



August 27, 2025

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Materials and Fuels Complex  
Idaho National Laboratory



# Overview of the INL Materials and Fuels Complex

# Our Heritage: *The National Reactor Testing Station drove nuclear innovation in the U.S. and around the world*

- 1<sup>st</sup>** Nuclear power plant
- U.S. city to be powered by nuclear energy
- Submarine reactor tested; training of nearly 40,000 reactor operators until mid-1990s
- Mobile nuclear power plant for the army

Demonstration of self-sustaining fuel cycle

Basis for LWR reactor safety

Aircraft and aerospace reactor testing

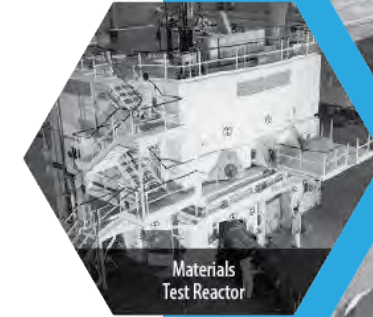
Materials testing reactors



Special Power Excursion Reactor Tests I through IV



Experimental Breeder Reactor-I



Materials Test Reactor



Loss of Fluid Test Facility



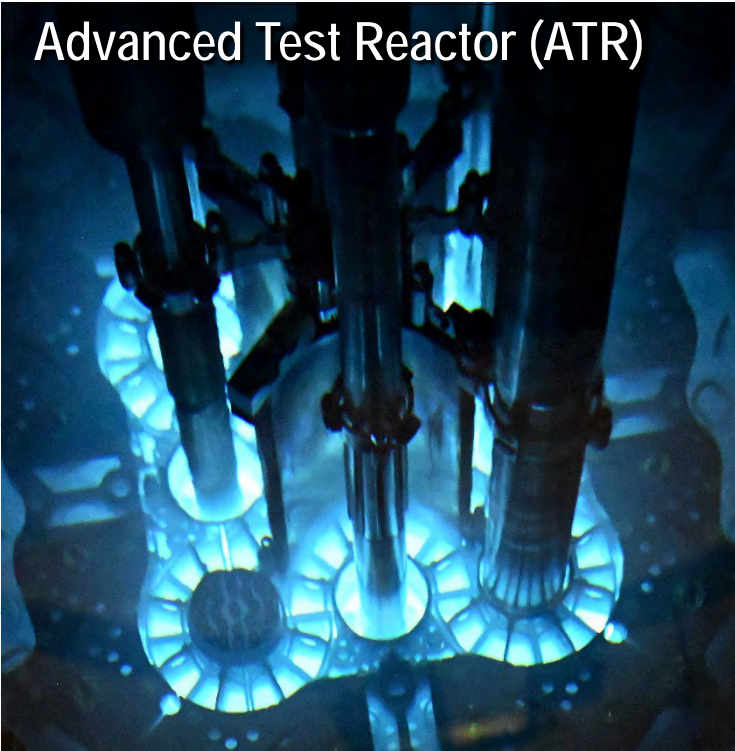
Boiling Water Reactor Experiments I-V



S1W - aka Submarine Thermal Reactor

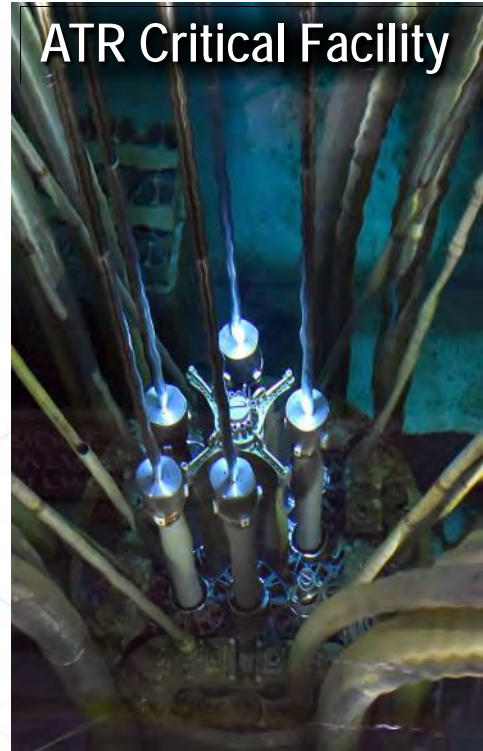
# INL's 4 operating research reactors in 2025

Advanced Test Reactor (ATR)



World's most powerful and versatile thermal spectrum test reactor (250 MW thermal)

ATR Critical Facility



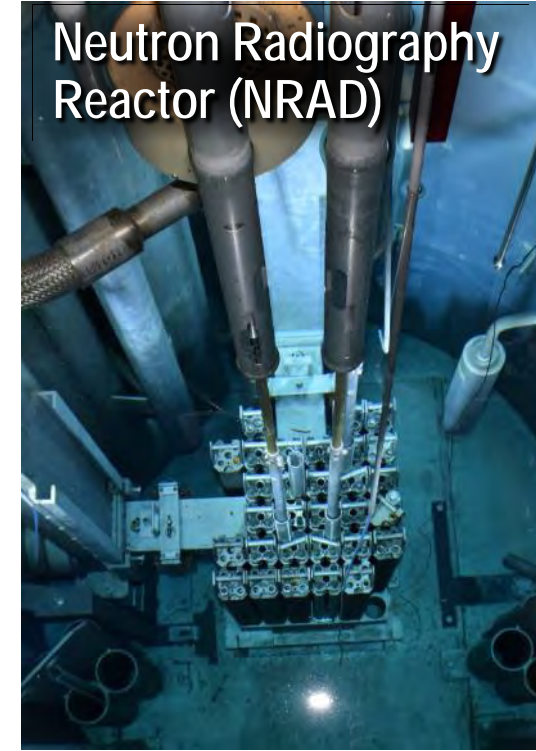
Low power support facility for ATR, and limited irradiation testing (600 W)

Transient Reactor Test (TREAT) Facility



World's most versatile reactor for testing under accident scenarios (120 kW steady state, 18 GW max pulse)

Neutron Radiography Reactor (NRAD)

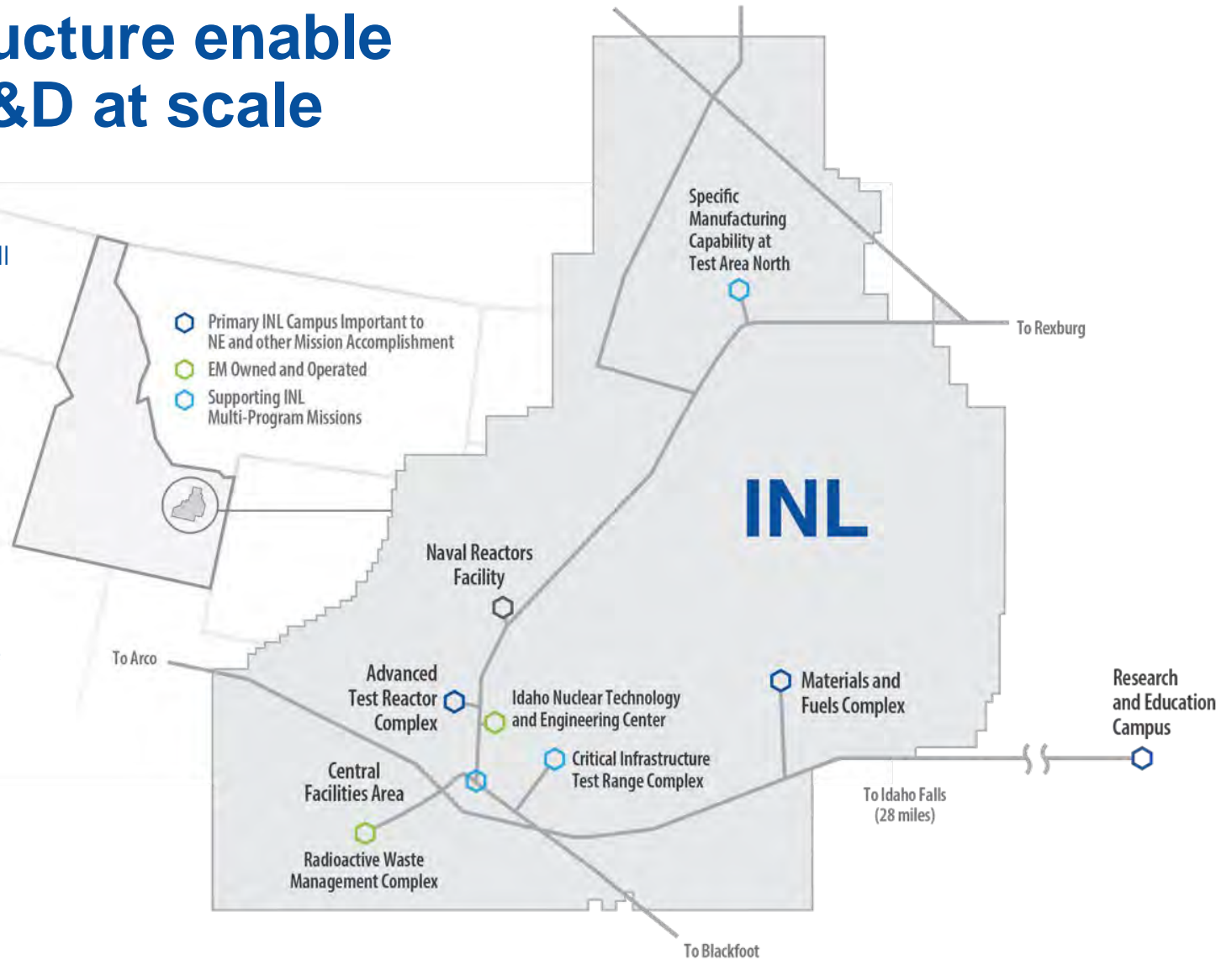


250kW research reactor used for neutron radiography, advanced imaging, and limited irradiation testing

# Unique site and infrastructure enable energy and security RD&D at scale

- 4 Operating reactors
- 49 Radiological facilities/activities
- 144 Miles high-voltage transmission & distribution lines
- 44 Miles primary roads (125 miles total)

- 22 Hazard Category II & III non-reactor facilities/activities
- 17.5 Miles railroad for shipping nuclear fuel
- 11 Substations with interfaces to three power providers
- 3 Fire Stations



# Creating an abundant, affordable, secure, resilient energy future



Advanced  
Test Reactor  
Complex



Energy &  
Environment  
Science &  
Technology



Nuclear Science  
& Technology



Materials and  
Fuels Complex



National &  
Homeland  
Security Science  
& Technology

# Nuclear Research, Development & Demonstration Team at INL

## *Unique Research Facilities and Infrastructure/Foundational Enablers*

**~2,000** staff working to revive, revitalize, and expand nuclear energy, enabled by unique research facilities, infrastructure, & capabilities

### Nuclear Science & Technology

Change the world's energy future by advancing nuclear energy.

- Nuclear fuels and materials
- Nuclear safety and regulatory research
- Nuclear systems design and analysis
- Advanced Scientific Computing
- Fuel cycle science and technology

**589 Employees** • **250 Ph.D.** • **140 Bachelor** • **16 Assoc./ Tech**  
• **146 Master** • **22 Postdocs** • **Some College**

### Materials & Fuels Complex

Experiments and engineering that drive the world's nuclear energy future.

- Transient testing
- Analytical laboratories
- Post-irradiation examination
- Space nuclear power and isotope technologies
- Fuel Fabrication
- Advanced characterization

**863 Employees** • **63 Ph.D.** • **293 Bachelor** • **150 Assoc./ Tech**  
• **106 Master** • **6 Postdocs** • **Some College**

### Advanced Test Reactor

Provide unique irradiation capabilities for nuclear technology research and development. Steady-state neutron irradiation of materials and fuels.

- Naval Nuclear Propulsion Program
- National laboratories and universities
- Industry

**408 Employees** • **3 Ph.D.** • **130 Bachelor** • **86 Assoc./ Tech**  
• **59 Master** • **0 Postdocs** • **Some College**

# MFC: Leading U.S. center for nuclear energy RD&D

- MFC is a center for nuclear energy research, development, & demonstration (RD&D)
  - Equipped with a diverse array of laboratories, hot cells, and other facilities designed for remote work on special nuclear materials, highly irradiated fuels and materials.
  - Missions supported include nuclear energy RD&D, national security research and training, assembly and testing of radioisotope power sources for space missions.
  - MFC reactors and facilities along with the ATR are designated as an International Centre based on Research Reactors (ICERR) by the International Atomic Energy Agency (IAEA).



**MFC is a national asset available to universities, industry, other national laboratories, international research organizations, and other federal agencies.**

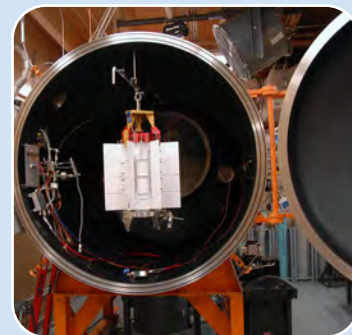
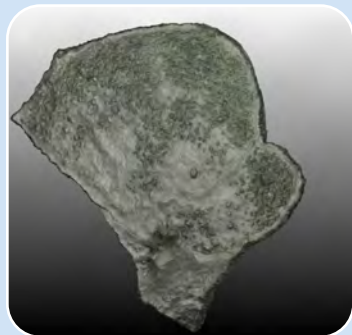


# MFC Mission: *Experiments, engineering and demonstrations that drive the world's nuclear energy future*

- 1,129 employees on site daily
  - 942 MFC
  - 187 support organizations
- 29 mission facilities, including
  - 2 operating reactors
  - 13 Hazard Category 2 or 3 facilities
- Dedicated to DOE-NE's mission to advance nuclear energy science and technology to meet the nation's energy, environmental, and economic needs



# MFC Nuclear RD & D Capabilities



## Fuel Fabrication

- Experimental Fuel Facilities
- Fuels & Applied Science Building
- Fuel Manufacturing Facility
- Zero Power Physics Reactor
- Analytical Laboratory
- Advanced Fuels Facility

## Fresh Fuel Characterization

- Fuels & Applied Science Building
- Analytical Laboratory
- Experimental Fuel Facilities

## Irradiation

- Transient Reactor Experiment & Testing (TREAT)
- Neutron Radiography Reactor (NRAD)
- Advanced Test Reactor (ATR)
- Offsite Reactors

## Post-Irradiation Examination & Characterization

- Hot Fuel Examination Facility
- Irradiated Materials Characterization Lab
- Fuel Conditioning Facility
- Analytical Laboratory
- Fuels & Applied Science Building
- Electron Microscopy Lab
- Neutron Radiography Reactor (NRAD)

## Space Nuclear Power and Isotope Technologies

- Space & Security Power Systems Facility
- Engineering Development Lab
- Idaho Nuclear Technology & Engineering Center

## Advanced Reactor Demonstration Test Beds

- Laboratory for Operations and Testing in the US
- Demonstration of Microreactor Experiments
- TREAT micro-Reactor Experiment Cell

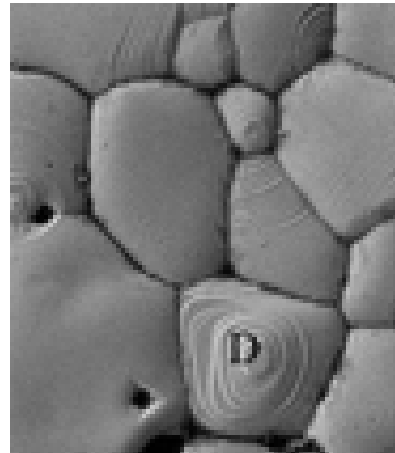
# MFC's Post-Irradiation Examination / Characterization capabilities span 10 orders of magnitude



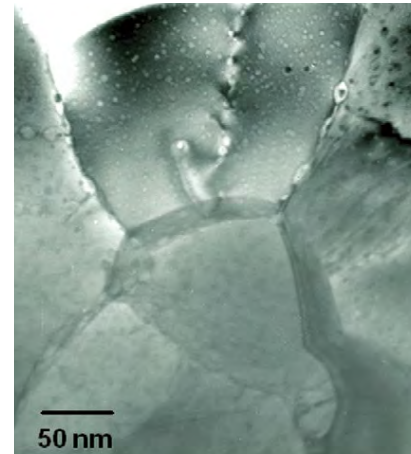
Fuel assembly (3 m)



Fuel pellet  
1 cm ( $10^{-2}$ )



UO<sub>2</sub> grain 10  $\mu$ m ( $10^{-5}$ )



50 nm  
UO<sub>2</sub> grain boundary  
2 nm ( $10^{-9}$ )

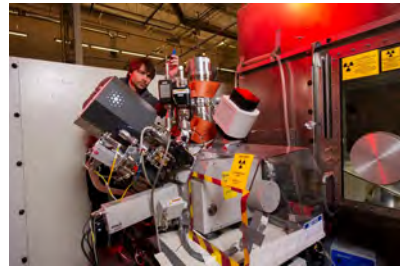


Individual atoms 3 Å ( $10^{-10}$ )

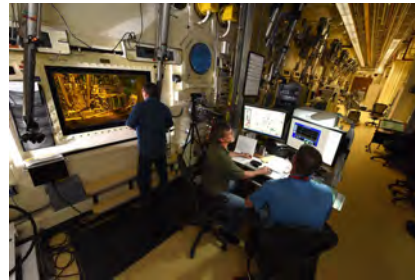
# MFC Main Facilities



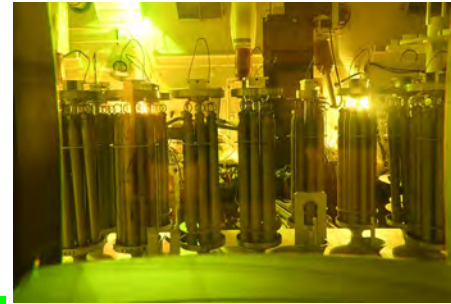
Analytical Laboratory



Irradiated Materials  
Characterization Laboratory



Hot Fuel Examination Facility



Fuel Conditioning Facility



Fuel Manufacturing Facility



Experimental Fuels Facility



EBR-II Dome



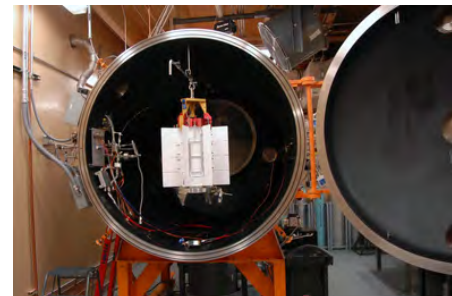
Transient Reactor  
Test Facility



Radiation  
Measurements  
Laboratory



Sample Preparation  
Laboratory



Space & Security Power  
Systems Facility



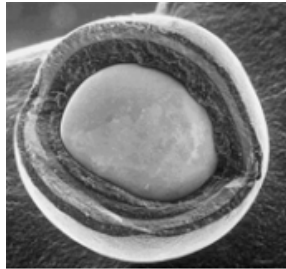
Radioactive Scrap & Waste  
Facility

# MFC Research, Development & Demonstration Core Competencies

Fuel Fabrication



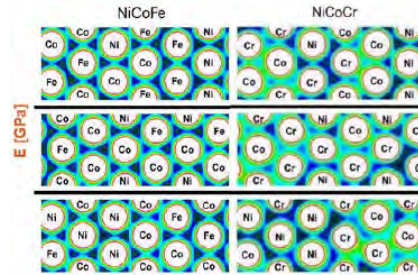
Fuel Characterization



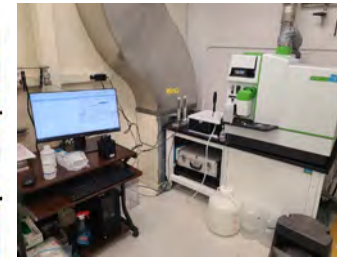
Fuel Recycling & Nuclear Material Management



Reactor Materials Characterization



Radioanalytical Chemistry



Transient Irradiation Testing



Reactor Safety - Design Integration, Authorization and Licensing



Test Bed Engineering and Advanced Microreactor Support



Nonproliferation & Nuclear Forensics



Isotope Production



Space Nuclear Power



Focused Basic Research



# MFC 5-Year Strategic Priorities

*Supporting INL's mission to discover, demonstrate and secure innovative nuclear energy solutions, other clean energy options and critical infrastructure*



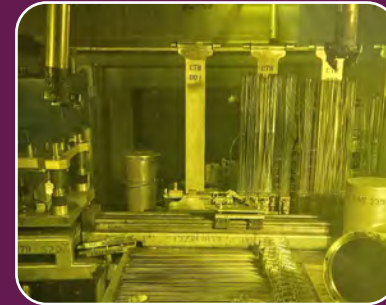
Enable demonstration of advanced reactors



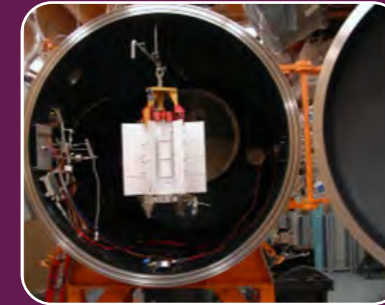
Fabricate nuclear fuel for testing innovative reactor fuel designs



Irradiate and analyze fuel and materials for nuclear energy applications

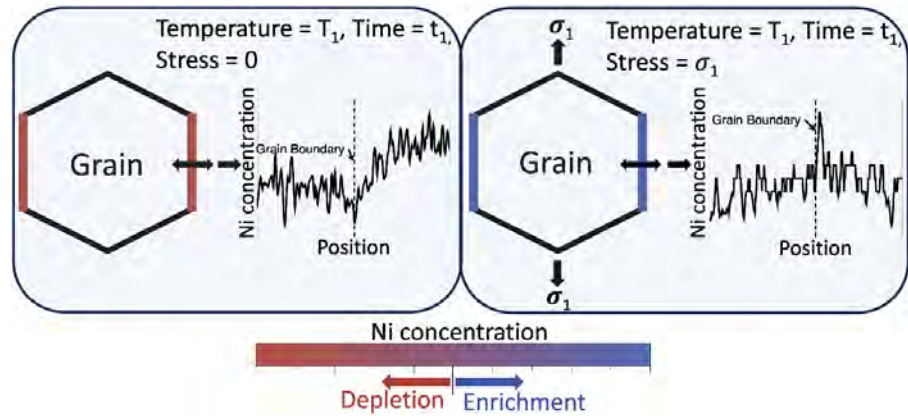


Fulfill environmental stewardship commitments and conduct fuel recycling R & D

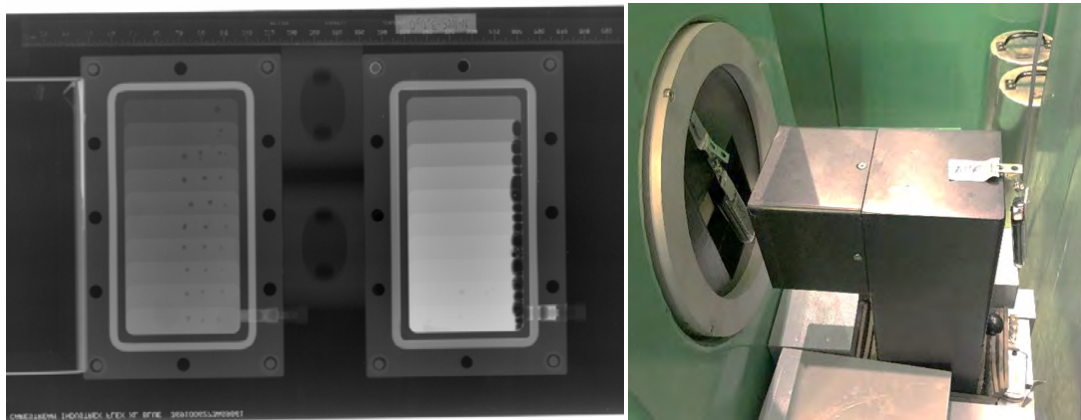


Provide components and technology for space radioisotope power systems

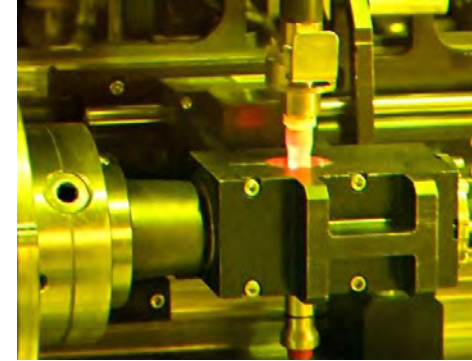
# Recent MFC Highlights



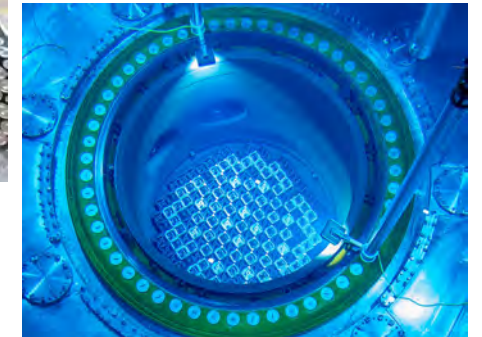
First experimental evidence for diffusional creep theories on creep-induced elemental redistribution in materials.



Record-breaking high-speed neutron imaging system at TREAT that enables two-phase flow visualization at PWR conditions



First reactivity-initiated accident testing of irradiated high-burnup LWR fuel in TREAT.



Loading of LEU+ fuel (up to 8%) in Vogtle-2. The higher-enriched  $UO_2$  powder was prepared and supplied by MFC.

# International Collaborations

- MFC has about thirty (30) ongoing international research collaborations.
  - 14 countries from Africa, Asia, Europe, North and South America
- Along with Oak Ridge National Laboratory, INL is designated as an IAEA International Centre based on Research Reactors (ICERR).
  - MFC personnel regularly participate in IAEA-sponsored missions such as Integrated Research Reactor Utilization Reviews (IRRURs).
  - MFC experts frequently contribute to updates and revisions of IAEA Nuclear Energy Series publications.



IAEA IRRUR meeting at La Reina Nuclear Centre, Chile



IAEA IRRUR meeting at South African Nuclear Energy Corporation (NECSA)



IAEA Technical Meeting on Applications, Products and Services of Research Reactors, Vienna



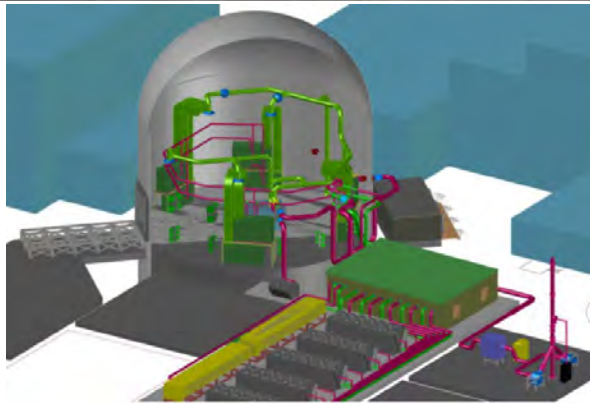
# **Advanced Reactor Demonstrations & Test Bed Preparation at MFC**

# Advanced Reactor Demonstration Test Beds at MFC

## DOME Test Bed (NRIC)

(Demonstration of Operational Microreactor Experiments)

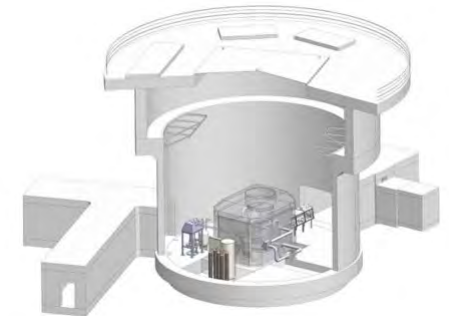
- Test bed for microreactors less than 20 MWt
- Reestablish capabilities of existing infrastructure



## LOTUS Test Bed (NRIC)

(Laboratory for Operation and Testing in the United States)

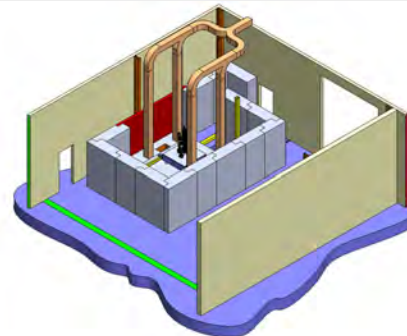
- Experimental test bed with 500kW heat rejection system



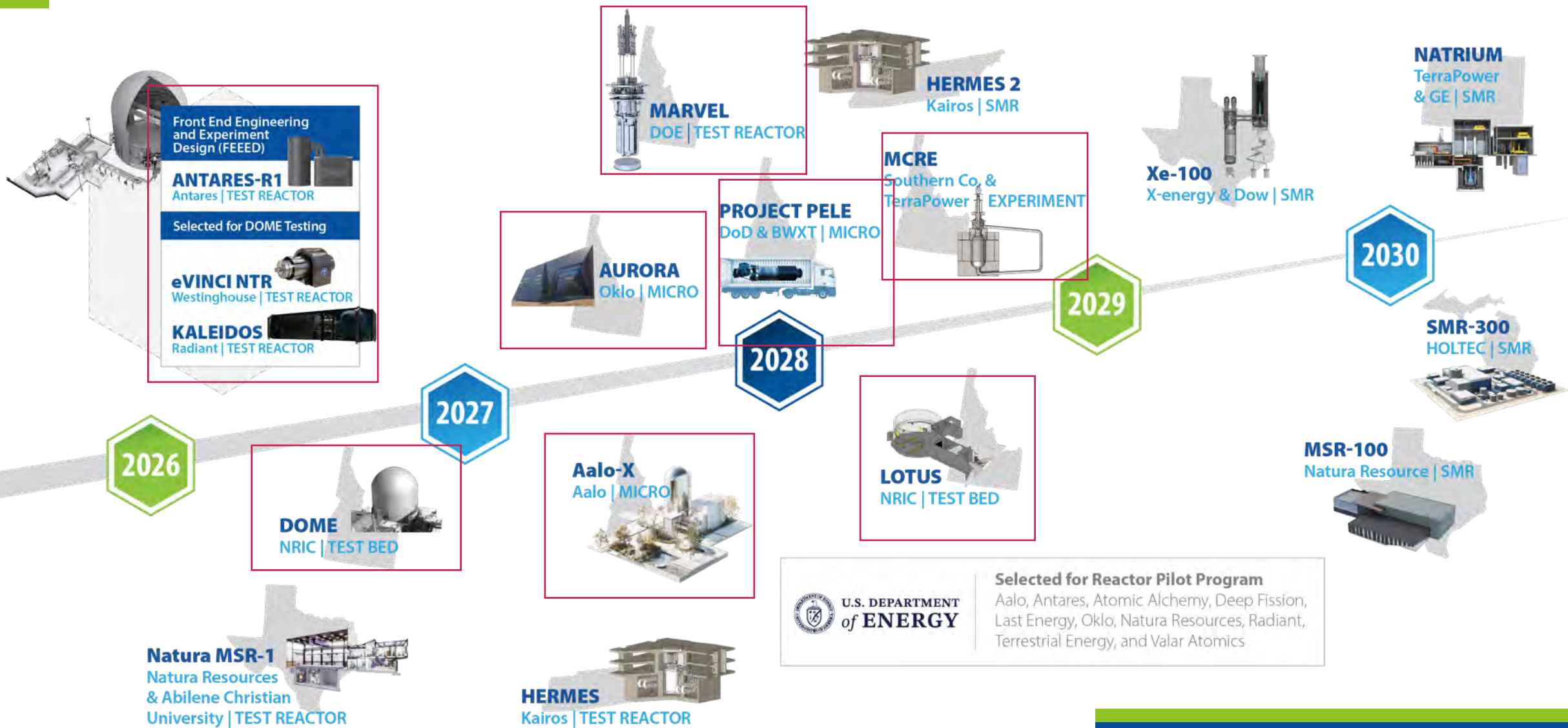
## (T-REXC) Test Bed

(TREAT micro-Reactor Experiment Cell)

Test bed for microreactors less than 100 kWt

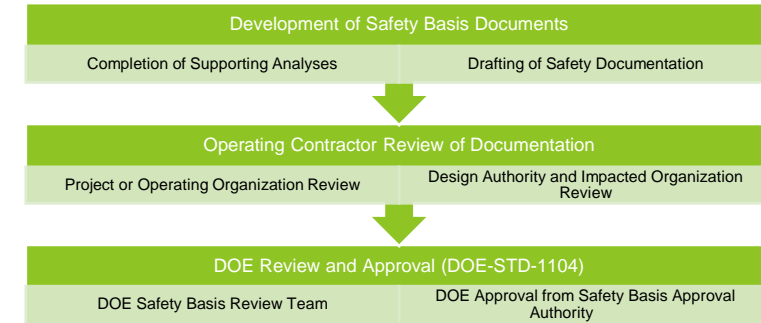


# Accelerating advanced reactor demonstration and deployment

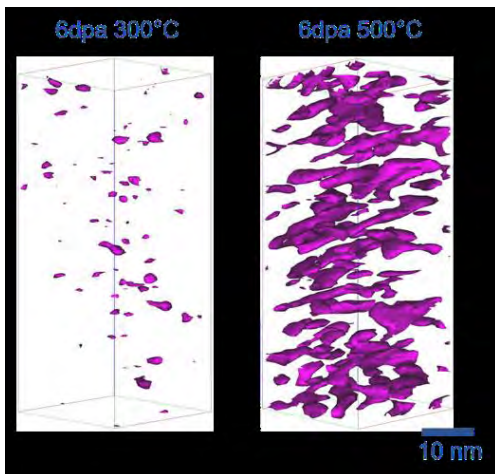


# INL research reactors are contributing to advanced nuclear RD&D on several fronts.

- The operating research reactors at INL are actively involved in the research, development and deployment of new fuels and materials for the next-generation advanced reactors and fuel cycle technologies.
  - Building on the rich legacy of INL test reactors to help bring about the current generation of commercial reactors,
- In addition to R & D, INL is leveraging its experience in research reactor licensing and operations to enable advanced reactor demonstrations.



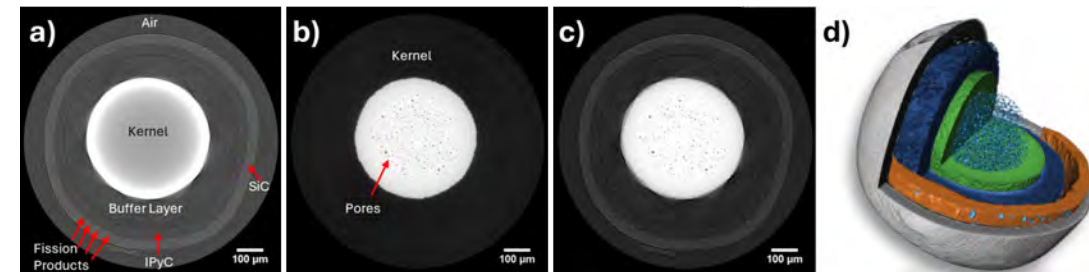
Design & licensing support for demonstration reactors



Atom Probe Tomography studies on FeCrMnNi compositionally complex alloy irradiated in ATR



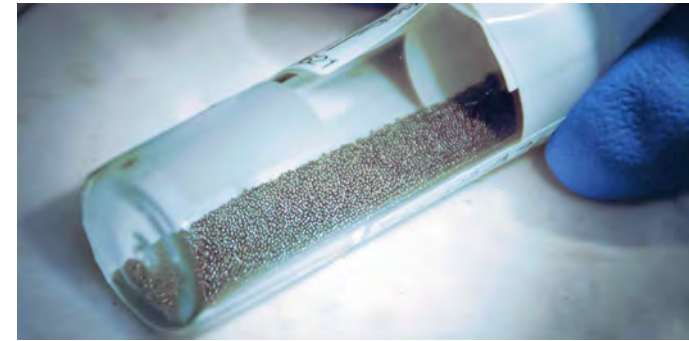
Fuel R & D - Irradiation of chloride-based HEU molten salt in NRAD



2D slices of a 3D reconstructed volume of an irradiated AGR-2 TRISO particle

# Fuel Supply for New Reactors

- MARVEL Fuel
  - Procured from TRIGA International
- MCRE Fuel Salt Synthesis Line
  - At scale process development Fuels & Applied Science Building (FASB)
  - Utilize institutionally-funded multi-purpose gloveboxes and systems being installed in the Fuel Manufacturing Facility (FMF)
  - Synthesis and store fuel salt in FMF
- OKLO- Aurora Fuel Fabrication Facility AF<sup>3</sup>
  - Upgrading MFC-798 to a new Hazard Category 2 nuclear facility
  - Design and install fabrication line (Injection casting)
  - Build first core





Idaho National Laboratory