclear non-proliferation and physical and cyber-based protection of energy systems and critical infrastructure, and integrated energy systems RDD&D. INL has been managed and operated by BEA, a wholly-owned company of Battelle, for the DOE since 2005. BEA is a partnership of Battelle; Babcock and Wilcox Technologies, Inc. (BWXT); Amentum (formerly AECOM); the Electric Power Research Institute (EPRI); the National University Consortium (Massachusetts Institute of Technology, the Ohio State University, North Carolina State University, University of New Mexico, and Oregon State University); and the Idaho University Collaborators (University of Idaho, Idaho State University, and Boise State University).

INL’s management and operations contractor is BEA. Brief descriptions of the BEA teams and their areas of expertise are described below.

1.2.2.1 *Battelle*

- A leading science and technology research, development and deployment organizations
- Premier manager of DOE national laboratories
- Successful expansion of scientific capabilities
- Successful transformation of laboratory culture
- Substantial increases in efficiencies and reduction of costs
- Innovative construction and modernization of research facilities and complexes, on time and within budget
- Successful small business programs.

1.2.2.2 *Electric Power Research Institute (EPRI)*

- 40 years of research and development management in support of global electricity infrastructure
- Long-established partnerships with the nuclear power industry
- Highly effective research collaborations and initiatives
- A mature, well-respected technology transfer process and organization

- Provides leaderships at INL in developing domestic and international partnerships and agreements with industry, which are essential to establishing the envisioned nuclear reactor programs and deploying results into the nuclear industry.

1.2.2.3 *National University Consortium*

- Currently partner with 14 first-tier universities
- The Massachusetts Institute of Technology—the world's leading nuclear-science and engineering university based on both its quality research and inquiry and a history of collaborative research and education—has committed to lead a national consortium of universities, initially composed of North Carolina State University, Ohio State University, Oregon State University, and the University of New Mexico, this is dedicated to renewal of nuclear science, technology, and engineering education in the United States
- The national university consortium will work with Idaho State University collaborators to assist with developing first-tier nuclear research and education programs.

1.2.2.4 *BWX Technologies (BWXT)*

- A global leader in energy and environmental technologies and services for the power and industrial markets, with operations, subsidiaries, and joint ventures worldwide
- Premier owner/operator of complex, high-consequence, nuclear manufacturing and national security facilities
- Manages and safeguards more highly enriched uranium than any other U.S. company
- Innovative approaches/solutions to increase efficiencies and decrease costs
- Nationally recognized small business services programs.

1.2.2.5 *Amentum (formerly AECOM)*

Amentum builds on a 116-year legacy of providing essential services to the federal government, including nuclear, environmental remediation, and project/facilities management.

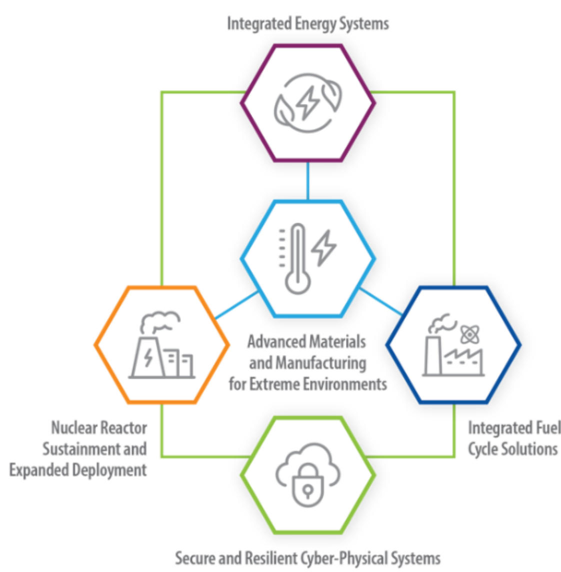


Figure 2. INL Science and Technology initiatives.

1.3 **Oak Ridge National Laboratory Overview**

Oak Ridge National Laboratory is the largest US Department of Energy science and energy laboratory, conducting basic and applied research to deliver transformative solutions to compelling problems in energy and security.

ORNL's diverse capabilities span a broad range of scientific and engineering disciplines, enabling the Laboratory to explore fundamental science challenges and to carry out the research needed to accelerate the delivery of solutions to the marketplace. ORNL supports DOE's national missions of:

- Scientific discovery—Assembling teams of experts from diverse backgrounds, equipping them with powerful instruments and research facilities, and addressing compelling national problems;
- Clean energy—Delivering energy technology solutions for energy-efficient buildings, transportation, and manufacturing, and studying biological, environmental, and climate systems in order to develop new biofuels and bioproducts and to explore the impacts of climate change;
- Security—Developing and deploying first-of-a-kind, science-based security technologies to make the world a safer place.

ORNL supports these missions through leadership in four major areas of science and technology:

- Neutrons—Operating two of the world's leading neutron sources, which enable scientists and engineers to gain new insights into materials and biological systems;
- Computing—Accelerating scientific discovery through modeling and simulation on powerful supercomputers, advancing data-intensive science, and sustaining US leadership in high-performance computing;
- Materials—Integrating basic and applied research to develop advanced materials for energy applications;
- Nuclear—Advancing the scientific basis for 21st century nuclear fission and fusion technologies and systems, and producing isotopes for research, industry, and medicine.

ORNL works with industry to move research to the marketplace and collaborates with other research institutions, universities, and the state of Tennessee to expand its capabilities, increase the availability of its facilities and expertise, and create research and educational opportunities for students and teachers.

ORNL leads two major multi-institutional partnerships: the BioEnergy Science Center (one of three DOE Bioenergy Research Centers) and the Consortium for Advanced Simulation of Light Water Reactors, a DOE Energy Innovation Hub. ORNL also hosts two DOE Energy Frontier Research Centers and manages the US contributions to International Thermonuclear Experimental Reactor (ITER), the international fusion project.

ORNL partners with more than 250 universities in some capacity and includes several major Southeastern U.S. research universities on the UT-Battelle management team. Those core university partners—Duke, Florida State, Georgia Tech, North Carolina State, Vanderbilt, the University of Virginia and Virginia Tech, in addition to the University of Tennessee (UT) and Oak Ridge Associated Universities (ORAU)—ensure broad engagement of faculty and students in ORNL's science programs.

1.3.1 ORNL at a Glance

Location: Oak Ridge, Tennessee

Type: Multi-program laboratory

Contractor: University of Tennessee–Battelle, LLC (UT-Battelle)

Responsible DOE Field Office: Oak Ridge Office

Website: https://www.ornl.gov/

ORNL Site: Five distinct campuses comprise the Oak Ridge Reservation, a site containing 58 square miles. ORNL is one of these campuses:

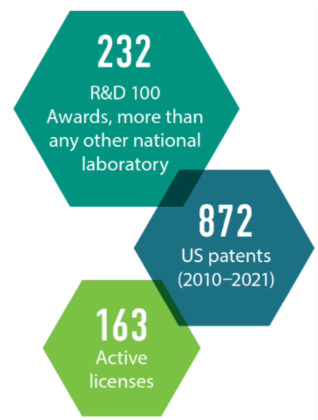
- Nine User Facilities
- Six Institutes
- Two Innovation Hubs
- Nine Research and Science Centers
- The High Flux Isotope Reactor
- Home to the U.S. National Isotope Development Center (NIDC) Business Office
- 872 U.S. Patents issued since 2001
- 163 Active technology license agreements as of Sept. 2015
- Two Historic Landmarks (X-10 Graphite Reactor and High Flux Isotope Reactor)
- Manhattan Project National Historic Park Site
- Security force
- Waste disposal facilities and an integrated waste disposition program

ORNL Snapshot:

- **Staff:** 5,800+ represnting over 60 nations
- **Annual Guest Researchers:** 3,200+
- **2,400+ Scientific Publications (2021)**
- **Budget:** US$2.2 billion (FY2022)
- **World's fastest supercomputer**

Impactful R&D

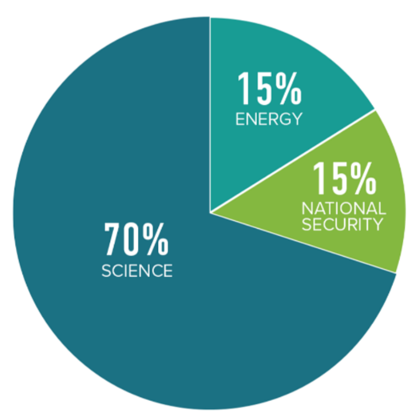
- Advance understanding, design and use of new materials and chemical processes
- Reveal unmatched insights through computing and data
- Ensure safe, clean nuclear power and secure nuclear materials
- Produce rare isotopes for medicine, industry, security, research and space exploration
- Increase and exploit understanding of biological and environmental systems, from genes to ecosystems



Fiscal Year 2015 human capital includes the following:

- 5,800+ full-time staff
- 3,200 annual users and visiting scientists
- 266 joint faculty with 51 universities including 2 foreign universities.
- 131 postdoctoral researchers
- 1,208 total interns.

Fiscal Year 2021 Research Funding: $2.2B, primarily for DOE Science and Technology research and development (accounting for 80% of all work).



Funding by DOE mission
FY22: $2.4B

1.3.2 ORNL Management Team

UT–Battelle, LLC, was established in 2000 as a private not-for-profit company for the sole purpose of managing and operating the

ORNL for the U.S. DOE. Formed as a 50-50 limited-liability partnership between the University of Tennessee and Battelle Memorial Institute, UT–Battelle is the legal entity responsible delivering the Department of Energy's research mission at ORNL.

Brief descriptions of the ORNL team are listed below:

1.3.2.1 *Battelle*

- A 7,500-person R&D organization, founded in 1929 in Columbus, Ohio, as a non-profit charitable trust with annual revenues of more than $3 billion.
- Manages or co-manages several other major research facilities, including DOE's Pacific Northwest National Laboratory (since 1965), the National Renewable Energy Laboratory (since 1998), Brookhaven National Laboratory (since 1998) and Idaho National Laboratory (since 2005); corporate laboratories in Columbus, Ohio, and other U.S. and European locations.
- Conducts more than 5,000 current projects for 1,100 government and industrial clients.
- Winner, including those received by its affiliate laboratories, of 191 prestigious R&D 100 awards.
- Winner of 41 Federal Laboratory Consortium Awards for outstanding accomplishments in science and technology.

1.3.2.2 *University of Tennessee*

- Established in 1794, UT has 54,000 students located at five campuses with an annual budget in excess of $1.5 billion.
- The University of Tennessee is classified as a *research university with very high research activity* (RU/VH) by the Carnegie Commission. The university conducts externally-funded research totaling more than $300 million annually, including some $17.3 million annually in research sponsored by ORNL.
- Areas of joint research with ORNL include the Bioenergy Science Center's work on cellulosic ethanol; the Center for Computational Sciences partnership with the National Science Foundation; and the Science Alliance, with divisions in biological, chemical, physical, and mathematical/computer science.

1.3.3 ORNL Joint Institutes, Centers, and Innovation Hubs Supporting ICERR

Six Institutes including four Joint Institutes, under partnerships between ORNL, UT, Vanderbilt and the state of Tennessee, combine distinct, but complementary resources in select, high-priority scientific and engineering fields.

The Joint Institute for Computational Sciences (JICS) advances scientific discovery and state-of-the-art engineering and computational modeling and simulation. JICS takes full advantage of the petascale and beyond computers in DOE's National Center for Computational Sciences and UT's National Institute for Computational Sciences.

The Joint Institute for Neutron Sciences promotes worldwide neutron scattering collaboration among researchers in biological and life sciences, energy sciences, polymer science, condensed matter physics and computational sciences through neutron analysis at ORNL's Spallation Neutron Source and HFIR.

The Joint Institute for Nuclear Physics and Applications unites ORNL, UT, and Vanderbilt University to promote and support basic nuclear-physics research and nuclear and radiological applications of common interest to the participants.

1.3.4 Consortium for Advanced Simulation of Light Water Reactors

The Consortium for Advanced Simulation of Light Water Reactors (CASL) is the first DOE Energy Innovation Hub established in July 2010, for the purpose of providing advanced modeling and simulation

(M&S) solutions for commercial nuclear reactors.

1.3.5 DOE Energy Frontier Research Centers

The Energy Frontier Research Centers program aims to accelerate such transformative discovery, combining the talents and creativity of our national scientific workforce with a powerful new generation of tools for penetrating, understanding, and manipulating matter on the atomic and molecular scales. ORNL is home to one of the DOE Energy Frontier Research Centers, the Fluid Interface, Reactions, Structures and Transport (FIRST) Center. The goal of the FIRST CFRC is to address the fundamental gaps in our current understanding of interfacial systems of high importance to future energy technologies, including electrical energy storage (batteries, supercapacitors) and heterogeneous catalysis for solar energy and solar fuels production.

1.3.6 Other Centers Overlapping ICERR

These centers also call ORNL home:

- National Center for Computational Sciences
- Radiation Safety Information Computational Center (RSICC)
- U.S. ITER Project Office.

1.4 Gateway for Accelerated Innovation in Nuclear

The mission of the Department of Energy Office of Nuclear Energy (DOE-NE) is to advance nuclear power as a resource capable of meeting the nation's energy, environmental and national security needs by resolving technical, cost, safety, proliferation resistance, and security barriers through RD&D.

Accomplishing this mission will realize the enormous potential of nuclear energy and maintain the United States' historic leadership in the field. While many innovative ideas exist, the RD&D needed to bring these concepts to a commercial readiness level is traditionally lengthy and expensive.

DOE-NE has established GAIN to provide the nuclear community with access to the technical, regulatory, and financial support necessary to move innovative nuclear energy technologies toward commercialization while ensuring the continued safe, reliable, and economic operation of the existing nuclear fleet.

INL leads the GAIN Initiative with support and direction from DOE-NE and in coordination with partners ORNL and ANL.

Since inception in 2016, GAIN awarded nearly $25M in vouchers enabling industry access to DOE national laboratories as shown below.

1.5 National Reactor Innovation Center

The National Reactor Innovation Center (NRIC) is a DOE-NE national program under NE-52 “Office of Nuclear Reactor Deployment.” NRIC’s purpose is defined in the Nuclear Energy Innovation

Capabilities Act (NEICA) of 2017. INL has been identified as the lead integration laboratory to partner with industry and the other DOE national laboratories to execute the NRIC mission.

NRIC enables demonstration of private sector reactor designs. The US benefits from the use of commercial nuclear power currently and new demonstrated reactor concepts enable the US global nuclear leadership position. The US ability to deliver operational nuclear reactors has atrophied over recent decades. Simply knowing how to build these machines is not enough; the US must exercise the ability to build and operate nuclear reactor systems with a routine cadence.

1.6 The U.S. DOE Microreactor Program

The U.S. DOE Microreactor Program supports research and development (R&D) of technologies related to the development, demonstration, and deployment of very small, factory fabricated, transportable reactors to provide power and heat for decentralized generation in civilian, industrial and defense energy sectors.

Led by INL, the program conducts both fundamental and applied R&D to reduce the risks associated with new technology performance and manufacturing readiness of microreactors. The intent of the program is to ensure that microreactor concepts can be developed, licensed, and deployed by commercial entities to meet specific use case requirements.

The program coordinates work and activities across participating laboratories, universities, and industry as well as other DOE programs. National laboratories participating in the Microreactor Program are INL, Oak Ridge National Laboratory, Argonne National Laboratory, and Los Alamos National Laboratory.

Under the auspices of the DOE-NE Microreactor Program, INL is leading the development of a nuclear microreactor applications test bed to perform research and development on various operational features of microreactors and enable improved integration of microreactors with end-user applications.

2. DESCRIPTIONS OF INL AND ORNL REACTORS AND ANCILLARY FACILITIES

INL research reactors and ancillary facilities to be considered as part of ICERR are identified and described in the following facility information sheets. The facilities discussed in those sheets handle a majority of the nuclear research at the two national laboratories; however, several other facilities (existing and planned) may be requested at a later date:

- INL Advanced Test Reactor (ATR)
- INL Advanced Test Reactor: Critical Facility (ATRC)
- ORNL High Flux Isotope Reactor (HFIR)
- Materials and Fuels Complex (MFC) Transient Reactor Test Facility (TREAT)
- MFC Hot Fuels Examination Facility (HFEF) and Neutron Radiography Reactor (NRAD)
- ORNL Irradiated Fuels Examination Laboratory (IFEL)
- MFC Sample Preparation Laboratory (SPL)
- MFC Irradiated Materials Characterization Laboratory (IMCL)
- ORNL Low Activation Materials Development and Analysis Laboratory (LAMDA)
- MFC Analytical Research Laboratories (ARL)
- MFC Electron Microscopy Laboratory (EML)
- ORNL Irradiated Material Examination and Testing Facility (IMET)
- MFC Experimental Fuels Facility (EFF)
- MFC Fuels Manufacturing Facility (FMF)
- MFC Fuels and Applied Sciences Building (FASB)
- ORNL Radiochemical Engineering Development Center (REDC)
- MFC Advanced Fuels Facility (AFF)
- MFC Engineering Development Laboratory (EDL)
- MFC Fuel Conditioning Facility (FCF)
- MFC Research Collaboration Building (RCB)
- MFC Radiochemistry Laboratory (RCL)
- MFC Zero Power Physics Reactor Facility (ZPPR).

Each of the following facility descriptions includes brief overviews of each facility, a current listing of instrumentation within the facilities, and a listing of capabilities for which ICERR designation is requested.

Advanced Test Reactor

Irradiation

Image of the Advanced Test Reactor

General contact
Joseph Campbell
208-533-4679
joseph.campbell@inl.gov

www.inl.gov

Idaho National Laboratory

The Advanced Test Reactor (ATR) supports nuclear science and engineering missions for the U.S. Department of Energy's Office of Nuclear Energy research and development programs, Naval Reactors, and a variety of other government and privately sponsored commercial and international research. It is the only U.S. research reactor capable of providing large-volume, high-flux neutron irradiation in a prototypical (e.g., pressure, temperature, and chemistry) environment. The ATR makes it possible to study the effects of intense neutron and gamma radiation on reactor materials and fuels in a much shorter timeframe, permitting accelerated research efforts.

BASIC CAPABILITIES AND FEATURES:

- Critical national and international irradiation testing capability
- High-power (250 MW) test reactor operating at low pressure and temperature, but with individual experiment conditions adjustable to >500°C and >1000 psig
- Reactor cooled by light water with a beryllium reflector for high neutron efficiency
- Unique serpentine core allows reactor's corner lobes to be operated at different power levels, making it possible to conduct multiple simultaneous experiments under different testing conditions

KEY INSTRUMENTS:

Large test volumes – up to 48 inches long and from 0.5 to 5 inches in diameter

- 77 testing positions
- High neutron flux (up to ~1015 n/cm2/sec) available
- Fast/thermal flux ratios ranging from 0.1 – 1.0
- Constant axial power profile
- Individual experiment pressure and temperature control possible
- Programmatic operational commitment to at least 2085
- A key capability within the Nuclear Science User Facilities (NSUF), Gateway for Accelerated Innovation in Nuclear (GAIN) and National Reactor Innovation Center (NRIC) programs
- The reactor is capable of isotope production (e.g., Cobalt-60) for commercial and other research applications

INL is a U.S. Department of Energy (DOE) national laboratory that performs work in each of DOE's strategic goal areas: energy, national security, science and environment. INL is the nation's center for nuclear energy research and development. Day-to-day management and operation of the laboratory is the responsibility of Battelle Energy Alliance.

20-50442_006_R0 (Updated: 2022)

Advanced Test Reactor: Critical Facility

Irradiation

BASIC DESCRIPTION:

One of four research and test reactors at Idaho National Laboratory, the Advanced Test Reactor Critical Facility (ATRC) is a low-power critical facility that directly supports the operations of INL's 250-megawatt Advanced Test Reactor (ATR).

Low-power critical facilities like ATRC support the operations of their more powerful counterpart test reactors by offering precise calculation of neutron flux levels that will be seen in the reactor core.

For any given operating cycle, the wide variety of fuel and material experiments can affect the flux levels seen within the reactor. If an ATRC test is required, the INL project team will work with the users to ensure necessary information is obtained and that the ATRC work is scheduled in the experiment planning.

In addition to its role supporting ATR, ATRC is a valuable tool on its own for physics testing of experiments and low power testing of instruments, such as low power fission detectors and high-temperature thermocouples.

BASIC CAPABILITIES AND FEATURES:

- Designed as a low-power version of the ATR's core, the ATRC enables the accurate prediction of these levels and helps ATR reactor engineers select the fuel assemblies to be used for each cycle.
- The ATRC core is a heterogeneous, pool-type reactor, dimensionally identical to ATR, and typically operates at power levels of 600 watts or less.

KEY SPECIFICATIONS AND INSTRUMENTS:

- Max power: 5KW; typical operating power is 600W or less
- Neutron flux (up to 4x1011 n/cm2/s at 1KW)
- Flux runs can use up to 1,000 enriched uranium-aluminum alloy wires, 93% enriched wires are 40 mil diameter, 0.25" long
- Control panel upgrade completed in 2019 enables precise, reliable control of key systems
- Electromagnetic safety rod drives automatically drop into core on power shutdown

INL is a U.S. Department of Energy (DOE) national laboratory that performs work in each of DOE's strategic goal areas: energy, national security, science and environment. INL is the nation's center for nuclear energy research and development. Day-to-day management and operation of the laboratory is the responsibility of Battelle Energy Alliance.

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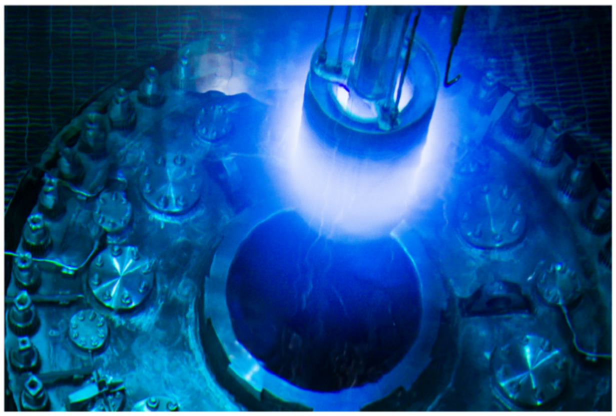
Idaho National Laboratory

20-50442_007_R0 (Updated: 2022)

Description

The High Flux Isotope Reactor (HFIR) first achieved criticality on August 25, 1965, and achieved full power in August 1966. It is a versatile 85-MW isotope production, research, and test reactor with the capability and facilities for performing a wide variety of irradiation experiments and a world-class neutron scattering science program. HFIR is a beryllium-reflected, light water-cooled and moderated flux-trap type swimming pool reactor that uses highly enriched uranium-235 as fuel. HFIR typically operates seven 23-to-27 day cycles per year. Irradiation facility capabilities include:



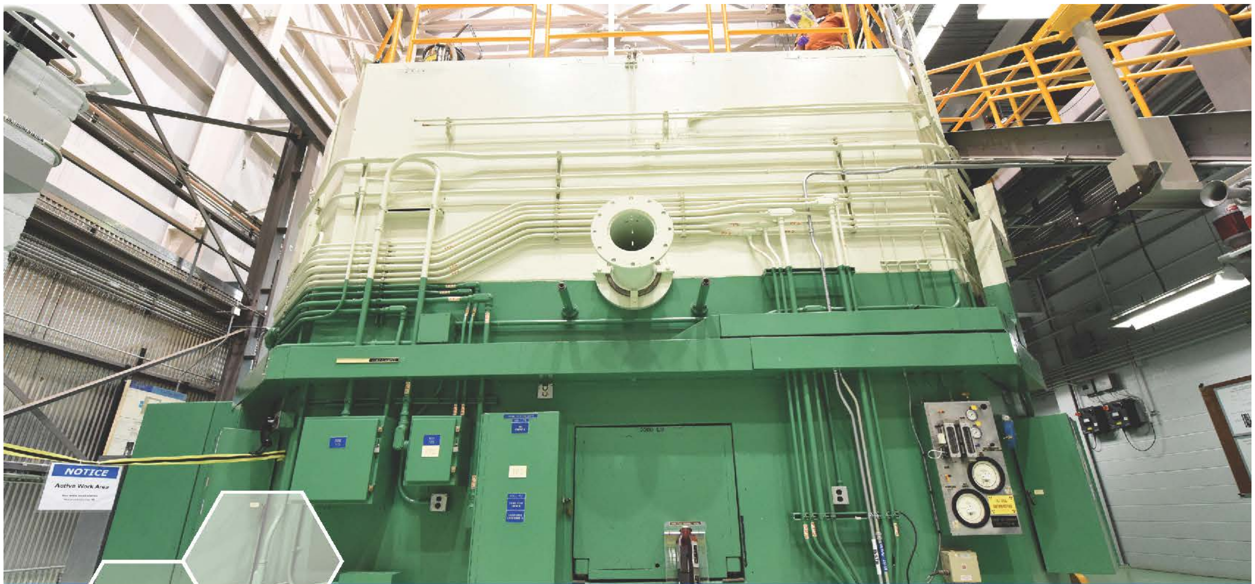
- Flux trap positions: Peak thermal flux of $2.5X10^{15}$ n/cm^2/s with similar epithermal and fast fluxes (Highest thermal flux available in the western world.)
- Instrumented reflector positions: Peak thermal flux of $1.0X10^{15}$ n/cm^2/s with similar epithermal and fast fluxes
- Uninstrumented reflector positions: Thermal fluxes of $1.0X10^{15}$ n/cm^2/s ranging down to $1.0X10^{14}$ n/cm^2/s in the outermost positions
- Two complimentary pneumatic tubes that shuttle samples from the core to the HFIR Neutron Activation Analysis (NAA) Laboratory
  - PT-1: $2.8X10^{14}$ n/cm2/s (Thermal/Epithermal = 40)
  - PT-2: $5.9X10^{13}$ n/cm2/s (Thermal/Epithermal = 200)
- Gamma irradiation Facility maximum dose rate: $1.0X10^{8}$ R/hr

Applications

- Thermal and cold neutron scattering science
- Isotope production
  - Californium-252
  - Other transcurium isotopes for R&D
  - Lighter isotopes that require high flux for production
- Fission and fusion reactor materials irradiation studies
- Advanced reactor fuels irradiation studies
- Neutron Activation Analysis

Specifications	
Reactor type	Beryllium reflected, light water cooled and moderated, flux-trap type reactor
Thermal neutron scattering instruments	3 horizontal beam tubes serving 7 instruments
Cold neutron scattering instruments	1 horizontal beam tube serving 5 instruments
Flux trap region irradiation positions	30 target positions, 6 peripheral target positions 1 hydraulic rabbit facility position
Reflector region irradiation positions	42 vertical irradiation positions 2 slant positions on reflector periphery
Materials Irradiation Facility	This facility supports instrumented and/or gas cooled experiments -2 flux trap positions -8 reflector positions (removable reflector)
Neutron Activation Analysis	2 pneumatic tubes shuttle samples from the NAA Lab to the reflector region
Gamma Irradiation Facility	In spent fuel flux trap

Oak Ridge National Laboratory



Transient Reactor Test Facility

Irradiation

The Transient Reactor Test (TREAT) Facility allows researchers to test nuclear fuels and materials in off-normal and accident conditions, providing key data that helps improve safety and efficiency.

The Transient Reactor Test (TREAT) Facility at Idaho National Laboratory is a national asset that provides unique test results in an essential nuclear research field. It will foster the development of new ways to provide baseload and load following electrical power. Transient testing is an essential component of the United States and international efforts to develop robust, safer nuclear fuels, and to bring innovative reactor technologies to the market.

Transient testing involves the application of controlled, short-term bursts of intense neutron flux directed toward a test specimen in order to study fuel and material performance under off-normal operational conditions and hypothetical accident scenarios. After the transient test, the fuel or material is analyzed at a post-irradiation examination (PIE) facility. The results of these examinations are then evaluated and used in advancing fuel or material design and qualification.

TREAT is a highly capable test reactor. Detailed real-time monitoring of the specimens during a test is possible via the hodoscope, a system that detects fast neutron signatures from experiments, and other experiment and core instrumentation. This instrumentation, coupled with PIE, allows scientists to determine the appropriate safety limits for the fuels and materials in nuclear power reactors. TREAT's simple, self-limiting, air-cooled design can safely accommodate multipin test assemblies, enabling the study of fuel melting, metal-liquid reactions, overheated fuel and coolant reactions, and transient behavior of fuels for high temperature system applications.

The TREAT facility operated from 1959 through 1994, when it was placed in standby mode. A resurgence of interest in developing innovative nuclear technologies has driven demand for transient testing. TREAT was restarted in 2017 and is currently supporting experiment programs.

TREAT provides transient testing of nuclear fuels and materials. The facility is used to study fuel melting behavior, interactions between fuel and coolant, and the potential for propagation of failure to adjacent fuel pins under conditions ranging from mild upsets to severe accidents.

Idaho National Laboratory

TREAT was restarted in 2017 after being placed on standby in 1994.

TREAT is an air-cooled, thermal-spectrum test facility specifically designed to evaluate the response of reactor fuels and structural materials to accident conditions. The reactor was originally constructed to test fast-reactor fuels, but its flexible design has also enabled its use for testing of light water reactor fuels as well as other exotic special purpose fuels, such as those used in space reactors. TREAT has an open-core design that allows for ease of experiment instrumentation and real-time imaging of fuel motion during irradiation, which also makes TREAT an ideal platform for understanding the irradiation response of materials and fuels on a fundamental level.

TREAT was placed on standby in 1994. TREAT was restarted in 2017 and is currently supporting experiment programs. TREAT provides a valuable capability to support efforts to develop accident-tolerant fuels for light-water reactors as well as the advanced reactor fuels, both of which will allow nuclear power to remain the primary source of emission-free baseload energy in the future.

BASIC CAPABILITIES:

- High-intensity (20 GW), short-duration (<100 ms) neutron pulses for severe accident testing
- Shaped transients at intermediate powers and times (flexible power shapes up to several minutes duration)
- 120 kW steady state operation
- Testing capability for static capsules, sodium loops, water loops, and hydrogen loops
- Neutron-radiography facility

KEY INSTRUMENTS:

- Nondestructive examination of assemblies up to 15 feet long in steady state operating mode by neutron radiography
- Neutron 'hodoscope,' providing real-time imaging of fuel motion during testing
- Open core design suitable to instrument experiments during testing

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21-50083_TREAT_R4 (Updated: 2022)

Hot Fuel Examination Facility

Post-irradiation Examination of Fuels and Materials

The Hot Fuel Examination Facility is the largest hot cell dedicated to radioactive material research at Idaho National Laboratory.

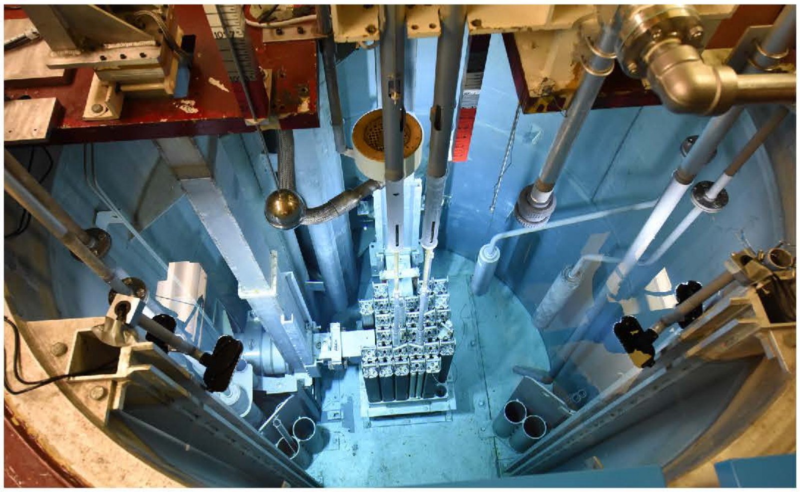
The Hot Fuel Examination Facility (HFEF) is Idaho National Laboratory's flagship facility for conducting post-irradiation examinations of fuels and materials. HFEF, located at the Materials and Fuels Complex, is a national research asset with the largest inert atmosphere hot cell dedicated to nuclear materials research in the U.S.

HFEF provides the ability to remotely handle and perform detailed nondestructive and destructive examination of highly irradiated fuel and material samples. Its argon-atmosphere hot cell, labs and special equipment handle a variety of fuel forms, including tiny particles, four-foot research reactor plates and full-sized commercial rods. HFEF supports INL's mission of research and development of safer and more efficient fuel designs.

KEY CAPABILITIES:

- HFEF has two large, shielded hot cells. The main cell, which is 70 by 30 feet, is stainless steel-lined. It's fitted with two 5-ton cranes and 15 workstations, each with a 4-foot-thick window of oil-filled glass and a pair of remote manipulators. The second hot cell is an air cell used to decontaminate materials and equipment.
- Laser puncture and gas collection with the gas assay sample and recharge (GASR) from fuel samples helps researchers gain needed information on fission gas and helium release.
- Precision gamma scanning (PGS) allows scientists to precisely determine the location of radioactive elements in fuel and material samples.
- The fuel accident condition simulator (FACS) furnace enables fuel and material sample testing under worst-case scenarios involving temperatures of up to 2,000 C for extended periods. This allows scientists to understand performance and improve the safety of fuel designs.
- The Neutron Radiography Reactor is a 250 kW steady state Training Research Isotopes General Atomics (TRIGA) reactor co-located within and adjacent to HFEF. It is equipped with two separate radiography stations for neutron radiography of fuel and materials.
- Fuel refabrication for testing in the Transient Reactor Test (TREAT) facility.

Idaho National Laboratory



The NRAD reactor provides a neutron source for indirect-film and digital radiography of irradiated fuels and materials, neutron computed tomography and neutron diffraction

The Hot Fuel Examination Facility (HFEF) is a multi-program hot cell facility. There are two adjacent shielded hot cells (the main cell and decontamination cell), a shielded metallography box, an unshielded hot repair area, and a waste-characterization area. HFEF provides shielding and containment for remote examination, processing, and handling of highly radioactive and TRU-bearing materials in its argon-atmosphere hot cells, unshielded labs, support areas and special equipment for handling, examining, and testing of highly radioactive materials.

BASIC CAPABILITIES:

- Nondestructive and destructive post-irradiation examination of irradiated samples in two large, heavily shielded hot cells.
  - » Machining and disassembly of fuel and material experiments
  - » Neutron film and digital radiography
  - » Neutron tomography
  - » Neutron diffraction
  - » Visual examination and dimensional examination
  - » Gamma scanning/ gamma tomography
  - » Fission-gas-release measurement
  - » Sample preparation for metallography, chemical and isotopic analysis, and optical microscopy
- Mechanical testing of irradiated fuels and materials
- Bench-scale electrochemical separations research.
- Precision milling, welding, and machining.
- Handling and loading facilities capable of receiving large shipping casks and fuel assemblies up to 13 feet long.
- Furnaces for simulating accident conditions at temperatures up to 2,000 C for extended periods.

KEY INSTRUMENTS:

Nondestructive instruments include:

- NRAD reactor
- Autoradiography
- Visual examination machine
- Eddy current probe for measurement of oxide thickness
- Precision gross and isotopic gamma spectrometer
- Element contact profilometer bow & length machine (fuel rods)
- Profilometry and eddy current measurement bench (fuel plates)
- Pycnometer

Destructive instruments include:

- Laser puncture gas collection and analysis system
- Fuel accident condition simulator (FACS) furnace
- Metal waste form furnace
- Remote load frame

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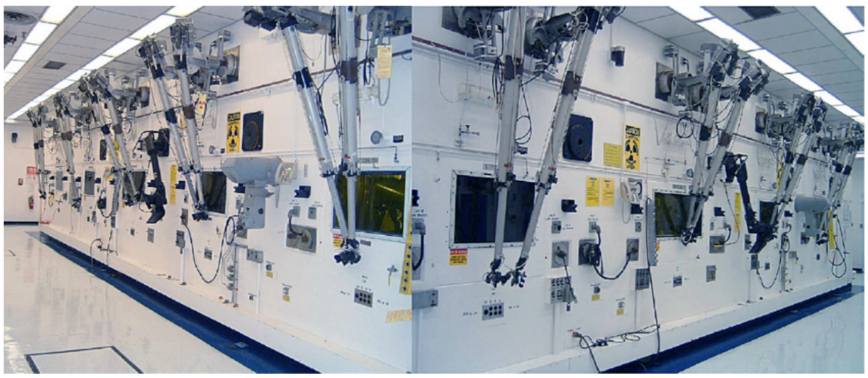
21-50083_HFEF_R0 (Updated: 2021)

Description

The Irradiated Fuels Examination Laboratory (IFEL) was initially designed and constructed to permit the safe handling of increasing levels of radiation in the chemical, physical, and metallurgical examination of nuclear reactor fuel elements



and reactor parts. The IFEL was constructed in 1963 and is a two-story brick building with a partial basement. The front or northern-most section is a single-story office area. The two story area to the immediate rear houses the cell complex, the operating areas, and other supporting activities. The office area is isolated from the main part of the building, so the office area can be excluded from the secondary containment zone. The facility has a gross floor area of about 27,000 ft2.

Applications

- Receipt and handling of irradiated materials (fuel or nonfuel in shielded casks)
- Capsule disassembly
- Nondestructive and destructive testing of irradiated materials
- Full-length LWR fuel examination
- Repackaging of spent nuclear fuel
- Packaging and shipment of irradiated materials (on-site & off-site)
- Examination and testing activities such as metrology; metallographic sample preparation by sectioning, grinding, and polishing; optical and electron microscopy; gamma spectrometry; and other physical and mechanical properties evaluations as appropriate to the experimental objectives of a particular program

Specifications	
Hot Cells	6 hot cells SEM cell Microprobe Microsphere gamma
Viewing Window	Lead glass and mineral oil
Cell Construction	High-density concrete used for front, rear, and top shielding
Ventilation	HEPA filtered
Services Available	Process and service compressed gases, air, demineralized water, process water, recirculating heating and cooling water, steam, vacuum, and electrical services
Intercell movement	Two small diameter horizontal transfer stations are used for small objects while larger items are transferred through the shielded airlock door system
Material Handling	Master-slave manipulators

Sample Preparation Laboratory

Post-irradiation Examination

The Sample Preparation Laboratory is under construction at the Materials and Fuels Complex. The facility is designed for high-throughput characterization of gamma-emitting materials.

Idaho National Laboratory's Sample Preparation Laboratory (SPL) is designed as a Hazard Category 3 facility to serve as a national center for accelerated research, development, and qualification of nuclear materials. SPL's nuclear materials analysis capabilities will increase the understanding of nuclear materials, leading to advancements that will extend the life of the current fleet of reactors and development and deployment of materials for advanced reactors.

Construction of SPL began in June 2020.

SPL will play an important role in America's energy future. Extending the life of the current reactor fleet requires a deeper understanding of the degradation mechanisms and service life of the in-core structural materials used in these systems. Likewise, the economic and safety performance of advanced reactor technologies relies on the development and qualification of improved fuel cladding and structural materials. The national infrastructure for mechanical testing, detailed microstructural examination, and surface characterization of high-activity irradiated material in the U.S. is limited. This limited infrastructure constrains critical material development and qualification activities; SPL is designed to fill this gap.

SPL provides dedicated high-throughput sample preparation, mechanical testing, surface science, and microstructural analysis that address these limitations.

Its automated operations in fourth-generation shielded cells will efficiently generate information on material mechanical performance, microstructure, and environmental effects over eight orders in length scales. Coupled with modeling and simulation, the increased quality and volume of information available will greatly reduce the time required for development of new radiation-resistant materials. SPL is designed as a user facility to allow visiting researchers access to scientific instruments while minimizing exposure to radiological environments. Instruments are operated from control consoles outside of facility radiological boundaries or remotely from the Research Collaboration Building on the MFC site.

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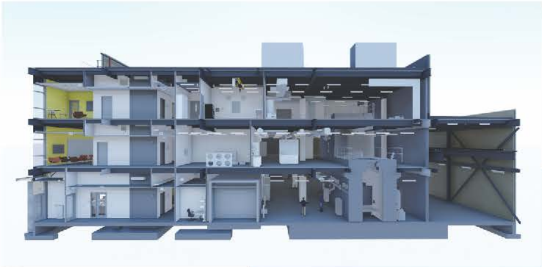

Construction of the Sample Preparation Laboratory began in June 2020.

The capability to handle medium-sized and small casks typically used for material shipments allows direct material shipment to and from other sites, removing a significant barrier to cooperation with industry, universities, and other U.S. and international laboratories. Electrical Discharge (EDM) and conventional machining allow fabrication of samples appropriate for testing from larger sections of structural materials retrieved from operating or decommissioned reactors. These materials can then be reinserted into INL's Advanced Test Reactor to further accumulate irradiation damage at an accelerated rate, allowing accurate predictions of material properties.

BASIC CAPABILITIES

- Hazard Category 3 nuclear facility
- Fatigue and fracture toughness testing
- Tensile testing at ambient and elevated temperature
- Charpy impact testing
- X-ray photoelectron spectroscopy (XPS)
- Electron microscopy
- Hardness testing
- Shielded x-ray diffraction
- High throughput sample preparation Receipt of mediumsized casks (BRR, NRBK, GE-100, etc.)
- Automated sample transfers to instruments
- Heat treatment of irradiated materials
- Receipt of medium-sized casks (BRR, NRBK, GE-100, etc.)
- Remote operation of instruments
- Long-term storage of critical material samples
- Research space for user-defined instruments

PROJECT STATUS

- DOE Mission Need Approval – June 2015
- Critical Decision (CD)-1, Approval of Alternative Analysis and Cost Range – September 2016
- Completion of Facility Design – October 2018
- CD-2/3, Approve Performance Baseline and Start of Construction – January 2020
- Construction Start – June 2020
- Construction Completion – 3Q FY 2023 (forecast)
- Start of Operations – 2Q FY 2025 (forecast)

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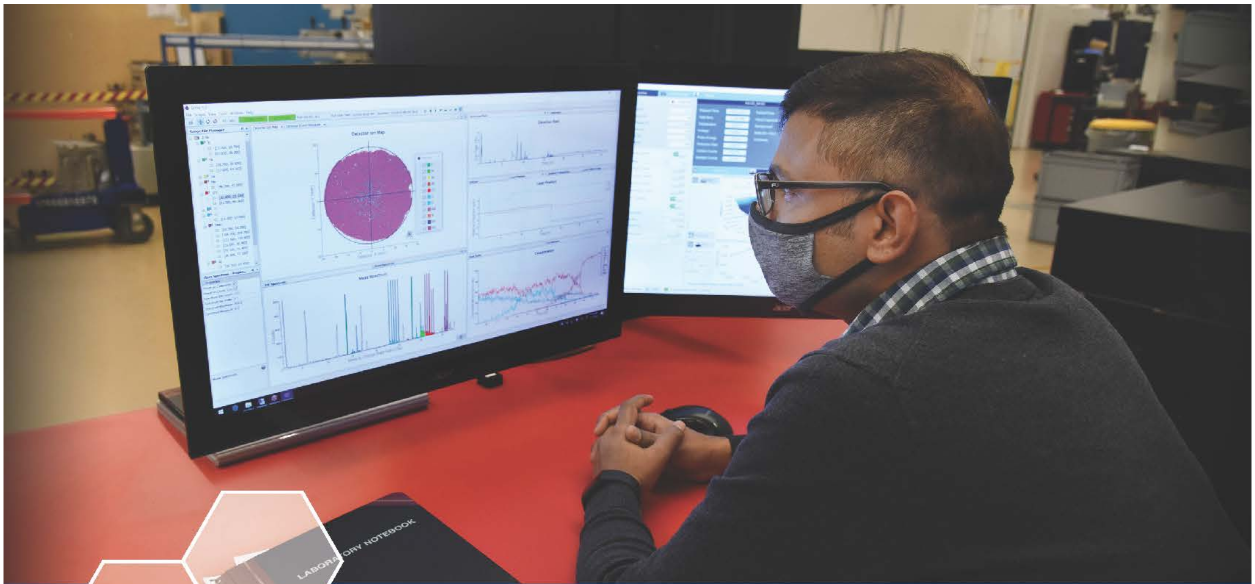
21-50083_SPL_R3 (Updated: 2022)



Irradiated Materials Characterization Laboratory

Advanced Post-Irradiation Examination

The Irradiated Materials Characterization Laboratory is home to a variety of high-end instruments that allow researchers to study irradiated fuels and materials at the micro, nano and atomic levels, which is where irradiation damage occurs.

The Irradiated Materials Characterization Laboratory (IMCL) is a unique, 12,000-square-foot facility located at Idaho National Laboratory's Materials and Fuels Complex. The hazard category 2 facility incorporates many features designed to allow researchers to prepare and conduct microstructural-level investigations on irradiated fuel safely and efficiently.

IMCL focuses on microstructural, microchemical, and micromechanical analysis and thermophysical characterization of irradiated nuclear fuels and materials. IMCL's unique design incorporates advanced characterization instruments that are sensitive to vibration, temperature, and electromagnetic interference into modular radiological shielding and confinement systems. The shielded instruments allow characterization of highly radioactive fuels and materials at the micro, nano, and atomic levels, the scale at which irradiation damage processes occur.

Enabled by its modular design, IMCL will continue to evolve and improve capability throughout its 40-year design life to meet the national and international user demand for high-end characterization instruments for the study of nuclear fuel and materials.

Combined with INL's advanced computer modeling techniques, this understanding will enable advanced fuel designs, and reduce the time needed for fuel development and licensing.

BASIC CAPABILITIES:

- Preparation of high-activity samples
- Optical microscopy
- Electron probe microanalysis (EPMA)
- Dual-beam focused ion beam (FIB)
- Transmission electron microscopy (TEM)
- Local electrode atom probe (LEAP)
- Scanning electron microscopy (SEM)
- Measurement of material physical and thermal properties
- X-ray microscopy (XRM)
- X-ray diffractometer (XRD)

Idaho National Laboratory

KEY CAPABILITIES/INSTRUMENTS:

Application	Instrument	Capabilities	Configuration
Sample Preparation	SSPA - Shielded sample preparation area	Optical microscope, polishing and grinding, sample cutting in hot cell, glovebox, and hood	Shielded
Advanced Microscopy, Microchemistry, Micromechanical Testing	SEM - JEOL 7600	High-resolution scanning electron microscope (SEM) equipped with electron back-scatter diffraction, energy dispersive X-ray spectroscopy (EDS) and wavelength dispersive spectroscopy (WDS) detectors	Benchtop
	EPMA - Shielded Cameca SX100R	Quantitative compositional analysis of solid specimens on a micrometer spatial scale. Detectors and electronics are shielded to 3 Ci of 137 Cs to allow for trace element detection. Measures elements from B to Cm.	Shielded
	STEM - FEI Titan Scanning Transmission Electron Microscope	Equipped with probe corrector, super-X EDS, electron energy loss spectroscopy (EELS), DENSolutions D6 heating holder (1573 K), tomography holders, vacuum transfer holder, Hysitron PI-95 PicoIndenter	Benchtop
	APT - LEAP 5000 Atom Probe	3D imaging and chemical analysis at sub-nanometer scale	Benchtop
	FIB - FEI Quanta 3D FEG Focus Ion Beam	Preparation of minute samples for TEM, APT, and micromechanical testing	Shielded
	FIB - Thermo G3 Plasma Focus Ion Beam	Preparation of block samples for rapid 3D reconstruction, micromechanical testing, and microscale thermal property testing	Shielded
	FIB - Thermo G4 Helios Hydra Plasma Focus Ion Beam with TOF-SIMS	Equipped with secondary ion mass spectrometer (SIMS), EDS, and electron backscatter diffraction (EBSD) for sample preparation, imaging, microstructural, and chemical analysis	Benchtop
Thermophysical property measurement	LFA - Netzsch LFA 427 laser flash analyzer	Thermal diffusivity, contact resistance from room temperature to 2000 C, specific heat, thermal conductivity (under development)	Shielded
	TGA/MS - Simultaneous TGA/DSC+MS Netzsch STA 409C Skimmer	Measure specific heat, phase transformation temperatures and enthalpies, fission off-gas composition, mass change from room temperature to 2000 C	Shielded
	TCM - Thermal conductivity microscope	Spatial resolved thermal diffusivity, thermal conductivity with a spatial resolution of 50 µm from room temperature to 300 C	Shielded
	PPMS - Quantum Design Physical Property Measurement System	Electrical, thermal, thermodynamic and magnetic property measurement at temperatures from 1.8 K to 400 K and magnetic field range 0-9 T	Benchtop
Structure analysis and tomography	XRD - PANalytical powder X-ray diffractometer	Bulk X-ray diffraction with heating stage	Benchtop
	XRM - ZEISS Xradia 520 Versa X-ray microscope	Nondestructive 3D imaging of materials over 4 orders of magnitude in length scales (0.1-100 cm)	Benchtop
Mechanical testing	Mini-tensile tester	Tensile testing with digital image correlation (DIC)	Shielded

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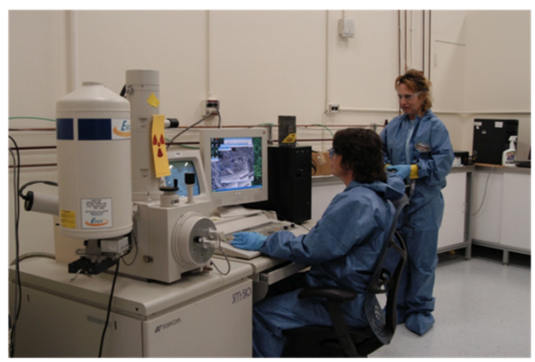
21-50083_IMCL_R2 (Updated: 2021)

Description

The LAMDA facility is a multipurpose laboratory for evaluation of materials with low radiological threat without the need for remote manipulation. The radiological threat is defined both by the potential for absorbed dose and the possibility of radiological contamination. All materials to be observed in the facility are accepted from one of the ONRL hot-cells with the radiological hazards previously identified. Once in the facility, they undergo a further radiological screening and decontamination.

Radiological area in the LAMDA lab

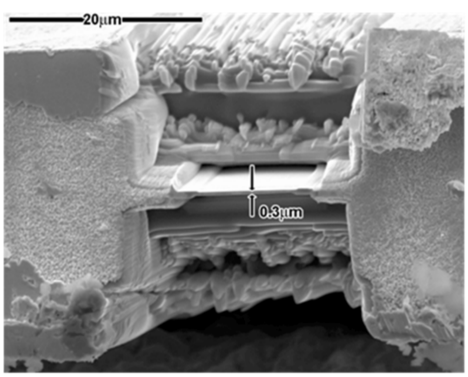
The LAMDA facility includes 5 laboratories with about 2 dozen specialized instruments—physical and mechanical properties. The preparation facilities for ultra-small samples allows researchers to leverage cutting-edge characterization equipment in the “open lab.” The use of small specimens is a key factor for the LAMDA capabilities. The dedicated LAMDA equipment, along with the “open lab” analytical capabilities, provides an unparalleled resource for radiation materials science.



Microscopy lab for examination of irradiated samples

Applications

- Examination of low activation materials



TEM sample prepared by focused ion-beam milling

Oak Ridge National Laboratory

An analyst works with the gas manifold in a laboratory.

Analytical Research Laboratories

The Analytical Research Laboratories (ARL) at Idaho National Laboratory's Materials and Fuels Complex provide the chemical, radiochemical, physical and analytical data needed for various research and engineering development programs, and for applied research and engineering development activities supporting advanced nuclear fuel design, waste management, environmental and other INL programs.

The laboratories receive samples from across INL, as well as outside entities. These samples include irradiated and unirradiated fuels and materials, and samples needed for testing related to material accountability, radiation monitoring, process monitoring and environmental monitoring. The laboratories also support engineering development activities such as the preparation of samples for irradiation testing.

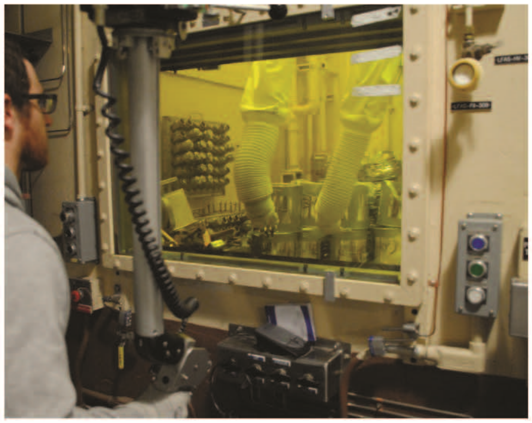
The main features and equipment in the labs' A-wing include six interconnected hot cells, gloveboxes, a chemistry laboratory, a 5-ton overhead bridge crane and other cask handling equipment. The primary features of the B-wing include state-of-the-art analytical instrumentation, general chemistry laboratories, air and inert atmosphere gloveboxes, fume hoods, counting rooms and assay equipment.

The ARL maintain equipment typical of a standard chemistry laboratory, including furnaces, X-ray diffractometers and equipment to test fundamental physical properties. The laboratories also host several unique fuel fabrication capabilities in the Casting Laboratory, including the INL-designed glovebox advanced casting system (GACS) furnace. This furnace casts metallic fuel samples containing transuranic elements with greater efficiency and less waste than previous designs.

BASIC CAPABILITIES:

- Analysis and characterization of as-built and post-irradiated nuclear fuels and reactor components.
- Analysis of hazardous, mixed, or highly radioactive waste, other waste forms, and samples.
- Analytical chemistry support for nuclear forensics.
- Determination of stable and radioisotopic content in a variety of matrices.
- Radioisotope separation.
- Characterization of engineered materials.
- Expertise in characterization of engineered materials and the nuclear fuel life cycle.

Idaho National Laboratory



An analyst receives samples in hot cell 1.

TECHNICAL INFORMATION

The mission of the ARL is to perform chemical, radiochemical and physical measurements, provide nondestructive analysis measurements and conduct applied research and engineering development activities that support advanced reactor design, waste management, environmental and other programs at MFC and INL. Our mission is accomplished through a broad range of analytical chemistry capabilities.

The ARL receive a variety of samples from across INL, as well as from outside entities. Sample types include liquids, solids, gases and irradiated/unirradiated fuels/materials related to research and development activities, material accountability, radiation monitoring, process monitoring and environmental monitoring. The labs also support engineering development and testing activities by creating unique standards and preparing samples for irradiation testing. ARL scientists possess a broad range of expertise as outlined below.

KEY EXPERTISE:

- Analysis and characterization of as-built and post-irradiated nuclear fuels, materials and reactor components
- Analysis of hazardous, mixed, or highly radioactive wastes, other waste forms and samples
- Analytical chemistry support for nuclear forensics.
- Burnup analyses.
- Determination of stable and radioisotopic content in a variety of matrices.
- Elemental/isotopic separation.
- Characterization of engineered materials and the nuclear fuel life cycle.
- Method development/experimental design.

KEY CAPABILITIES/ INSTRUMENTATION:

- Six interconnected air atmosphere hot cells
- Gloveboxes
  - » Hot cell #1
  - » Shielded ICP-OES at hot cell #6
  - » Special projects
  - » Radiochemistry
  - » Waste form testing
  - » Casting lab
  - » Wet prep
  - » Fresh fuels
  - » CNO (carbon/nitrogen/oxygen)
- Fume hoods
- Counting laboratories
  - » Gamma
  - » Alpha spec
  - » Gas flow proportional counters
  - » Liquid scintillation
  - » Low background counting laboratory in pre-WWII steel vault using low-background concrete
- Gas chromatograph
- Gas pressurized extraction chromatography (GPEC) (manual and automatic)
- Gas mass spectrometer (portable)
- High resolution multi-collector fission gas mass spectrometer (MC-GMS) (2022)
- Mass spectrometers
  - » Inductively coupled plasma (Quad-ICP-MS)
  - » High-resolution inductively coupled plasma (HR-ICP-MS)
  - » Multi-collector inductively coupled plasma (MC-ICP-MS)
  - » Inductively coupled plasma time of flight (ICP-TOF)
  - » Thermal ionization mass spectrometer (TIMS)
- Elemental analysis
  - » Optical emission (ICP-OES)
  - » Femtosecond laser-induced breakdown spectrometer (fs-LIBS)
- Light element (CSONH) combustion and inert fusion analyzers
- Capillary electrophoresis (CE)
- High performance liquid chromatography (HPLC)
- X-ray fluorescence (XRF)
- Microwave-assisted digestor
- 3D laser scanning confocal microscope
- 4K digital microscope
- Hot cell particle picking microscope
- Hot cell entrained gas collector
- Mass separator (rad and non-rad)
- Non-destructive barrel scanner
- Hot uniaxial press (HUP), muffle, well, and tube furnaces
- Glovebox advanced casting system (GACS) furnace
- Wet chemistry laboratories

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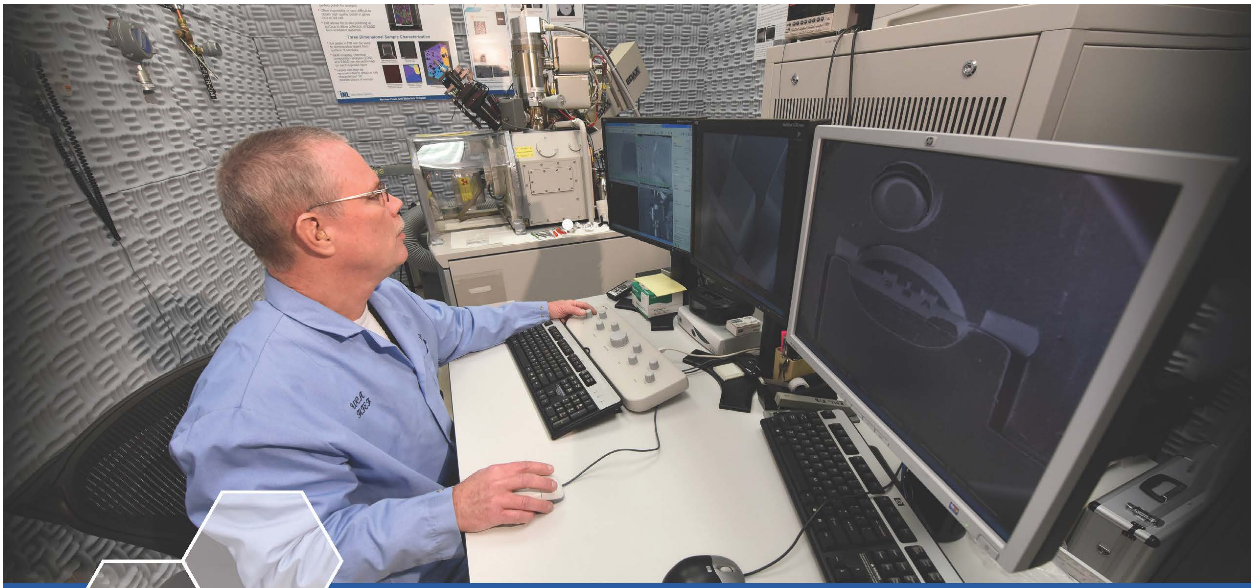
21-50083_AL_R1 (Updated: 2021)



Electron Microscopy Laboratory

Post-irradiation Examination

The Electron Microscopy Laboratory (EML) is a user facility dedicated to materials characterization, using primarily electron and optical microscopy tools. Sample preparation capabilities for radioactive materials ensure that high-quality samples are available for characterization.

BASIC CAPABILITIES:

- Scanning electron microscopy (SEM) with microchemical analysis and grain-orientation imaging
- Dual-beam focused ion beam (FIB) with microchemical analysis and orientation imaging
- Transmission electron microscopy (TEM) with microchemical analysis
- Optical microscopy
- Microhardness testing
- Precision ion polishing and coating systems
- Sample preparation of irradiated metals, ceramics, and small quantities of irradiated fuel for examination in gloveboxes and chemical hoods

KEY INSTRUMENTS:

- JEOL JSM-7000f SEM with energy dispersive X-ray spectroscopy (EDS), wavelength dispersive spectroscopy (WDS) and electron backscatter diffraction (EBSD) detectors
- Gatan precision ion polishing systems (PIPS-2)
- Gatan precision etching and coating system (PECS)
- LYRA 3GM is a FIB/SEM workstation from TESCAN. The system is equipped with Aztec Oxford Instruments suite for EDS/EBSD characterization, LEICA cryo-stage, and Alemnis nanomechanical testing. The microscope has the Omniprobe200 manipulator for in-situ sample lift out, and two gas injection systems for carbon and platinum deposition. The integration of complementary analytical tools will allow researchers to characterize complex samples and rapidly solve analytical problems.
- FEI Talos F200x S/TEM equipped with Super-X EDS, Gatan Quantum electron energy loss spectroscopy (EELS) and ASTAR/TOPSPIN systems, enabling high-resolution/high-speed imaging and chemical analysis and grain orientation and strain mapping

Researchers at the Electron Microscopy Laboratory use electron and optical microscopes to characterize materials as well as prepare high quality samples from radioactive materials.

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Idaho National Laboratory

Description

The Irradiated Material Examination and Testing (IMET) Facility was designed and built as a hot cell facility. It is a two-story block and brick structure with a two-story high bay that houses six heavily shielded cells and an array of sixty shielded storage wells. It includes the Specimen Prep Lab (SPL) with its associated laboratory hood and glove boxes, an Operating Area, where the control and monitoring instruments supporting the in-cell test equipment are staged, a utility corridor, a hot equipment storage area, a tank vault room, office space, a trucking area with access to the high bay, and an outside steel building for storage. The tests and examinations are conducted in six examination "hot" cells and/or in a laboratory hood or modified glove boxes in the SPL.

Applications

- Physical and mechanical properties testing
- Examination of irradiated materials
- Irradiated specimen storage
- Sample preparation

Specifications	
Hot Cells	6 hot cells
Viewing Window	Lead glass and mineral oil
Cell Construction	High-density concrete used for front, rear, and top shielding
Ventilation	HEPA filtered
Services Available	Process and service compressed gases, air, demineralized water, process water, recirculating cooling water, recirculating heating water, steam, vacuum, and electrical services
Intercell movement	Intercell conveyor system
Material Handling	Master-slave manipulators

Experimental Fuels Facility

Fuel Fabrication, Process Development

EFF includes uranium metal forming equipment, including a computer numerical control (CNC) lathe, electrical discharge machine, a cold rolling mill, and other fabrication equipment, which enable the creation of virtually any fuel type.

The Experimental Fuels Facility (EFF) is a 5,000-square-foot nuclear fuel fabrication facility at Idaho National Laboratory's Materials and Fuels Complex. EFF houses a wide range of fuel fabrication and material handling capabilities. Established in 2012, EFF supports INL's mission as the lead nuclear energy research lab for the nation.

Equipment and processes in EFF support customers in DOE's Office of Nuclear Energy and private industry partners. EFF hosts a wide range of INL's new lab-scale capabilities for supporting the nation's need to develop even safer, more reliable nuclear fuels.

Basic uses of EFF include uranium and uranium alloy casting and extrusion, processing uranium metal and ceramics at all enrichments, fabrication and handling of alloys and powders, and a machine shop with radiological and non-radiological areas.

KEY EQUIPMENT:

- 4 fume hoods (3 radiological)
- Inert atmosphere uranium processing glovebox line for fabrication and handling of alloys and powders
- High-temperature applications (arc melting furnace, molten salt bath, billet casting furnace, high-temperature annealing furnace)
- Cold crucible gas atomizer with a 5kg capacity able to process uranium alloys
- Fuel experiment assembly equipment (annealing quench furnace, sodium glovebox, sodium settling furnace, orbital capsule, and cladding welding)
- Various other mills, presses, and other fabrication capabilities to support advanced fuels development
- Machine shop for machining encapsulated fuel components
- 150-ton extrusion press system (including a molten salt furnace and a straightener/draw bench)

Idaho National Laboratory

The Experimental Fuels Facility supports customers in the Department of Energy's Office of Nuclear Energy and private industry partners.

The Experimental Fuels Facility (EFF) houses a wide range of fuel fabrication capabilities, supporting customers in the Department of Energy's Office of Nuclear Energy and private industry partners through Idaho National Laboratory's cooperative research & development program.

BASIC CAPABILITIES:

- Uranium and uranium-alloy processing (all enrichments):
- Alloying
- Casting
- Extrusion
- Atomization
- Machining
- Inert-atmosphere uranium processing glovebox line for fabrication and handling of alloys and powders
- Multiple furnaces with temperature capability up to 2,000°C in vacuum, argon, air, hydrogen and nitrogen atmospheres
- Machine shop with both radiological and non-radiological areas to support advanced fuel development

KEY INSTRUMENTS:

- Radiological fume hoods (3)
- Inert-atmosphere, radiological gloveboxes (3)
- Powder metallurgy process equipment
- Fuel experiment assembly equipment
- Annealing quench furnace
- Sodium glovebox
- Sodium-settling furnace
- Orbital capsule and cladding welding
- Uranium forming and machining
- Computer numerical control (CNC) lathes and mills
- Electrical discharge machine
- Centerless grinder
- Rolling mill
- Shears and punches
- 150-ton extrusion press
- Hydraulic straightener/ draw bench
- Gas atomizer
- Arc-melting furnaces
- Molten salt bath
- Billet-casting furnace
- High-temperature annealing furnace

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21-50083_EFF_R0 (Updated: 2021)

Fuel Manufacturing Facility

Fuel Fabrication, Nuclear Material Management

Arc melting in the Advanced Fuel Cycle Initiative (AFCI) glovebox supports fabrication of experiments for irradiation at reactors such as the Advanced Test Reactor.

The Fuel Manufacturing Facility (FMF) is a nuclear facility that consists of multiple workrooms and a material storage vault. This facility complements a host of capabilities within the Materials and Fuels Complex at Idaho National Laboratory, the nation's lead nuclear energy research lab.

FMF was constructed in 1986 for the purpose of housing binary (i.e., uranium and zirconium) fuel and its associated equipment to fabricate the driver fuel for the Experimental Breeder Reactor-II (EBR-II). With the shutdown of the EBR-II reactor, this equipment was removed and the focus at FMF transitioned to research and development (R&D) of transuranic metallic and ceramic fuels. Additionally, the material storage vault contains and supplies various INL and off-site facilities with feedstock materials

KEY EQUIPMENT/ CAPABILITIES:

4 inert gloveboxes

- Advanced Fuel Cycle Initiative (AFCI) glovebox
  - » Provides the capabilities to develop transuranic metallic and ceramic fuel experiments for irradiation
  - » Feedstock production/ purification
  - » Characterization sample fabrication
  - » Equipment includes:
    - Arc melter
    - Distillation/ tube furnace
    - Sintering furnace
    - Orbital welder
    - Ceramic powder mixing/pressing equipment
- Neptunium repackaging glovebox (NRG):
  - » Provides the capability to recertify neptunium packages for transport to other DOE facilities
  - » Supports material inspection/inventory
- Special nuclear materials (SNM) glovebox:
  - » Provides the capability for legacy uranium material recovery for reuse
  - » Supports uranium material inspection/ inventory/breakouts
  - » Uranium roasting and casting capabilities

Material processing in the special nuclear material (SNM) glovebox is part of an ongoing material disposition program that supports work at INL and other DOE labs.

The Fuel Manufacturing Facility (FMF) is a hazard category 2 nuclear facility that consists of multiple workrooms and a material storage vault. The workrooms house the equipment utilized to support multiscale fuel development. The vault contains and supplies the feedstock materials used for numerous programs in multiple facilities at MFC.

BASIC CAPABILITIES:

- Transuranic metallic and ceramic fuels development
- Transuranic and enriched-uranium materials storage
- Transuranic and enriched-uranium feedstock production, purification and breakouts

KEY INSTRUMENTS:

- Gloveboxes:
  - » Advanced Fuel Cycle Initiative glovebox (AFCI)
    - Experiment assembly
    - Ceramic processing
    - Metal processing
    - Feedstock distillation/ purification
  - » Special nuclear materials (SNM) glovebox
    - Roasting
    - Casting
    - Feedstock breakout
  - » Neptunium repackaging glovebox (NRG)
    - Recertification of neptunium packages
  - » Transuranic breakout glovebox (TBG)
- Radiography
- Vault storage
- Active-well neutron center
- Arc-melting furnace
- Distillation furnace
- Sintering furnace

- Transuranic breakout glovebox (TBG)
  - » Supports transuranic material inspection/ inventory/breakouts

Radiography

- Provides the capability for verification of experiment fabrication requirements such as fuel placement and rodlet/capsule welding

Vault storage

- Receipt and storage of programmatic materials

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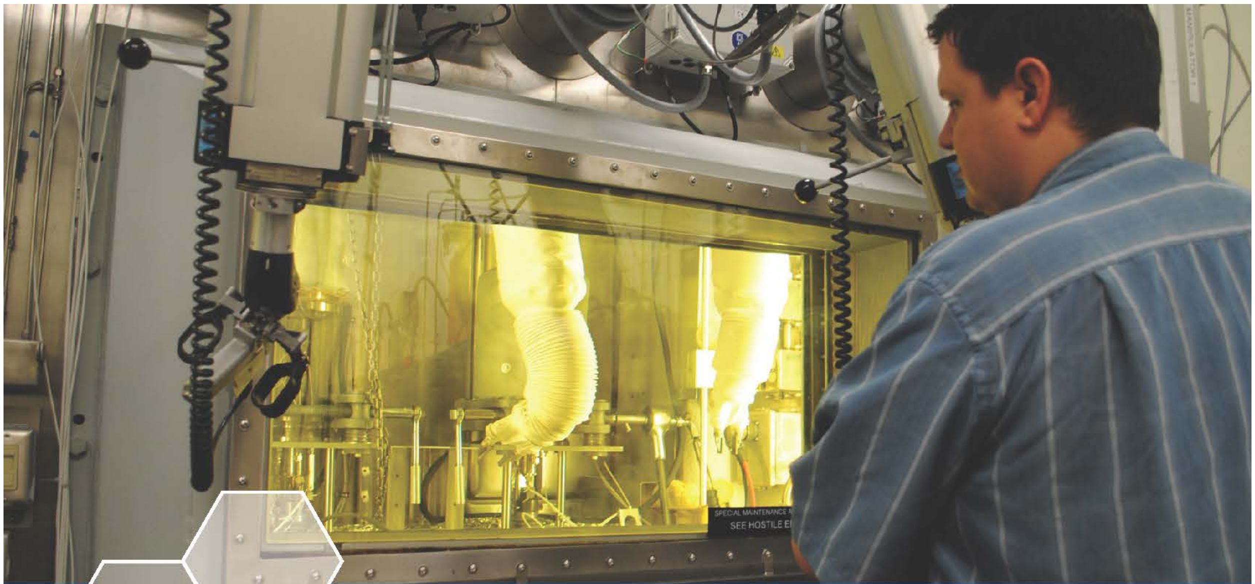
21-50083_FMF_R1 (Updated: 2021)



Fuels and Applied Science Building

Fuel Fabrication, Irradiation, Characterization, Post-irradiation Examination, Process Development

The Irradiation-Assisted Stress Corrosion Cracking hot cells are located in FASB's west room.

The Fuels and Applied Science Building (FASB) is a radiological facility that houses small hot cells, gloveboxes, hoods, and a variety of equipment that supports nuclear energy research and development. This facility is a key part of the fuel development mission of the Materials and Fuels Complex at Idaho National Laboratory. FASB's capabilities include research and development related to nuclear fuel fabrication, used fuel treatment options, nuclear waste management, and other scientific activities.

The FASB west room contains inert atmosphere gloveboxes used for development of various nuclear fuels, treating waste from glovebox operations, working with corrosive materials and testing equipment that will be used in other facilities. A set of small hot cells houses an irradiation-assisted stress corrosion cracking system used for evaluating structural material for nuclear light water reactor life extension.

The east room contains material processing areas, a thermal properties laboratory, a sample preparation area and a characterization area that contains electron and optical microscopes and X-ray diffraction X-ray fluorescence equipment.

KEY CAPABILITIES:

- Irradiation-assisted stress corrosion cracking hot cells
- Two inert fuel development gloveboxes
- Pyrochemistry glovebox
- 3 radiological hoods and one non-radiological hood
- Thermal properties characterization instruments (laser flash, dilatometer, differential scanning calorimeter)
- Cobalt-60 gamma irradiator
- Lab-scale fabrication equipment (hot isostatic press, arc melting furnace)
- Metal and ceramic powder processing equipment (atomizer, milling, mixing, pressing/sintering)
- Numerous heat treating and sintering furnaces

The Fuels and Applied Science Building (FASB) is a radiological facility that has broad capability in fuel fabrication and characterization in support of nuclear energy research and development.

Idaho National Laboratory

In addition to the Gamma Irradiation Test Loop shown here, FASB contains inert atmosphere gloveboxes used for fuel development, treating waste from other glovebox operations, and testing equipment that will be used in other facilities.

The building houses laboratory scale fuel fabrication capability for both dispersion and foil bearing nuclear fuel plates, a pyrochemistry glovebox housing a laboratory scale electrorefiner and other furnaces to perform separations experiments. It also has a set of hot cells, including one that houses an irradiation assisted stress corrosion cracking system that measures corrosion and crack propagation in nuclear reactor structural materials as part of the light water reactor life extension program.

The building also contains a sample preparation and characterization suite with optical and electron microscopes, thermal properties and other characterization equipment.

BASIC CAPABILITIES:

- Uranium fuel development at all enrichments
- Materials characterization
- IASCC testing of irradiated materials
- Multiple uranium gloveboxes to support fuel development
- Cobalt-60 gamma irradiator with a radiolysis/hydrolysis test loop

KEY INSTRUMENTS:

- Two inert fuel fabrication gloveboxes
  - » Arc-melting furnace with casting capability
  - » Hydraulic press
  - » Gram-scale atomizer
  - » Hydriding/nitriding apparatus
  - » Inert box welding station
- Inert pyrochemistry glovebox
  - » Molten salt electrorefiner
  - » Oxide reduction furnace
  - » Sodium distillation furnace
  - » Fuel form casting
  - » Multi function furnace
- Three radiological fume hoods
- Irradiation assisted stress corrosion cracking
  - » Decontamination station
  - » In-cell imaging microscope
  - » Pressurized water reactor testing rig
  - » Boiling water reactor testing rig
- Fabrication equipment
  - » Hot isostatic press
  - » Hot rolling mill
  - » Multiple furnaces
- Sample preparation and characterization
  - » High- and low-speed saws
  - » Auto polisher
  - » Three scanning electron microscopes
  - » X-ray diffractometer
  - » X-ray fluorescence
  - » Optical microscopes
  - » Particle-size analysis
  - » Microhardness testing
  - » Density measurement (helium pycnometer)
  - » Differential scanning calorimeter
  - » Dilatometer
  - » Laser-flash thermal diffusivity
  - » Positron-annihilation spectroscopy
  - » Tensile, compression and bend testing
  - » Ultrasonic testing
- Cobalt-60 gamma irradiator
- Solvent test loop

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21-50083_FASB_R0 (Updated: 2021)

REDC
Radiochemical Engineering Development Center

Description

The Radiochemical Engineering Development Center (REDC) is comprised of two facilities – Building 7920 and Building 7930.

Building 7920 was designed and built as a hot cell facility that also houses glove box laboratories for radiological work, laboratories for nonradiological work, and a chemical make up area. Building 7920 is classified as a Category 2 nuclear facility. The building is a two-level structure containing heavily shielded hot cells, hot cell support areas, laboratories, a high bay area, and an office wing.

Building 7930 was designed and built as a hot cell facility with glove box laboratory capabilities for radiological work and chemical makeup laboratories. Building 7930 is classified as a Category 2 nuclear facility. The building is a three-level structure with a basement containing heavily shielded hot cells, hot cell support areas, laboratories, a high bay area, and an office wing.

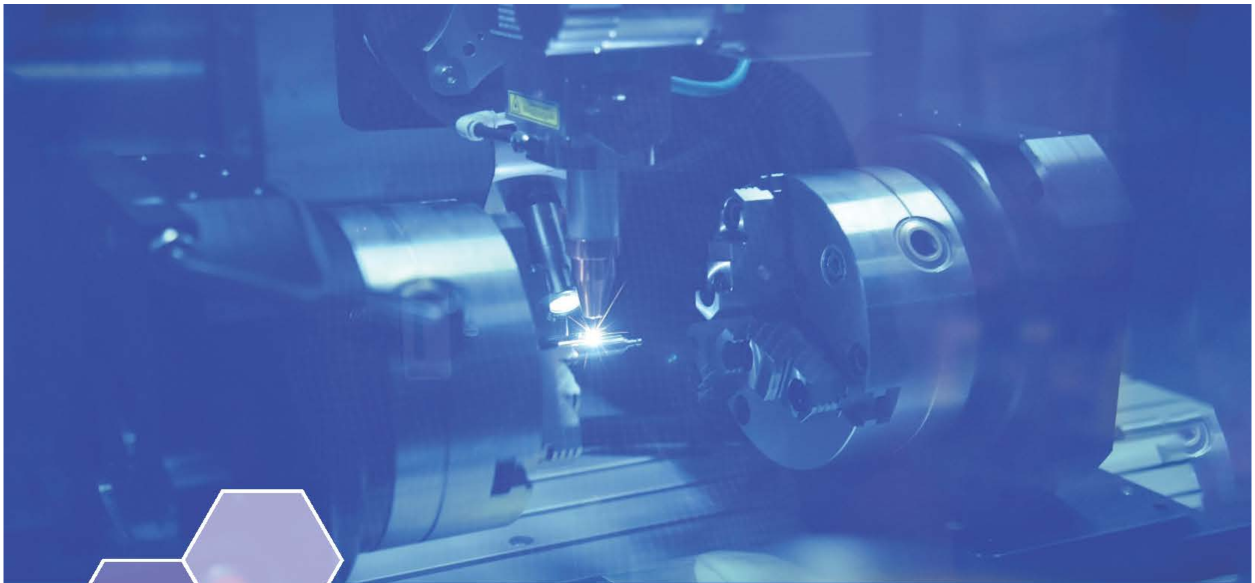
Both facilities are served by many of the same utility supply systems and support organizations that serve the Melton Valley Area.

Applications

- Transuranium element product recovery
- Cf, Bk, Es, and Fm production and research
- Am/Cm separations and purification processing
- Target design and fabrication
- Research and development of miscellaneous radiochemical processing operations
- Distribution of select radioisotopes throughout the world

Specifications	
Hot Cells	7920: 9 hot cells with associated tanks 7930: 7 hot cells
Viewing Window	7920: Lead glass and mineral oil 7930: Lead glass with zinc bromide
Cell Construction	High-density concrete used for front, rear, and top shielding
Ventilation	All primary and secondary confinement systems exhaust streams are HEPA filtered
Services Available	Process and service compressed gases, air, demineralized water, process water, recirculating heating and cooling water, steam, vacuum, and electrical services
Intercell movement	Pneumatic transfer system between facilities 7920: Pneumatic motor driven intercell conveyer system 7930: Pneumatic transfer tube system
Material Handling	Master-slave manipulators and glove boxes

Oak Ridge National Laboratory



Advanced Fuels Facility

Fuel and Material Fabrication

The laser welder allows for high precision closure welding on materials that are difficult to weld.

The Advanced Fuels Facility (AFF) is a 4,920 square-foot facility located at Idaho National Laboratory's Materials and Fuels Complex (MFC). This less than hazard category 3 radiological facility has been repurposed for nuclear fuel fabrication. AFF features a range of material handling and fuel fabrication capabilities used for advanced manufacturing processes. It supports INL's mission as the nation's lead nuclear energy lab.

AFF's operations involve research and development primarily with uranium-bearing fuels and associated surrogate materials to increase MFC's advanced fuel manufacturing capabilities.

Equipment and processes in AFF support customers in the Department of Energy's Office of Nuclear Energy and private industry partners. AFF hosts a wide range of INL's new lab-scale capabilities for supporting the nation's need to develop advanced nuclear fuels.

ENGINEERED SPACES

AFF is a radiological space where uranium nuclear fuel is routinely handled. This material is safely contained in gloveboxes, hoods, and other contamination areas where the equipment and processes are protected from contamination spread by engineered systems. Inert gloveboxes are also employed to prevent metal fuels from oxidizing in air. The equipment includes:

- 2 fume hoods, one radiological
- Inert radiological gloveboxes
  - Experiment vehicle assembly glovebox to provide a large inert volume for experiment assembly. It can maintain an atmosphere of helium, argon, and helium/argon mixtures to aid in targeting specific irradiation conditions.
  - Spark plasma sintering glovebox
  - Laser welding glovebox containing a 700W laser and capable of helium, argon, or mixed helium/argon environments.
  - Advanced manufacturing machine glovebox housing the LENS laser 3-D printer
  - Advanced manufacturing feedstock glovebox which houses powder handling and powder processing equipment
- Inert, non-radiological glovebox
  - Mockup glovebox providing a test bed to evaluate equipment prior to installation in a radiological glovebox

The SPS glovebox provides the capability to press radiological and nonradiological powder compacts while passing electric current through the material being compacted.

ADVANCED MANUFACTURING

AFF employs new fabrication technology for nuclear fuel and other nuclear components. This results in materials that have properties and geometries that cannot be achieved through traditional fabrication methods. The manufacturing is done through advanced powder metallurgy in the case of the SPS and the dry bag isostatic press and through 3D printing with the various systems in the facility. Key equipment includes:

- Spark plasma sintering (SPS)/field assisted sintering (FAS) system
- Dry bag isostatic press system to manufacture unique material shapes from constituent powders using a high-pressure fluid.
- Feedstock preparation and processing
- LENS laser 3D printer
- Direct energy deposition (DED) additive manufacturing system
- Digital light processing (DLP) additive manufacturing system

EXPERIMENT ASSEMBLY

AFF is also used to assemble irradiation experiments that will be tested in various nuclear reactors. The experiments range from rodlet specimens consisting of fuel and cladding to capsule assemblies which often integrate a suite of instrumentation and fuel specimens of various types and geometries. This involves tightly controlled tolerancing, complex assembly of the sample and the various instrumentation needed for monitoring, targeted atmospheric control, and novel welding methods to ensure proper closure and specimen atmosphere. The key equipment supporting this work includes:

- Laser welding system for fuel cladding and irradiation test vehicles.
- Micro-TIG welding system for assembly of delicate capsule instrumentation
- Leak testing equipment to support helium leak checks of specimens up to 7 ft long and 5.5" in diameter
- Weld under pressure system (WUPS) used to seal-weld rodlet and capsule specimens pressurized up to 500psig with any inert gas.
- Capsule assembly pressurization system (CAPS) used to pressurize experiment capsules through a one-way valve integral to experiment assemblies
- Custom lathe welder for rodlet instrumentation and development of techniques applicable to pre-irradiated fuel specimens.

OTHER EQUIPMENT/ PROCESSES

- Small metallographic station for optical analysis
  - » Medium speed saw
  - » Hot mount press
  - » Rotary polisher
  - » Leica optical microscope for examination of metallography mounts or other specimens
- Plunge EDM for processing fuel specimens requiring a high degree of precision.
- Czochralski method crystal puller to obtain pure, single crystals for scientific analysis

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21-00083_AFF_R0 (Updated: 2021)

Engineering Development Laboratory

Fabrication, Assembly, and Testing of Research, Development, and Production Equipment

The Engineering Development Laboratory is used for fabrication, assembly, mock-up and testing for the Space Nuclear Power & Isotope Technologies Division.

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The Engineering Development Laboratory (EDL) is used to fabricate, assemble, mock up and test various research, development and production equipment. The majority of work conducted in EDL is for the Space Nuclear Power & Isotope Technologies Division. The EDL is a non-nuclear facility, managed as a laboratory space in accordance with Idaho National Laboratory work control requirements.

The EDL occupies most of Building 772 at the Materials and Fuels Complex (MFC). Two rooms within the building are used by the MFC Quality Assurance organization for nondestructive examinations, e.g., radiography and film processing. Two mezzanines, which constitute the second floor, can be moved to accommodate tall equipment (30-foot floor-to-crane hook). The facility includes equipment and gloveboxes for welding, including an electron-beam welder; furnaces for bake-out of graphite components; forming equipment for heat source hardware; and various machine tools.

BASIC CAPABILITIES:
- Fabrication
- Assembly
- Mock-up
- Testing

KEY INSTRUMENTS:
- Inert-atmosphere gloveboxes
- High-temperature bake-out furnaces
- Welding systems
- Forming equipment
- Pre-assembly operations for radioisotope power systems

Idaho National Laboratory

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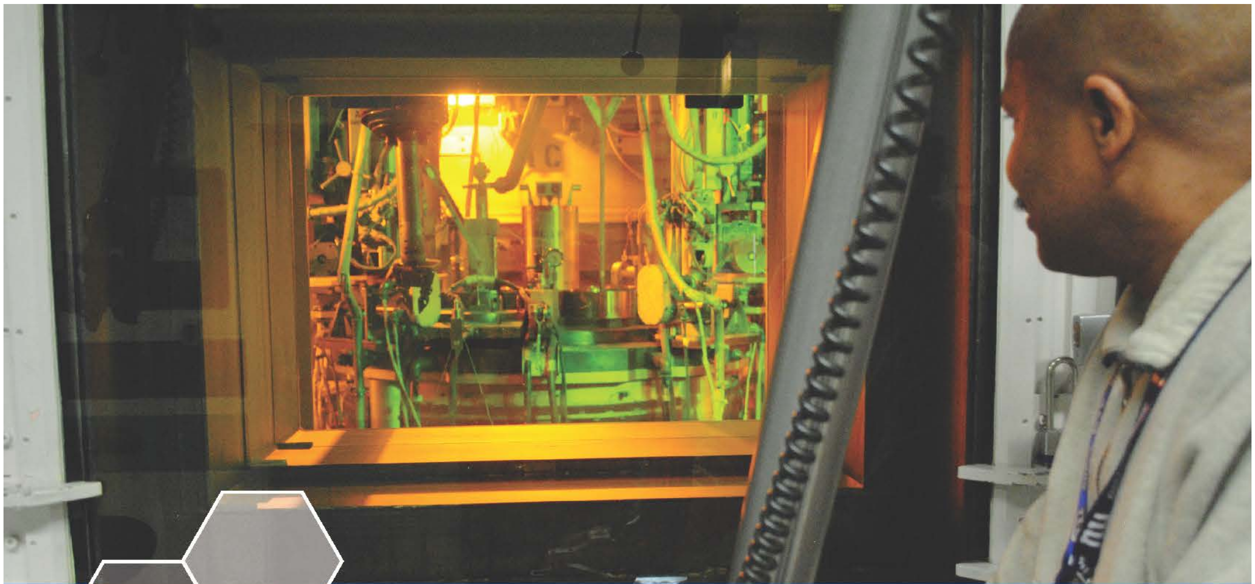


Fuel Conditioning Facility

Advanced Fuel Cycle Research On Material Separations and Waste Form Development

INL's Fuel Conditioning Facility supports work to demonstrate the technical feasibility of a nuclear recycling technique called pyroprocessing.

The Fuel Conditioning Facility (FCF) at Idaho National Laboratory's Materials and Fuels Complex supports nuclear energy research and development for the U.S. Department of Energy and other customers. FCF's unique capabilities make it an ideal facility for its primary mission to support treatment of DOE-owned sodium-bonded metal fuel.

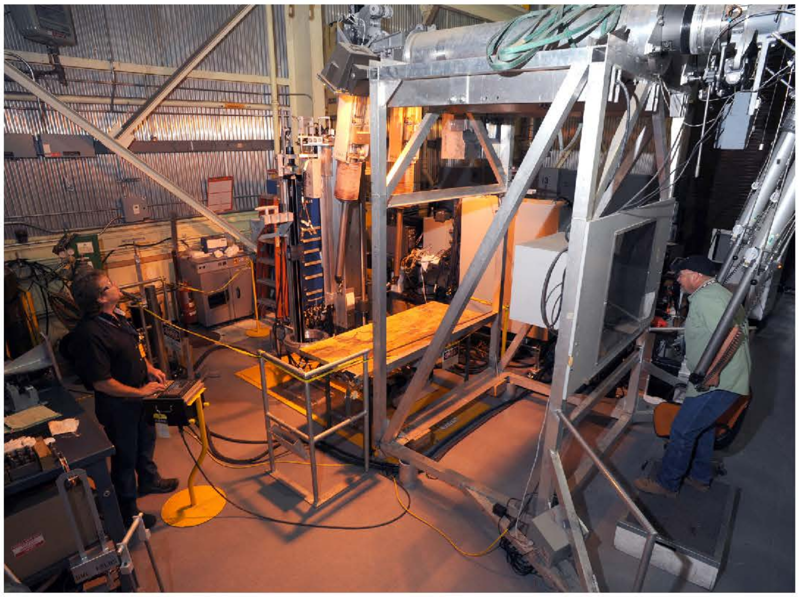
In a secondary role, FCF also supports multi-program work related to integrated fuel cycle research and development with a focus on material recovery and waste form development.

FCF consists of two hot cells, one having an air atmosphere and the other having an inert argon gas atmosphere, which enables technicians to work safely with radioactive nuclear materials from behind 5-foot-thick shielding walls.

KEY CAPABILITIES

- Two heavily shielded hot cells equipped with remotely operated manipulators to safely handle irradiated fuels and materials
- Instruments used to prepare and size elements for treatment, such as element chopper, vacuum inspection, and the vertical assembler/dismantler
- Engineering-scale equipment including molten salt electrorefiners and high temperature furnaces capable of sodium neutralization and uranium recovery
- Systems to support handling of heavily shielded shipping casks for fuel receipt and water disposal
- Pneumatic "rabbit" system for transfer of material samples to and from MFC's Analytical Laboratory (AL) or its Hot Fuel Examination Facility (HFEF)
- Mock-up area to allow thorough testing of new remotely operated systems prior to their installation into FCF, HFEF, or AL hot cells
- Advanced Fuel Cycle R&D argon atmosphere glovebox

Idaho National Laboratory



FCF includes a mock-up shop where technicians can build and test new hot cell equipment before installing it into the hot cell.

TECHNICAL INFORMATION

The Fuel Conditioning Facility's (FCF) primary mission is to support pyroprocessing treatment of DOE-owned sodium-bonded metal fuel.

BASIC CAPABILITIES:

- Engineering-scale equipment for treatment of sodium-bonded metallic fuel to deactivate the reactive sodium metal, recover fissionable uranium, and separate fission and activation products for incorporation into solid waste forms suitable for geologic disposal
- Systems to support handling heavily shielded shipping casks for fuel receipt and waste disposal
- Lab-scale process development in inert atmosphere gloveboxes

KEY INSTRUMENTS:

- Electrochemical separations/sodium neutralization experimentation/ treatment via two molten salt electrorefiners
- High temperature vacuum atmosphere furnaces (cathode processor, casting furnace, & multi-function furnace)
- Pneumatic rabbit transfer system
- Canister-cutting machine
- Manipulator repair glovebox
- Vacuum inspection station/bottle cutting, production element chopper
- Air & argon atmosphere hot cells
- Suited entry repair area
- Mock-up shop

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21-50083_FCF_R2 (Updated: 2022)

Research Collaboration Building

The Research Collaboration Building (RCB) provides dedicated space for visiting researchers to interact with INL research staff at the Materials and Fuels Complex.

The two-story, 13,901-square-foot RCB is located outside of MFC's perimeter security fence west of the entrance, providing a landing spot, collaborative working space and training areas for the growing number of students, visiting researchers and postdoctoral researchers at MFC.

Funding for the RCB was provided through the Nuclear Science User Facilities (NSUF), which facilitates the advancement of nuclear science and technology by providing nuclear energy researchers access to world-class capabilities at no cost to the researcher.

BASIC CAPABILITIES:

- 28 offices for MFC researchers, NSUF staff and long-term visitors.
- 23 researcher work stations and five collaboration spaces where INL scientists can host and work with their research partners and analyze data.
- A 1,000-square-foot laboratory (non-radiation) that will be used to develop and test instrumentation before it is installed in a radiological facility.
- The ability for researchers to monitor research equipment at the Irradiated Materials Characterization Laboratory (IMCL), which focuses on microstructural, thermal, and mechanical characterization of irradiated nuclear fuels and materials.

The Research Collaboration Building, completed in 2019, provides a landing spot, collaborative working space and training areas for the growing number of students, visiting researchers and postdoctoral researchers at MFC.

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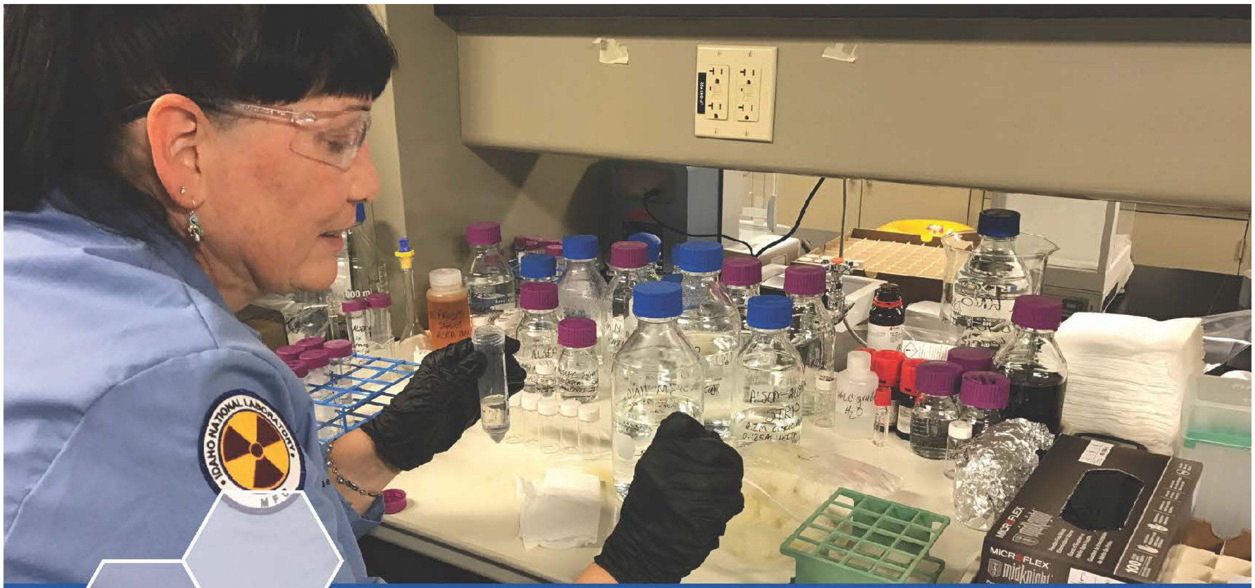

Radiochemistry Laboratory

Characterization, Post-irradiation Examination

The Radiochemistry Laboratory is located adjacent to the Analytical Research Laboratories and focuses on analysis and characterization of nuclear fission products, radioisotope separation and element dissolution.

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Idaho National Laboratory

The Radiochemistry Laboratory (RCL) houses several laboratories for aqueous separations science and technology, actinide chemistry, radiochemistry research, and metals and isotopic analyses on radioactive materials. The RCL contains two radiochemistry laboratories, an instrumentation laboratory, a counting laboratory and a glovebox laboratory, as well as necessary chemical and source storage areas. RCL supports work from various outside entities and federal agencies, including the Department of Homeland Security and the Department of Energy.

BASIC CAPABILITIES

- Analysis and characterization of nuclear fission products using aqueous chemistry
- Radioisotope separation
- Element dissolution of radioisotopes using advanced chemistry techniques
- Ability to create unique organic solvents for use in separations type work

KEY INSTRUMENTS

- Counting Laboratory (gamma counters, liquid scintillation, nuclear magnetic resonance)
- Gas chromatograph/ ion chromatograph
- Spectrometers (inductively coupled plasma-mass spectrometer and inductively coupled plasma-optical emission spectrometer)
- Spectrophotometer
- Argon separations glovebox
- Air separations gloveboxes
- Fume hoods
- Furnaces

21-50083_RCL_R0 (Updated: 2021)

Zero Power Physics Reactor Facility

Nuclear Material Management, Nonproliferation Activities

The east and west transuranic surveillance gloveboxes are used for material inspections and packaging. They were placed into service in 2014.

The Zero Power Physics Reactor (ZPPR) is a nuclear facility at Idaho National Laboratory's Materials and Fuels Complex. The reactor portion of ZPPR was operated by Argonne National Laboratory-West between 1969 and 1992. In 1992, the ZPPR reactor was placed into nonoperational standby. The ZPPR reactor and auxiliary equipment have since been removed from the facility. The current capabilities of the ZPPR facility include storage, inspection, and repackaging of transuranic elements and enriched uranium. The facility also provides suitable areas and material handling capabilities to support homeland security material detection experiments and the training of military and first responders to deal with nuclear materials.

The ZPPR facility consists of a workroom, cell area, and material storage vault. Current facility activities are material inspections and packaging in the workroom/vault, National and Homeland Security testing and detection training in the cell area, and transuranic and uranium material storage in the vault. This includes routine activities conducted in the ZPPR vault/workroom to monitor and maintain the integrity of the ZPPR fuel plates and other fissile materials in storage.

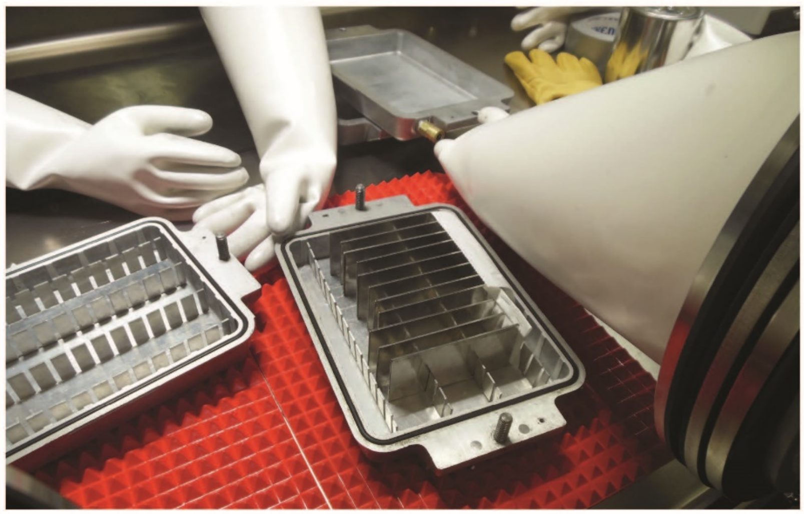
Planning is underway to modify the cell area to host reactor demonstrations and other nuclear projects.

KEY EQUIPMENT:

- Workroom hood
- East and west transuranic surveillance glovebox
- Vault storage for special nuclear material
- Cell area with very low radiation background environment

Idaho National Laboratory

The Zero Power Physics Reactor was placed in nonoperational standby in 1992, and has since been dismantled, which frees the space for nuclear material storage, inspection, and repackaging.



ZPPR operators performing material inspections in the transuranic surveillance glovebox.

Zero Power Physics Reactor (ZPPR) is a Hazard Category 2 nuclear facility that consists of a workroom, cell area and material storage vault. The workroom houses the equipment utilized for material inspection and repackaging. The cell area is used for experiment and detection training for various customers, including National and Homeland Security. The vault contains and supplies materials used for programs in multiple facilities at the Materials and Fuels Complex and other Idaho National Laboratory locations.

BASIC CAPABILITIES:

- Transuranic and enriched-uranium materials storage
- Transuranic and enriched-uranium material inspection/repackaging
- Transuranic and enriched-uranium material handling for experiments/training

KEY INSTRUMENTS:

- Transuranic surveillance glovebox line
- Vault storage
- Cell area that can be reconfigured as necessary for experiment/training activities

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21-50083_ZPPR_R0 (Updated: 2021)

3. ICERR CRITERIA AND SELF-ASSESSMENT

Objectives and expectations for ICERR are set forth in “Terms of Reference for IAEA designated International Center based on Research Reactor (ICERR),” (hereafter referred to as the ToR). The ToR makes clear IAEA’s desire to facilitate access to research reactors and other, ancillary nuclear-research facilities for its member states that seek to develop their own nuclear capabilities based on the national priorities set by their governments. Although IAEA envisions a time when those member states will develop research reactors and facilities, these future capacities will be better informed as a result of the work researchers will have accomplished at existing facilities within ICERR.[c]

The ICERR designation presupposes that designees will offer access to facilities, host both international and regional scientists, engineers, and technicians, and provide them with sources of expertise. IAEA envisions cooperative research and development platforms and education in both the work and research instruments used within nuclear facilities. This training would move academically instructed trainees into the working world of nuclear facilities and allow close cooperation with experts.[c]

“Designation as ICERR” is contingent upon operating a research reactor and a demonstrated ability to host both international and regional participants. The specific qualifications of INL and ORNL to meet logistical, technical, and sustainability criteria delineated in the ToR are demonstrated in the following three subsections.[c]

The COVID-19 pandemic globally impacted in-person collaborative opportunities along with many other impacts. International research collaborations became more complex to support. ORNL and INL responded by instituting health and safety protocols including maximum teleworking for non-essential personnel not required for onsite continuity of operations along with masking, distancing, and testing. Travel was essentially eliminated. Many conferences and meetings were cancelled and are only now slowly returning to some level of normalcy. Virtual conferences and meetings replaced onsite collaborative research. The last two years was a very restrictive environment as everyone is most familiar with. Both ORNL and INL were/are able to support robust research missions despite the impacts from COVID-19.

3.1 Logistical Criteria

Having an established, demonstrated process, adequate infrastructure and internal organization and experience to host international/regional scientists, engineers, technicians and students, including:

- *Demonstrated capacity and adequate internal organization to provide training at international/regional level (i.e., with a significant number of trainees from outside of the host country), including by secondment of staff, also to fill the gap between academic education and product-oriented training;*
- *Demonstrated experience in hosting international/regional conferences, workshops, symposia, seminars, etc., with a significant number of participants from outside of the host country.*[c]

Both INL and ORNL have long histories of hosting researchers and research activities, training personnel in operational matters, and cooperating with governments, academic institutions, other laboratories, and commercial entities to foster the creation of beneficial outcomes. Additionally, each has been the venue of symposia and conferences at which research outcomes are presented by scientists from around the world.

c. IAEA, “Terms of Reference for IAEA designated International Centre based on Research Reactor (ICERR),” International Atomic Energy Agency.

3.1.1 Hosting Foreign Researchers

The laboratories have several processes available to support collaborations with member states.

Formal working partnerships with member states can be accessed through Work for Others (WFO), Cooperative Research and Development Agreements (CRADAs), and Strategic Partnership Projects (SPP). These can range from collaborative research efforts to service provider type support.

Other opportunities, discussed in more detail later, include internships for university students, post-doctoral appointments, and hosting international researchers. These opportunities can be worked directly through technical counterparts at either laboratory or through organizations such as Contracts Management or University Partnerships and Outreach organization at both laboratories.

Another method to access the laboratories is through Argonne National Laboratory (ANL) International Programs, housed under the Nuclear Engineering Division of ANL. This office serves in a technical-coordination role, administering a work-for-others contract for the US Department of State. More information for accessing this resource can be found at https://international.anl.gov/about.html. Additional access is available for isotope research and production or simple materials irradiations through the Isotopes Business Office of the National Isotopes Development Center (www.isotopes,gov).

3.1.1.1 *Oak Ridge National Laboratory*

Oak Ridge has hosted thousands of interns and post-doctoral researchers over the previous 5 years, demonstrating capacity to provide for researchers' logistical needs. ORNL has the organizational infrastructure to ensure that visitors receive the proper security vetting and documentation to allow them to live in the area and work at the Laboratory. Figure 3 and Table 1 show the numbers of foreign interns and post-doctoral researchers hosted by ORNL from 2018 through 2021.

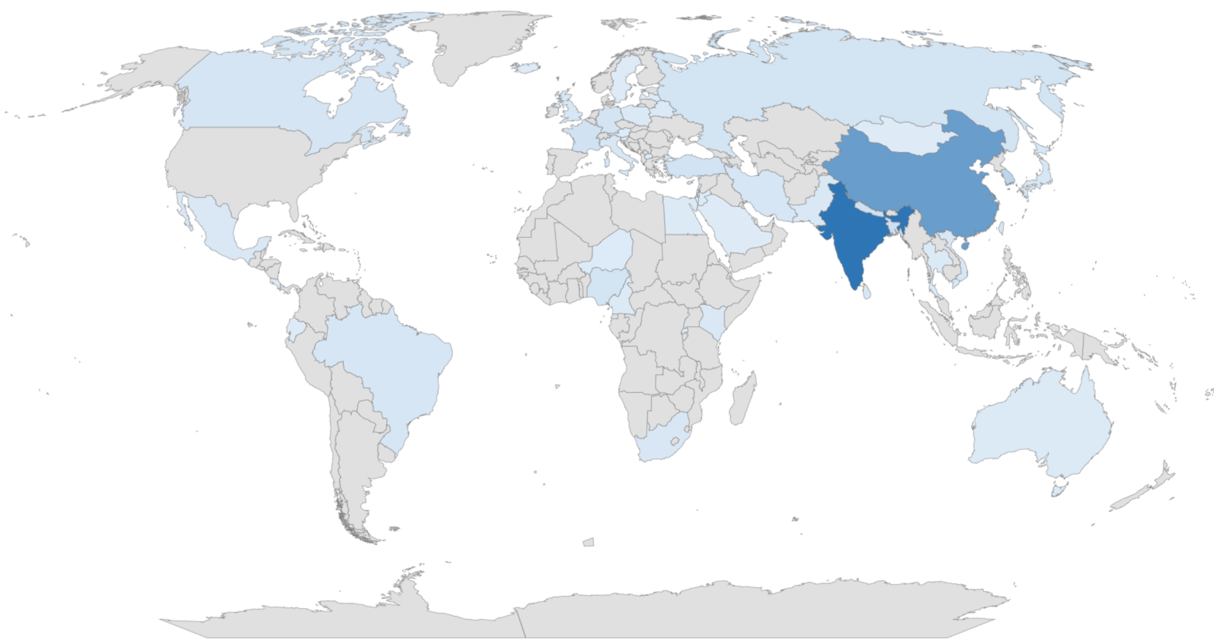

Figure 3. ORNL Interns and PostDocs and their Citizenship.

Table 1. ORNL Interns and their Citizenship.

	FY2018	FY2019	FY2020	FY2021
China	49	41	10	10
India	47	73	28	17
Korea, South	9	13	6	3
Turkey	7	4	1	0
Russian Federation	6	2	2	1
Nepal	5	5	3	2
Bangladesh	5	9	2	1
Puerto Rico	4	2	0	0
Germany	4	3	2	1
Viet Nam	3	2	1	1
Kenya	3	2	0	0
Japan	3	4	0	0
France	3	6	2	2
Canada	3	4	1	1
Thailand	2	1	0	0
Taiwan	2	5	2	0
Sri Lanka	2	3	1	1
South Africa	2	2	1	1
Poland	2	2	0	0
Nigeria	2	4	1	4
Iran	2	2	2	2
Brazil	2	3	1	2
Belarus	2	1	1	0
Australia	2	1	0	0

3.1.1.2 *Idaho National Laboratory*

Regional access to INL nuclear facilities is currently provided under the auspices of Nuclear Science User Facilities, a designation bestowed by DOE-NE. ATR is an NSUF participant, with the mandate to merge nuclear research infrastructure with intellectual capital, pairing the best ideas with needed capabilities. The process is based on open competitive peer review, and a similarly transparent process can be envisioned with ICERR participants. Through ATR NSUF, INL cooperates with ORNL, the Pacific Northwest National Laboratory, eight universities in the United States, and Westinghouse's Materials Center of Excellence Laboratory to provide access to nuclear infrastructure that is state-of-the-art and beyond the reach of any one laboratory.

INL has a long tradition of working with national and international visitors by hosting conferences, workshops, and training events. Multiple avenues for accessing these opportunities exist. Selected opportunities include the following:

- University Partnerships—INL supports college internships, joint appointments, postdoctoral appointments, academic visitors, and international research exchanges, as well as the National University Consortium.
- User Facilities—INL leads three major user facilities that provide state-of-the-art resources across the nation and the world. NSUF is the most applicable to ICERR and is discussed in more detail earlier in this report. INL also hosts the Biomass Feedstock National User Facility and Wireless National User Facility.
- Industry and Technology Deployment—INL works to transfer the discoveries and inventions created at the laboratory. INL has hundreds of technologies and many unique capabilities that can be made available to benefit laboratory customers.

- INL Internships—INL offers a diverse number of internship positions (Figure 4) to high school, undergraduate, and graduate-level students. These internship opportunities enable students to collaborate with experienced scientists and engineers to develop innovative solutions to challenging real-world projects. The internship programs are of critical value to INL's scientific community because they enable student engagement and a pipeline for human-capital development to support current and future science, technology, engineering, and math workforce needs. Key areas of interest to this designation include, but are not limited to, the following:
    - Material science
    - Modeling and simulation
    - Nuclear science
    - Nuclear engineering
    - Nuclear nonproliferation
    - Occupational health
    - Physics.
- INL Postdoctoral Research Program—The goal of INL's Postdoctoral Research Associate Program is to develop postdoctoral researchers that support establishment of INL as the pre-eminent nuclear-energy laboratory and as a leader in development of unique national and homeland-security capabilities and sustainable energy systems. In general, these appointments are reserved for individuals who have recently received their qualifying doctorate degree. Postdoctoral research associates are provided a mentored research experience and the highest quality training to prepare the program participant for transition to research independence.
- INL International Researchers Program—The INL International Researchers Program operates under the DOE Exchange Visitor Program. The purpose of the International Researchers Program is to provide foreign nationals with opportunities to participate in educational and cultural exchanges in the United States and return home to share their experiences, which supports the Department of State efforts in furthering educational and cultural exchanges as part of the foreign policy objectives of the United States. The program is of critical value to the INL scientific community and the future of INL user facilities.

Figure 4 details the numbers of foreign nationals who came to INL as interns and post-doctoral research positions.

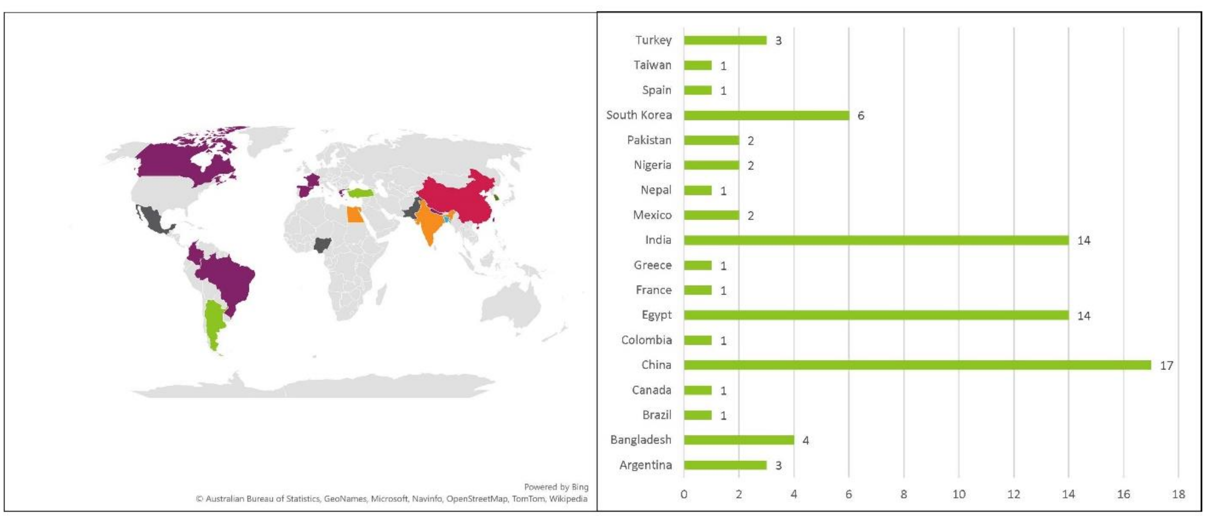

Figure 4. Fiscal Year 2021 Foreign Intern Participation and INL Graduate Fellows.

3.1.2 Symposia and Conferences

3.1.2.1 *Idaho National Laboratory*

INL regularly hosts symposia and conferences sponsored by international research organizations. Table 2 lists the selected examples of recent events sponsored or co-hosted by INL and their alignment with the technical criteria described in the ICERR terms of reference.

Table 2. Selected examples of recent events sponsored or co-hosted by INL.

Conference or Workshop Hosted or Co-Hosted	Subject	Date	General Description of Attendees
Demonstrated capacity and adequate internal organization to provide training at international/regional level (i.e., with a significant number of trainees from outside the host country), including by secondment of staff, and to fill the gap between academic education and product-oriented training.			
Advanced Reactors Summit V	INL senior leadership participated to speak at this US Nuclear Industry Council (USNIC) event. INL NS&T and GAIN will exhibit at this event.	February 2018	USNIC represents approximately 80 companies engaged in nuclear innovation and supply chain development, including technology developers, manufacturers, construction engineers, key utility movers, and service providers.
Workshop on Reactor Irradiation Rig Development, Instrumentation, and Qualification	The workshop offers irradiation testing experts the unique opportunity for technical exchange on the design, fabrication, and operation of irradiation test rigs in test reactors.	July 2018	Belgian Nuclear Research *Centre* (SCK-CEN), Japan Atomic Energy Agency (JAEA), France (CEA), PNNL, INL
France Versatile Test Reactor Workshop	This is a 3-day workshop focusing on collaboration opportunities.	September 2018	INL, ANL and Oak Ridge will be participating along with French industry representatives
French Alternative Energies and Atomic Energy Commission / VTR Workshop	Collaboration discussions on next generation reactors	September 2018	France
Nuclear Regulatory Commission, Nuclear Energy Institute (NEI) Light Water Reactor Sustainability (LWRS) Workshop	This is a 2-day workshop to review the LWRS program and identify future actions	October 2018	Nuclear Regulatory Commission, Nuclear Energy Institute, various INL researchers
Intl SMR & Adv Reactor Summit 2019	This was a 2-dqy conference supported by INL	April 2019	The world's largest nuclear SMR and advanced reactor meeting, bringing together 250+ decision makers from the industry's major buyers, technology designers, service providers and regulatory bodies.

Conference or Workshop Hosted or Co-Hosted	Subject	Date	General Description of Attendees
Nuclear Energy Technology Knowledge Transfer Workshop	Transfer selected fundamental nuclear energy technology history and experience – including important lessons learned – to the next generation of leaders from industry, government and academia.	May 2019	Participants include commercial nuclear industry, academia, the national laboratory complex, DOE, NRC, professional societies and trade organizations
Light Water Reactor Sustainability Program Nuclear Innovation Workshop	This covered approaches for vetting fast track innovation initiatives that reduce overall cost and risk. Attendees leanred how they can leverage the unique capabilities of the LWRS Program to successfully overcome barriers and enhance the overall benefits when developing advanced technologies. This also focus on lessons learned and industry perspectives from utilities, innovation partners, and research organizations related to managing plant modernization and innovation.	June 2019	DOE, private industry, other national laboratories including INL
Heat Storage Workshop	2-day event hosted by INL partnering with the Massachusetts Institute of Technology (MIT) on heat storage related issues and technologies	July 2019	INL researchers, MIT researchers, other invited guests
2019 Test Research and Training Reactors (TRTR) Annual Conference	INL hosted the 4-day event. TRTR is an affiliation of those associated with the operation, management, and regulation of non-power reactors. TRTR serves as a forum to share useful information with respect to operation, maintenance, and utilization of such facilities.	September 2019	TRTR membership includes managers and directors of research reactors, educators, administrators, regulators, research scientists, and engineers

Conference or Workshop Hosted or Co-Hosted	Subject	Date	General Description of Attendees
IAEA, Workshop on Cost Estimation and Cost Analysis of Nuclear Projects and Programs	The IAEA 4-day Workshop on Cost Analysis of Nuclear Projects and Programs hosted by the LWRS program at INL. The purpose is to provide guidance and tools to support the development and analysis of nuclear cost estimates for areas such as: government organizational setup and policy development; establishment of a regulatory body; grid design and capability; engineering, procurement and construction; and the funding of future liabilities attached to reactor decommissioning and the management of SNF and radioactive fuel.	September/October 2019	National and international participants from government and industry nuclear newcomers/countries with expanding programs
Bison User Training at ORNL	VTR and metallic fuel	January 14-16, 2020	ORNL staff
Bison User Training	Information for new and existing users	February 2020 June 2020	Universities, national laboratories
The Metals, Minerals, and Materials Society (TMS) Annual Meeting and Exhibition	Modeling the Coevolution of Microstructure and Properties using the MOOSE Framework	February 2020	Universities, industry, national laboratories
Bison User Training at Westinghouse	TRISO fuel modeling	February 4, 2020	Westinghouse staff
Grizzly User Training at NRC	Reactor pressure vessel analysis	Nov 8 & 15, 2021	NRC research staff
"Characterization of Point Defects and Their Impact on Material Properties" hosted by INL	This talk described a few uncommon, powerful techniques for defect characterization and present examples to show how our characterization and navigation of point defects revealed interesting new physics in oxides and provided unique tools to manipulate the material properties and drive their response in many applications	February 2022	DOE national laboratories, universities, industry

Conference or Workshop Hosted or Co-Hosted	Subject	Date	General Description of Attendees
"GAIN-INL Energy Supply Chain Workshop" hosted by Gateway for Accelerated Innovation in Nuclear	The "GAIN-INL Energy Supply Chain Workshop" convenes supply chain and procurement leaders from the energy industry sector to explore gaps, opportunities, and solutions in the advanced nuclear supply chain. Discussions will bring awareness and teamwork to ensure sustainable and competitive deployment of advanced reactors	April 2022	
Advanced Reactor Summit IX & Technology Trailblazers Showcase Sponsored, in part, by INL S	The U.S. Nuclear Industry Council (USNIC) is the leading U.S. business advocate for the advancement of applications for nuclear energy technology, and promotion of the U.S. supply-chain worldwide.	April 2022	The Advanced Reactor Summit is attended by most, if not all of the US Microreactor developers, many of whom are speaking on the status of their concepts
Establishing Standards and Impacting Economic and Workforce Development (Industrial Cyber Security)	**This workshop is a follow-up of activities and developments from the ICS Community of Practice focused on industrial cybersecurity education, training and workforce development efforts to include government, academia, and industry. The Community integrates stakeholders and practitioners with similar interest in a consolidated framework, develop common views on career pathways in industrial cybersecurity, and map foundational pedagogical paradigms to educate and train our workforce.**	May 2022	Interested federal, industry, and academic personnel
ANS Nuclear and Emerging Technologies for Space 2022 Assistant General Co-Chair (INL), Technical Program Co-Chair (ORNL)	Provides a platform for leading experts, scientists, and engineers worldwide to share their expertise, and recent research progress in the field of space nuclear systems	May 2022	The NETS 2022 conference will bring attention to the latest advancements in space nuclear systems and provide a forum for researchers, engineers and managers to discuss progress on current activities.

Conference or Workshop Hosted or Co-Hosted	Subject	Date	General Description of Attendees
Framatome Accident Tolerant Fuel workshop	Framatome representatives join INL staff for a two-day workshop on the Framatome ATF testing program. During their visit they toured some REC Labs and MFC facilities and wrap up their visit on the 19th meeting with the DOE-ID team	May 2022	France
The OECD Nuclear Energy Agency (NEA) is organizing the Sixth International Workshop on Structural Materials for Innovative Nuclear Systems (SMINS-6).	**The OECD Nuclear Energy Agency (NEA) and Idaho National Laboratory are co-organizing the Sixth International Workshop on Structural Materials for Innovative Nuclear Systems (SMINS-6). The workshop will be held in Idaho Falls (ID, US) from 12 to 15 September 2022, hosted by Idaho National Laboratory, in co-operation with the International Atomic Energy Agency (IAEA).**	September 2022	**The OECD Nuclear Energy Agency (NEA) is an intergovernmental agency that facilitates co-operation among countries with advanced nuclear technology infrastructures to seek excellence in nuclear safety, technology, science, environment and law**

3.1.2.2 *Oak Ridge National Laboratory*

As was previously noted, ORNL hosted one of the earliest reactor schools for operators and opened the school to students from IAEA member states 60 years ago. Both ORNL and INL have hosted foreign nationals since the 1950s to train students in both the theory and practice of work done in nuclear facilities.

Table 3. Selected examples of recent events sponsored or co-hosted by ORNL.

Conference or Workshop	Month	Location
Nuclear Security Workshop	January 2018	AMMAN, Jordan
Versatile Test Reactor (VTR) Integration Meeting	February 2018	OAK RIDGE, TN, US
Nuclear Security Workshop	March 2018	AMMAN, Jordan
REDC American Nuclear Society Nuclear Historic Landmark Dedication	May 2018	OAK RIDGE, TN, US
Nuclear Safeguards Implementation Workshop for Liberia	May 2018	MONROVIA, Liberia
Process Modeling for Nuclear Material Accounting and Control Workshop	May 2018	ALBUQUERQUE, NM, US
SNMMI 2018: Society of Nuclear Medicine and Molecular Imaging Annual Meeting (ORNL-Hosted Side Meetings)	June 2018	PHILADELPHIA, PA, US
Nuclear Security Best Practices	July 2018	WASHINGTON, DC, US
Technologies to Reactors: Enabling Accelerated Deployment of Nuclear Energy Systems	July 2018	OAK RIDGE, TN, US
Advancing Nuclear Safety and Security	September 2018	SAO PAULO, Brazil
Molten Salt Reactor Workshop 2018 - Creating a Self-Sustaining Environment for MSR Success	October 2018	OAK RIDGE, TN, US
Nuclear Security Workshop	October 2018	AMMAN, Jordan
Nuclear Safeguards Implementation Workshop for Sub-	October 2018	VIENNA, Austria

Conference or Workshop	Month	Location
Saharan Africa		
Advanced Manufacturing for Nuclear: Applications, Techniques, Needs and Challenges	December 2018	KNOXVILLE, TN, US
International nuclear safeguard	December 2018	COTONOU, Benin
Advancing nuclear security culture	March 2019	JOHANNESBURG, South Africa
2019 International Training Course on State Systems of Accounting for and Control of Nuclear Materials	March 2019	OAK RIDGE, TN, US
Nuclear Safeguards Implementation Workshop for Liberia	April 2019	MONROVIA, Liberia
Neutron Sciences in Support of Nuclear Power 2019	May 2019	OAK RIDGE, TN, US
SCALE Microreactor Workshop	May 2019	ROCKVILLE, MD, US
SNMMI 2019 Society of Nuclear Medicine and MolecularImaging Annual Meeting (ORNL-Hosted side meeting)	June 2019	ANAHEIM, CA, US
Workshop on Modeling Molten Salt Reactor Chemistry and Corrosion - CANCELED	July 2019	OAK RIDGE, TN, US
Molten Salt Reactor Workshop 2019 - Science, old, new, accelerating the deployment of molten salt reactors	October 2019	OAK RIDGE, TN, US
Workshop on Changing Behavior to Advance Nuclear Security Culture for the Nuclear Operations Division	November 2019	JOHANNESBURG, South Africa
Nuclear Security Training	December 2019	AR-RAMTHA, Jordan
Advanced Transportation Security for Nuclear Materials	December 2019	CAIRO, Egypt
IAEA International Conference on Nuclear Security (ICONS) 2020	February 2020	VIENNA, Austria
Canceled due to coronavirus - Workshops on further advancing nuclear security culture within NECSA . Meetings to observe implementation and perform security training.	March 2020	JOHANNESBURG, South Africa
CANCELED - Due to Corona Virus - Nuclear and Emerging Technologies for Space (NETS) 2020	April 2020	KNOXVILLE, TN, US
VIRTUAL - SNMMI 2020 Society of Nuclear Medicine and Molecular Imaging Annual Meeting (ORNL-Hosted side meetings)	June 2020	NEW ORLEANS, LA, US
VIRTUAL - Molten Salt Reactor Workshop 2020	October 2020	KNOXVILLE, TN, US
SARP Analyst Course - Radiation and Nuclear Criticality Analysis of RAM Packages (NP 607)	March 2021	OAK RIDGE, TN, US
Perspectives from Past DOE Nuclear Energy Official	March 2021	OAK RIDGE, TN, US
VIRTUAL -Nuclear and Emerging Technologies for Space (NETS) 2021	April 2021	OAK RIDGE, TN, US
NENG 612 - Nuclear Engineering Laboratory	July 2021	OAK RIDGE, TN, US
Nuclear Security Training	September 2021	AMMAN, Jordan
Office of International Nuclear Safeguards Nonproliferation Workshop University of Michigan	October 2021	OAK RIDGE, TN, US
Fundamentals of Nuclear Safeguards	November 2021	OAK RIDGE, TN, US

3.2 Technical Criteria

Having demonstrated experience in promoting and participating in collaborations at international/regional level, including:

- *Demonstrated capability to accomplish the requests of international/regional potential users (with possibility to communicate in regional languages and/or selected languages) in specific areas of the research reactors field of activities;*
- *Demonstrated transparent selection and decision mechanisms to evaluate the requests of potential users, prioritize the activities and provide the feedback to the applicants; for this purpose, when a dedicated access to the reactor or to its ancillary facilities is required, the ICERR candidate should have in place some type of an advisory board (e.g., Scientific Committee) while, for human resources development requests, the ICERR candidate should have in place adequate managerial measures;*
- *Demonstrated capability to provide potential users with access to relevant technology, methodology and standards in the area(s) of the research reactor activities for which designation is requested.*[c]

3.2.1 Communication, Selection, and Decision Mechanisms

INL and ORNL demonstrate their capacity to transparently evaluate and select between requests for access in their existing regional NSUF and joint institute programs and in continuing international relationships and training programs. These are long-standing and robust, with provision made for both long-term research projects and, by the standards of nuclear research, quick-turnaround research.

Table 4 compiles international training events held at ORNL or presentations to international symposia made by ORNL in the previous three years. Though not comprehensive, it gives a measure of the commitment to international training and collaboration found at Oak Ridge.

Table 4. Selected international training/collaboration visits to ORNL, 2018-2021. COVID-19 significantly affected ORNL’s ability to conduct these international training events.

Event	Subject	Date	Collaborating Country
Virtual Transportation Response Training	Overview of the transportation of radioactive sources and the response if there is an attempted theft of the source material for individuals responsible for security management, transportation security and first, secondary and tertiary responders who will aid. Using presentations, group discussion, and interactive virtual exercises, the Workshop allows students to apply the information over the 4-day experience.	July 2021	Indonesia
Training courses for SCALE code system	SCALE is a comprehensive modeling and simulation suite for nuclear safety analysis and design used to perform reactor physics, criticality safety, radiation shielding, and spent fuel characterization for nuclear facilities and transportation/storage package designs	March 2018 September 2018 October 2020 February 2021 April 2021	France Many Virtual due to COVID-19
DOE-IAEA international SSAC course	State Systems for Accounting for and Controlling nuclear material	April 2015	Multiple
5th Workshop on HTGR SiC Material Properties and meeting of the Generation IV International Forum (GIF) VHTR Fuel and Fuel Cycle Project Management Board (FFC-PMB)	The workshop is an opportunity for leading experts from the high temperature gas-cooled reactor (HTGR) research community to discuss critical topics concerning HTGR fuels and materials challenges. The meeting of the Generation IV International Forum (GIF) VHTR Fuel and Fuel Cycle Project Management Board (FFC-PMB) provides a forum to discuss ongoing cooperative projects between GIF members and plan future efforts and focuses.	May 2019	Multiple
International Collaboration on Advanced Neutron Sources (ICANS XXIII)	ICANS is an informal network of laboratories whose scientists and engineers are involved in developing pulsed neutron sources and accelerator-based spallation neutron sources. The collaboration was founded in 1977 as a forum to promote discussions and collaborative work, and to share information on three main topics: accelerators, targets and moderators, and instruments.	October 2019	Multiple
2022 Molten Salt Reactor Workshop (Virtual)	The 2022 Hybrid Molten Salt Reactor Workshop will include sessions on salt chemistry, modeling and simulation, materials testing, safety and licensing, radionuclide releases, international activities, waste and fuel cycle activities, and reactor development and deployment.	October 2022	Multiple

Key examples of recent international collaboration work at INL and ORNL include the following:

- Advanced reactor fuels development collaborations
  - DOE-Commissariat à l'Energie Atomique (CEA) Bilateral Civil Nuclear Agreement. INL collaborates in the areas of transmutation fuels, fuel-performance codes, advanced cladding development, and light-water reactor accident-tolerant fuels. ORNL is finalizing a similar collaboration.
  - DOE-Japan Atomic Energy Agency Bilateral Civil Nuclear Agreement. INL and ORNL support work with the Japan Atomic Energy Agency, including identifying attributes of accident-tolerant fuels and quantifying metrics, determining accident-tolerant fuels core components, exchanges of data and data-evaluation results, understanding fundamentals of cladding and next-generation reactor materials, and experimenting on Japan Atomic Energy Agency-provided samples.
  - DOE-Japan Atomic Energy Agency Fuel Cycle Working Group on Advanced Fuels. INL collaborates on establishing basic properties of oxide fuels, PIE techniques, modeling and simulation of MA-MOX fuels performance, and MA-MOX irradiations test planning.
  - United States-China Civil Nuclear Energy and Research Working Group. Nuclear Safety and Enhancement Working Group at INL to support material performance testing, modeling, analytical assessment, and irradiation and post-irradiation examination.
  - International Nuclear Energy Research Initiatives–United States-Euratom. This research focuses on material recovery and waste-forms development, with INL supporting assessment of field-assisted sintering for fabrication of advanced fuels, thermodynamic equilibria, and modeling support.
  - Halden Reactor Collaborations. INL supporting in-pile testing of accident-tolerant fuels concepts, in-pile instrumentation, and BISON-modeling validation. ORNL is part of several active materials research collaborations with Halden.
- Joint fuel cycle initiative collaborations
  - INL is working with the Korean Atomic Energy Research Institute on fabrications and performance of recycled metallic fuel, including development of a remote casting furnace and plans for fabrication and irradiation of fuel.
  - INL is working with private industry (i.e., TerraPower) to support fuel-feedstock preparation, fuel fabrications, cladding-material development, and irradiation and post-irradiation examination.
- Materials separations and waste form collaborations
  - The DOE-CEA (France) collaboration is leveraging many decades of glass research and development from both countries to help improve formulation and processing of future waste forms. The activity also supports an international effort to develop a consensus glass leaching rate law. The INL has a strong collaborative role in the following areas:
    - The radiation stability and degradation mechanisms of monoamide extractants is being investigated with joint experiments at CEA and INL. These extractants are of interest to both countries for selective extraction of actinide elements.
    - A number of advanced sorbent materials have been developed in the United States for capturing iodine and krypton from off-gas resulting from used fuel processing. The United States does not have a facility to test sorbents during dissolution of actual used fuel; therefore, they are leveraging small-scale experiments being performed in France at a unique research facility (i.e., ATALANTE) to test U.S. sorbent materials.
    - The DOE-CEA collaboration has initiated a study to benchmark actinide separation processes and compare relative strengths and weaknesses of respective approaches in an effort to improve the separation processes.

- Supporting DOE, INL participated in the European Union Safety of Actinide Separation Processes Research and Development Program. This collaboration is utilizing unique capabilities in the United States for studying the degradation of solvent extraction solvents by radiation and acidic hydrolysis. Testing of U.S. separation processes in small-scale continuous equipment at a European facility using simulated dissolved fuel is in the planning stages.
- INL participates in planning for a new collaboration that is underway as the United Kingdom is moving toward establishing a new nuclear energy research and development program. Discussions have been held and preliminary topics, including neptunium chemistry in separation processes, thermodynamics of advanced actinide separation processes, and waste form development and performance, have been proposed as initial areas for collaboration.

Table 5 lists selected international visits that demonstrate international collaboration opportunities hosted by the INL.

Table 5. Selected international training/collaboration visits to INL, 2017–2022.

Event	Subject	Date	Collaborating Country
Consulate General of Canada – March 14-15, 2017	Laboratory overviews and collaboration opportunities	March 2017	Canada
French Alternative Energies and Atomic Energy Commission – May 25, 2017	General laboratory overview and collaboration discussions	May 2017	France
General Fusion – June 1, 2017	General laboratory overview and collaboration discussions	June 2017	Canada
Department of Energy International Strategy Discussion – July 10-11, 2017	General laboratory overview	July 2017	
Council on Foreign Relations – Aug. 7, 2017	General laboratory overview	August 2017	Various
Ambassador Laura Holgate – United States ambassador to the United Nations International Organizations in Vienna Aug. 10, 2017	General laboratory overview to support IAEA relationship	August 2017	Special brief to UN representative to IAEA
AREVA – December 13-14, 2017	AREVA's visit will include an exchange of technical information focused on INL's research and capabilities.	December 2017	France
SAKAE Casting – Jan. 23, 2018	General site overview and collaboration discussions	January 2018	Japan
Ministry of Science, Korean Atomic Energy Research Institute, and Korea Nuclear International Cooperation Foundation Visitors - August 14-15, 2018	Program review of Joint Fuel Cycle Study equipment	August 2018	Korea
UK PhD Candidates INL Familiarization Visit September 10-11, 2018	INL tour and overview	September 2018	United Kingdom
Korea Atomic Energy Research Institute / VTR Collaboration Meeting – Sept. 12-13, 2018	Collaboration discussions on next generation reactors	September 2018	Korea
Korea Atomic Energy Research Institute – Nov. 12, 2018	Collaborative meetings on joint pyroprocessing recycling research	November 2018	Korea

Event	Subject	Date	Collaborating Country
Ministry of Education, Culture, Sports, Science and Technology (Japan) – Nov. 12, 2018	Site tours and training on INL research capabilities	November 2018	Japan
Mitsubishi (Japan) – Feb. 7, 2019	Site tours and training on INL research capabilities regarding advanced reactors	February 2019	Japan
Generation IV International Forum – Feb. 12, 2019	Workshops and collaboration on Gen IV nuclear technology	February 2019	Various
Israeli government officials – March 12-14, 2019	Training in INL facilities, research capabilities, and current research	March 2019	Israel
UK Ministry of Defense – June 10, 2019	Discussion with Naval Reactors and ATR staff	June 2019	United Kingdom
Central Bohemian Governor Jermanova (Czech)– June 12, 2019	Provided overviews of INL and NSUF as well as discussions n SMR's and materials research.	June 2019	Czech
International Atomic Energy Agency – Aug. 5, 2019	Briefing workshop on INL research initiatives	August 2019	IAEA
Israeli government officials – Aug. 6, 2019	Training in INL facilities, research capabilities, and current research	August 2019	Israel
Nuclear Energy Agency – Aug. 14-15, 2019	Nuclear Energy Agency, (NEA) INL 70th Symposium and Collaboration Meeting	August 2019	NEA
Nuclear Regulation Authority (NRA) of Japan – Aug. 26, 2019	Training in INL facilities, research capabilities, and current research	August 2019	Japan
Japan Atomic Energy Agency (JAEA), Ministry of Economy, Trade, and Industry (METI), and the Ministry of Education, Culture, Sports, Science and Technology (MEXT) – Sept. 10, 2019	Training in INL facilities, research capabilities, and current research	September 2019	Japan
IAEA Workshop on Cost Analysis of Nuclear Projects and Programmes – Sept. 9-Oct. 3, 2019	Workshop on performing cost analysis of nuclear projects	September 2019	IAEA
UK Academics – Oct. 17-18, 2019	Site tours and training on INL research capabilities and research initiatives	October 2019	United Kingdom
CEA/French Embassy – Nov. 12-13, 2019	Site tours and training on INL research capabilities and research initiatives	November 2019	France
Czech Academy of Sciences – Dec. 3-4, 2019	Site tours and training on INL research capabilities and research initiatives	December 2019	Czech
Civil Nuclear Engineering Group – Jan. 21-23, 2020	Site tours and training on INL research capabilities and research initiatives	January 2020	Japan

Event	Subject	Date	Collaborating Country
British Consulate – Feb. 4, 2020	Site tours and training on INL research capabilities	February 2020	United Kingdom
Japan Atomic Energy Agency – Feb. 24-25, 2020	Discussion and status briefings on collaborative research	February 2020	Japan
Waseda University, Kyoto University, Kindai University, Nagoya University, and Tokyo Institute of Technology. – Feb. 26-27, 2020	Site tours and training on INL research capabilities	February 2020	Japan
VIRTUAL – Brazil/INL partnership signing	Enables collaboration between the INL and the Brazilian Institute of Energy and Nuclear Research	February 2021	Brazil
Nuclear Infrastructure, Assessment and Characterization Course	American Soldiers from Nuclear Disablement Team 2 and South Korean troops from the Republic of Korea's Nuclear Characterization Teams honed their skills at America's premier nuclear research facility	October 2021	Korea
Chubu Electric Power Co. – Dec. 9, 2021	Site tours and training on INL research capabilities. Overview training on UAMPS and SMR's and integrated power systems	December 2021	Japan
Korea Nuclear International Cooperation Foundation – Feb. 3, 2022	Collaborative meetings on joint research opportunities	February 2022	Korea
Singapore delegation – April 14-15, 2022	Site tours and training on INL research capabilities	April 2022	Singapore

Table 6. Recent events sponsored by GAIN (INL led) and led by various national laboratory partners/organizations

Workshops	Location	Date	Comments
GAIN Molten Salt Reactor Workshop	ORNL, Oak Ridge, TN	Oct 2-3, 2019	ORNL Led
GAIN ART Workshop on Legacy Metallic Fuel Irradiation and Testing Databases	INL, Idaho Falls, ID	November 1, 2019	ART, ANL, INL
GAIN-EPRI-NEI HALEU Virtual Workshop	GTW-Virtual	April 28-29, 2020	DOE-NE, HALEU Prog
GAIN-EPRI-NEI Microreactor Program Virtual Workshop	GTW-Virtual	August 18-19, 2020	Microreactor Prog
ORNL-GAIN Molten Salt Reactor Workshop	ORNL, Oak Ridge, TN	Oct 2-3, 2020	ORNL Led
GAIN-EPRI-NEI Sensor Technologies for Advanced Reactors Virtual Workshop	GTW-Virtual	Oct 13, 2020	INL Sensor Program
GAIN-EPRI-NEI Advanced Reactors Safeguards & Security Virtual Workshop	GRW-Virtual	April 13-15, 2021	Safeguards Program-SNL

Workshops	Location	Date	Comments
GAIN-EPRI-NEI Microreactor Stakeholders Virtual Workshop	GTW-Virtual	May 12-13, 2021	Microreactor Program
Advanced Methods for Manufacturing Workshop	GTW-Virtual	August 24-25, 2021	AMM Program
GAIN-EPRI-NEI Artificial Intelligence/Machine Learning Technologies for Ars	ANL	October 5-6, 2021	ANL Initiative
ORNL-GAIN Molten Salt Reactor Workshop-Virtual	ORNL, Oak Ridge, TN	Oct 12-13, 2021	ORNL Led
GAIN-INL Energy Supply Chain Workshop	Sun Valley Inn, Sun Valley, Idaho	April 5, 2022	GAIN-INL coordinated – embedded in United States Nuclear Industry Council Advanced Reactors Summit

3.2.2 Technical Capabilities

The research reactors that these two laboratories operate provide some of the best technical capabilities in the world. INL includes four working test or research reactors. These are the ATR and ATR-Critical facility (ATRC), the Neutron Radiography Reactor (NRAD), and the Transient Reactor Test Facility (TREAT). ORNL’s HFIR is the highest-flux reactor-based source of neutrons for condensed matter research, isotope production, and neutron-damage studies in the United States. This suite of research reactors can be used to simulate conditions in reactors, irradiating materials and fuels to demonstrate the effects of years of reactor service in a few months. They provide neutrons to study physics, chemistry, materials, engineering, and biology. They are effective tools for examining materials for flaws in the deep structures of irradiated experiments, and TREAT provides a capacity to simulate transient conditions inside a commercial reactor.

In addition to the research reactors listed, support facilities proximate to the reactor facilities allow for examinations to be performed with exacting precision and accuracy. At INL, these facilities include the Analytical Laboratory (AL), with capabilities in chemical, radiochemical, and physical measurement, non-destructive analysis, and applied research using assay equipment, a wide variety of mass spectrometry, casting furnaces, and chemical laboratory equipment. The Hot Fuels Examination Facility (HFEF) provides a large array of characterization and sample preparation as well as many PIE capabilities. The Electron Microscopy Laboratory (EML) provides optical and both scanning and transmission electron microscopy, a dual-beam focused ion beam, microhardness testers, and automated precision polishing of metallurgical samples. The Experimental Fuels Facility (EFF) and Advanced Fuels Facility (AFF)support advanced fabrication of metal and ceramic nuclear fuels through casting, extrusion, and machining, performed under a variety of atmospheric conditions, from vacuum to air, and including inert atmospheres like argon and nitrogen. Finally, the Irradiated Materials Characterization Laboratory (IMCL) provides post-irradiation examination capabilities that support preparation of high-activity samples, electron-probe microanalysis, scanning and transmission electron microscopy, dual-beam focused ion beam, thermal-property characterization, and mechanical testing.

ORNL’s ancillary facilities to be included in the ICERR designation include the Irradiated Material Examination and Test Facility (IMET), a large hot cell with facilities for specimen preparation and testing, comprising sorting and identification, sample machining, annealing, welding, ultrasonic cleaning, high-temperature, high vacuum testing, tensile testing, microhardness testing, profilometry, and scanning electron microscopy. The Irradiated Fuels Examination Laboratory (IFEL) is capable of examining full length fuel rods from a commercial light water reactor, repackaging spent fuel, metrology, metallography (including sample polishing) with optical and electron microscopy and gamma spectrometry. It also can sample fission gas and perform gamma analysis to the level of a fuel particle. Low-activity sampling and analysis is performed in the Low Activation Materials Development and Analysis Laboratory (LAMDA). Materials testing is performed on graphite, silicon carbide, and composite materials. In addition to sample preparation and metallography, LAMDA has the capability to measure thermal diffusivity, dilatometry, elastic modulus, calorimetry, electrical resistivity, and density measurement, as well as state-of-the-art microscopy technology. The Radiochemical Engineering Development Center (REDC) offers capabilities for heavy-actinide research, radioactive-isotope target fabrication, post-irradiation chemical processing, as well as full analytical capabilities.

For greater specificity and detail, see the individual facility data sheets, provided above.

3.3 Sustainability

Demonstrated mid-term commitment (3-5 years) in terms of financial and human resources availability to assure continuous and reliable support to Affiliates;

Demonstrated mid-term (3-5 years) capability to maintain sustainability for operation, training, licensing, waste management, etc.;

Continuous improvement plan in place to provide potential users with access to relevant technology, methodology and standards in the area(s) of the research reactor activities for which designation is requested.[c]

ORNL has been in operation for more than 70 years, and INL for more than 60. Each has been actively involved in international cooperation from the time of the Atoms for Peace program of the early 1950s.

3.3.1 Idaho National Laboratory

INL is the lead nuclear laboratory for the DOE. DOE-NE awarded BEA a contract extension on March 27, 2014. The BEA team at INL continues to build on the important GAIN and NRIC missions along with the other INL research missions continues to lead the nation in in partnership with ORNL and Argonne National Laboratory in establishing a world-leadership role in advanced nuclear energy.

The sustainability criteria also include “demonstrated mid-term (3 to 5 years) capability to maintain sustainability for operation, training, licensing, waste management, etc.”

INL will maintain and improve on all current operations, training, licensing (i.e., permitting), and waste management throughout the life of the INL contact managed by BEA. BEA has been operating INL since 2004. On April 3, 2018, DOE extended the INL Contract for an additional 5 years to run through September 30, 2024. All INL operations programs, training, licensing, and waste-management activities are conducted under a rigorous conduct-of-operations strategy, with contactor self-assessments and other oversight efforts to monitor effectiveness of the process. These processes (such as the INL waste disposition process) have mature implementing procedures and effective executing organizations. DOE oversees the INL contract and provides quarterly assessment feedback to BEA. BEA continues to monitor all laboratory operations and implement process improvement when efficiencies are identified. BEA is committed to excellence in research and operations throughout the lifetime of the INL contract, and continuous improvement is central to that commitment.

The INL ATR shut down in April 2021 to begin an overhaul called a Core Internals Changeout (CIC), a process that replaces and updates internal reactor components. CIC successfully completed in March 2022. This is ATR’s sixth core overhaul since it began operation in 1967. The overhaul process occurs approximately every 10 years. The latest CIC enables ATR operability and availability to support research for the next decade.

3.3.2 Oak Ridge National Laboratory

ORNL is the largest science laboratory within the department of energy, and its multi-program, multi-mission operation will continue to drive research in the areas of nuclear-power programs, materials science, high-performance computing, neutron science, isotope production and both manufacturing technologies and energy efficiency.

DOE's annual budget shows consistent commitment from the Office of Science. All indications show the DOE Office of Science will continue to support important utilization of the HFIR for many applications affecting fusion-energy research, isotope production, nuclear-power programs and materials science, with both national and international partners for the foreseeable future.

One point of sustainability is the current planning effort for a future reactor pressure vessel replacement at HFIR. In 2020, the U.S. DOE, Office of Science – Basic Energy Sciences (BES) convened a subcommittee to evaluate the future of reactor-

The sustainability criteria also include "demonstrated mid-term (3 to 5 years) capability to maintain sustainability for operation, training, licensing, waste management, etc."

ORNL continues to maintain and improve operations and facilities. ORNL expects new capabilities and competencies will be added over the coming five years, particularly in the areas of isotope production and materials irradiations in HFIR, as well as post-irradiation examination and analysis competencies. We believe there is absolutely no issue with mid-term sustainability of HFIR or our other ancillary facilities.

4. SELF ASSESSMENT OF KEY INDICATORS

4.1 Logistical Indicators

Logistical Indicators	INL/ORNL Compliance With Criterion
a. ICERR candidate organizational structure dedicated to visitor issues in place (such as VISA, transportation, lodging, etc.)	Both laboratories have mature capabilities to assist in travel and site access. Facilitating and hosting international guests is accomplished through well-established organizations at both laboratories. COVID-19 restrictions can complicate these efforts. (See also Figures 2–4 and Section 3.1.1)
b. Demonstrated ability and experience to provide logistic support via accommodation, transportation, lunch/dining options, etc., to host international/regional scientists, engineers, technicians and students and/or agreements in place to facilitate hosting	Both laboratories have mature capabilities to assist in travel and site access. Facilitating and hosting international guests is accomplished through well-established organizations at both laboratories. COVID-19 restrictions can complicate these efforts. (See also Figures 2–6 and Section 3.1.1)
c. Number of international/regional conferences/workshops/symposia hosted and/or coordinated by the ICERR candidate	See Table 2 and Table 3 and Section 3.2.1.

4.2 Technical Indicators

Technical Indicators	INL/ORNL Compliance With Criterion
a. Number of international/regional programs (R&D and training) hosted and/or coordinated by the ICERR candidate in the area(s) of research reactor activities for which the designation is requested. i. Output of the programs (e.g., Final Reports). A selection of the outputs relevant to area(s) of research reactor activities for which the designation is requested will be reviewed.	See Table 4 and Table 5 and Section 3.2.1. Detailed bibliographies from both laboratories' publication record can be made available on request.
b. Number, duration and complexity of international/regional collaborative Agreements (including contracts) ongoing or successfully completed.	Numbers and durations of international and regional collaborative agreements such as CRADAs and SPPs discussed in Section 3.1.1 are available through the laboratories' contracts management organizations. "Complexity" is a metric currently not measured for these collaboration agreements. Also, see Section 3.2.1.
c. Number of international/regional hosted scientists/engineers/technicians/students involved in ICERR candidate activities; duration and complexity of these activities.	Totals for all international and regional individuals involved in collaborative activities are not collected and measured in s single cohesive database. Numbers of visitors, interns, post-docs involved with the laboratories have been identified in Section 3. Complexity is a metric not measured. Also, see Section 3.2.1.

Technical Indicators	INL/ORNL Compliance With Criterion
d. Evidence (meeting minutes, protocol, agreement, logbooks etc.) of existence of some type of an advisory board (e.g., Scientific Committee) to evaluate the requests of potential users in case of the dedicated access to the reactor is required.	Individual working groups assess both research-reactor and nuclear-facility work requested and support available at both laboratories. The ATR User's Working Group, for example, develops the Integrated Strategic Operating Plan for each operating cycle for the reactor to ensure this capability is optimized across all requestors. At MFC, a detailed mission outcome list of performance milestones is developed and tracked, in conjunction with end users, to plan out R&D support for the year. The HFIR participates in multiple advisory panel reviews, covering both operations and scientific productivity. Scientific reviews are primarily focused on scientific output of the neutron scattering scientific output. NSUF has a formal process for proposal calls that can access INL and ORNL facilities for domestic-led research teams. Neither lab structure currently supports international calls for proposals outside NSUF.
e. Evidence (meeting minutes, protocol, agreement, logbooks etc.) of managerial measures taken to evaluate the requests of potential users for Human Resources development requests.	Argonne National Laboratory (ANL) partners with INL and ORNL, supporting the DOE sponsored GAIN initiative (see Section 3.3). The ANL International Programs Office provides support to the US Department of State regarding peacetime IAEA matters. It provides technical coordination, administering IAEA support across the US. ORNL and INL would coordinate support to IAEA member states through ANL International Programs. Both laboratories are part of the DOE NSUF and participate in annual requests for proposals. Proposals are currently led by a domestic entity (American university, US government agency, or US industrial partner) and can include international participation.
f. Number, duration and complexity of international/regional users requests accepted and completed or in progress in the area(s) of research reactor activities for which the designation is requested compared with the total number of requests received.	The laboratories do not capture this statistic. Several methods for collaboration are available, and statistics for current CRADAs, for example, are available. Requests for support from the laboratories are routed through channels depending on the nature of the request, as discussed in Section 3.1. The only measurable data that ORNL tracks are DOE User Facility statistics, which total over 3100 users per year. Over 490 of these users visited HFIR in 2015 for neutron scattering research. Of those, 239 users were U.S. citizens, 126 were foreign nationals from non-sensitive countries, and 125 were foreign nationals from sensitive countries. Nuclear materials and fuels research is not part of a formal user facility and is not tracked as such. Limitations arise from operating capacity and commitments for laboratory capabilities that exist at the time of a request.

Technical Indicators	INL/ORNL Compliance With Criterion
g. Quantity of feedback provided to the IAEA call for proposals to assist Member States seeking access at a nuclear infrastructure to develop a specific capability.	INL and ORNL currently do not track this metric. Argonne National Laboratory coordinates IAEA requests through a US State Department contract for work for others.
h. Number of long-term (>3 months) Secondees hosted and integrated in the local team	Along with post-doctorate and internship opportunities, the Department of Energy provides has an Exchange Visitor Program Participant process. ORNL and INL currently host international visitors, and the INL currently hosts 16 international visitors through this program, with stays varying from a few months to up to a year. This is coordinated through the INL University Partnerships and Outreach organization.
i. Output production of Secondees after their stay at the ICERR candidate.	Statistics related to output of international visitors after working at the ORNL or INL are currently not captured.
j. Users (Secondees/researchers/trainees/ etc.) feedback (investment vs. benefit value statement).	Post-docs, interns, and international visitors are interviewed prior to departing the INL. Questionnaires supporting this process are filled out during by participants. This information is used to enhance the experience for future participants. ORNL collects detailed feedback from user facilities, but no exit feedback is requested from non-User-facility visitors.
k. Evidence of ICERR candidate staff and organizational structure dedicated to training issues.	Both laboratories have mature, dedicated training organizations with capabilities to develop training programs as needed for laboratory operations and to assist technical groups in developing technical-training programs for interested parties. Also, see Section 3.2.1.

4.3 Sustainability Indicators

Sustainability Indicators	INL/ORNL Compliance With Criterion
a. Evidence (e.g., letter of commitment, Annual Activity and Progress Report, Strategic Plan, etc.) of mid-term (3-5 years) commitment regarding financial and human resources made available to assure continuous and reliable operation of the ICERR candidate's research reactor(s).	Both laboratories are operated for the DOE and are part of the annual federal budgeting process. Both laboratories have developed detailed strategic initiatives to ensure sustained continuity of operations well into the future (e.g., the MFC Five-Year Investment Strategy (5YS), ATR Long-Term Asset Management Investment Strategy (ATR-LTAM), HFIR 3-yr plan, INL and ORNL Lab Plans, and ORNL Hot Cell 3-year plans). As part of the federal budget process, each laboratory has a 5-year budget plan in place to support research operations. These budgets are developed with DOE and are updated and submitted on an annual basis as part of the federal government annual budget.
b. ICERR candidate's research reactor(s) Operating License(s) expiration date; if necessary, evidence of ongoing renewal process.	Reactors and ancillary facilities are operated for, and regulated by, the DOE. Both laboratories have long-term missions and are operated under non-expiring licenses.

Sustainability Indicators	INL/ORNL Compliance With Criterion
c. Evidence that the ICERR candidate is aware of the latest development worldwide of technology, methodology and standards in the area of the research reactor activities for which designation is requested and, if applicable, has addressed identified gaps.	INL and ORNL are actively engaged both nationally and internationally with nuclear R&D. Staff from both laboratories actively lead and participate in nuclear technology methodology and standards development, identification of research-capability gaps, and proactive development of new capabilities to address these gaps. Also, see Section 2 and Section 3.2.2.
d. Evidence that fuel issues (HEU, LEU, and HALEU conversion, fuel supply and back-end) are addressed by the ICERR candidate in order to sustain operation.	LEU fuels are being developed for ATR, ATRC, and HFIR. NRAD has already converted to LEU. TREAT has never needed a refuel but is on the docket for fuel development. This conversion effort began as the RERTR program funded by the Department of Energy and continues today. INL is actively producing HALEU to support advanced reactor fuel feedstock. Fuel production and disposition is well-established and stable for the foreseeable future.
e. Evidence that ageing management issues are addressed by the ICERR candidate in order to maintain reliable operation.	Both laboratories are proactive in identifying lifecycle management activities necessary to ensure sustained operations into the future. For example, the ATR reactor complex and MFC, as well as HFIR and ORNL hot cells, have plans in place to sustain operations well into the future. (MFC 5YS, ATR-LTAM). Both INL and ORNL have multi-year strategic plans and mature maintenance programs to ensure continuity of operations well into the future.
f. Evidence that waste management issues are addressed by the ICERR candidate in order to maintain reliable operation.	The INL and ORNL have mature waste management programs in place to support research operations and the disposition of materials resulting from these operations. These include licensed waste treatment, storage, and disposal facilities on-site as well as commercial and federal off-site waste disposition partnerships.

5. SUMMARY

The U.S. Department of Energy operates two laboratories with research reactors that offer unique capabilities that can serve the needs of IAEA member states. While the individual missions of these laboratories and reactors are unique, the overall mission of the DOE is to ensure security and prosperity by addressing energy, environmental ,and nuclear challenges through transformative science and technology solutions.

The mission of DOE-NE is to advance nuclear energy science and technology to meet the nation's energy, environmental, and economic needs.[d] Accomplishing this mission will realize the enormous potential of nuclear energy worldwide.

The mission of the DOE Office of Science is the delivery of scientific discoveries and major scientific tools to transform our understanding of nature and to advance energy, economic, and national security. DOE-NE has established GAIN to provide the nuclear community with access to the technical, regulatory, and financial support necessary to move innovative nuclear energy technologies toward commercialization, while ensuring the continued safe, reliable, and economic operation of the existing nuclear fleet. INL has been selected by DOE-NE as the lead nuclear energy laboratory for GAIN. INL, in partnership with ORNL and Argonne National Laboratory, has been tasked to implement this important new initiative. Developing collaborative partnerships nationally and internationally with universities, private industry, and IAEA member states is a crucial part of this strategy to develop advanced nuclear energy technologies. IAEA designation as an ICERR will provide a powerful vehicle to support this crucial national and international role.

ORNL operates programs primarily within DOE's Office of Science. This includes work in the areas of Basic Energy Sciences (the funding agency of the HFIR), Office of Nuclear Physics, Office of Fusion Energy, as well as Biological Sciences and Leadership Computing.

Nuclear-related work at ORNL involves research into revolutionary materials for current and next-generation reactors and fusion energy, research in the areas of isotope production, and heavy element research, supporting new, super-heavy element discoveries.

INL and ORNL have research reactors and ancillary support facilities that play an important role in developing advanced nuclear energy technology. These facilities and the international research community will benefit from an ICERR designation and the collaborative opportunities resulting from this important designation.

d. *DOE Office of Nuclear Energy Strategic Vision*, January 2021.