INL/RPT-23-71911-Revision-0

Idaho National Laboratory Fuel Cycle Science & Technology Overview

April 2023

Michael Anthony Norato

Changing the World's Energy Future

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

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Idaho National Laboratory
Idaho Falls, Idaho 83415

http://www.inl.gov

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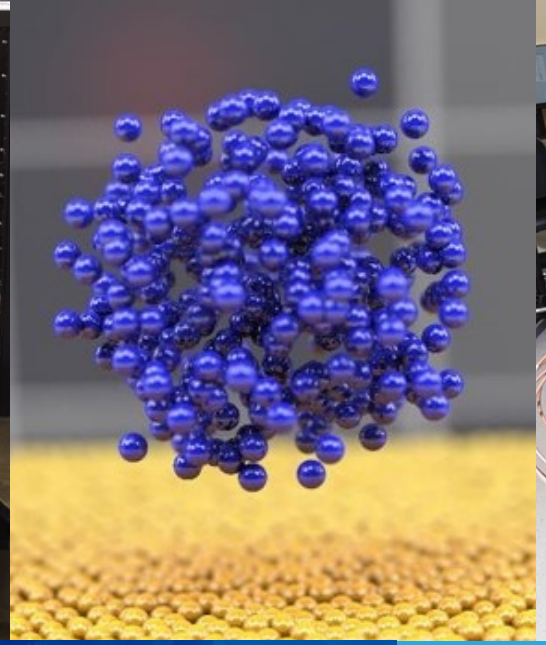



Michael A. Norato, PhD
Director, Division of Fuel Cycle Science & Technology

Nuclear Science & Technology Directorate

Idaho National Laboratory
Fuel Cycle Science & Technology Overview

Wyoming State Legislature Joint Committee on Minerals, Business & Economic Development Visit
April 18, 2023

INL is managed by Battelle Energy Alliance for the US Department of Energy

Idaho National Laboratory

Addressing the world's most challenging problems through research, development, and demonstration





VISION

INL will change the world's energy future and secure our critical infrastructure.

MISSION

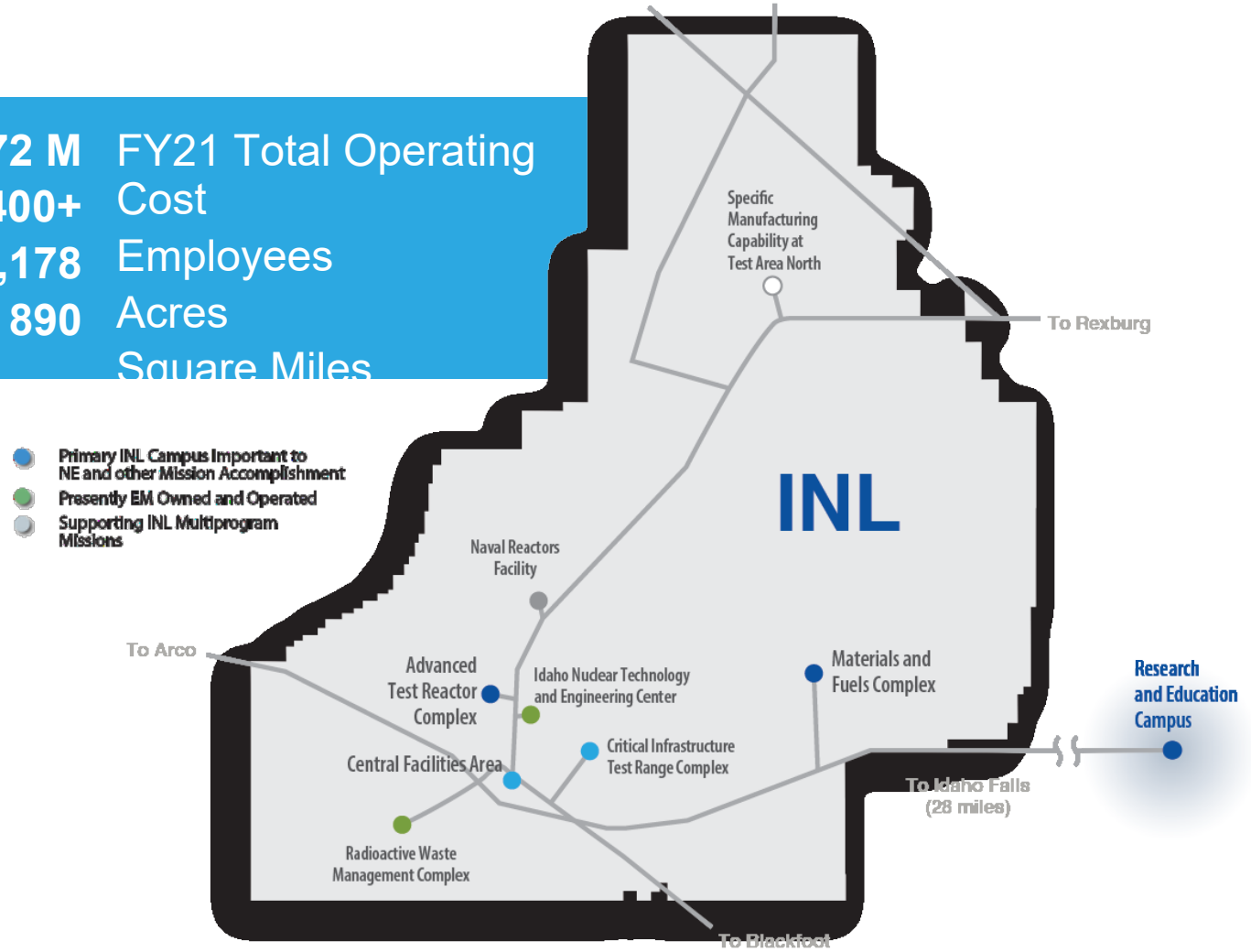
Discover, demonstrate and secure innovative nuclear energy solutions, clean energy options and critical infrastructure.

VALUES

Excellence, Inclusivity, Integrity, Ownership, Teamwork, Safety

Leveraging INL site, infrastructure, and facilities to enable energy and security R&D at scale

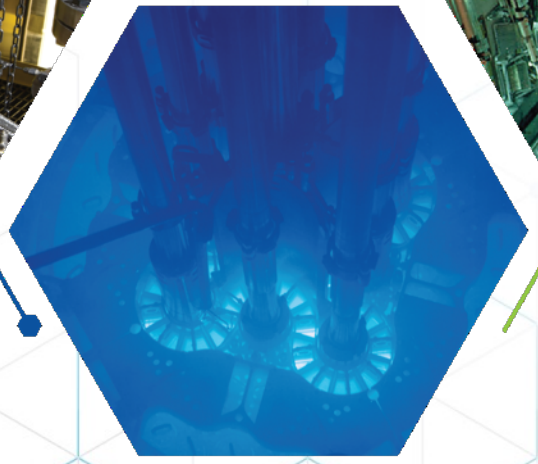
$1,572 M	FY21 Total Operating Cost
5,400+	Employees
569,178	Acres
890	Square Miles



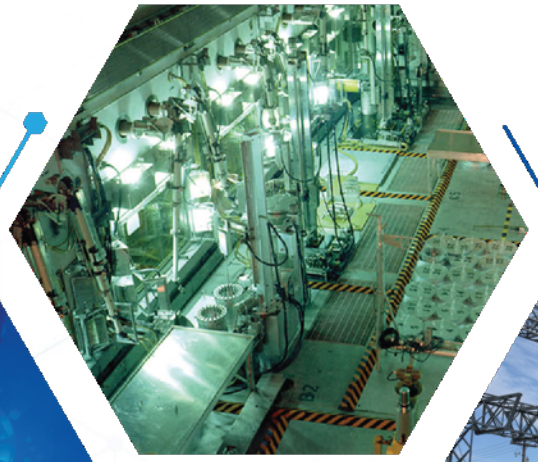
12	Miles high-voltage transmission lines
17.8	Miles railroad for shipping nuclear fuel
5	
4	Operating reactors
12	Hazard Category II & III non-reactor facilities/activities
50	Radiological facilities/activities
3	Fire Stations

Creating a secure, resilient, clean energy future

Nuclear Science & Technology



Advanced Test Reactor Complex

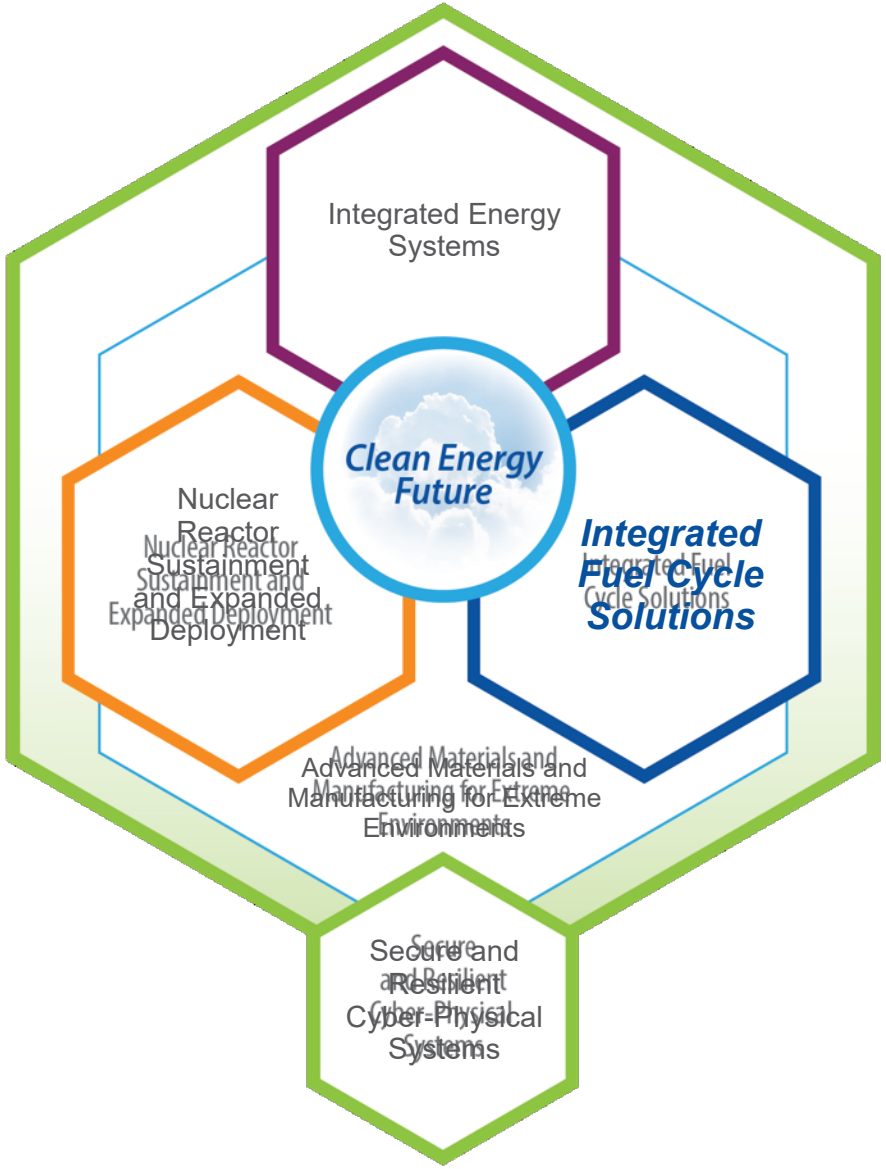


Materials and Fuels Complex

Energy & Environment Science & Technology

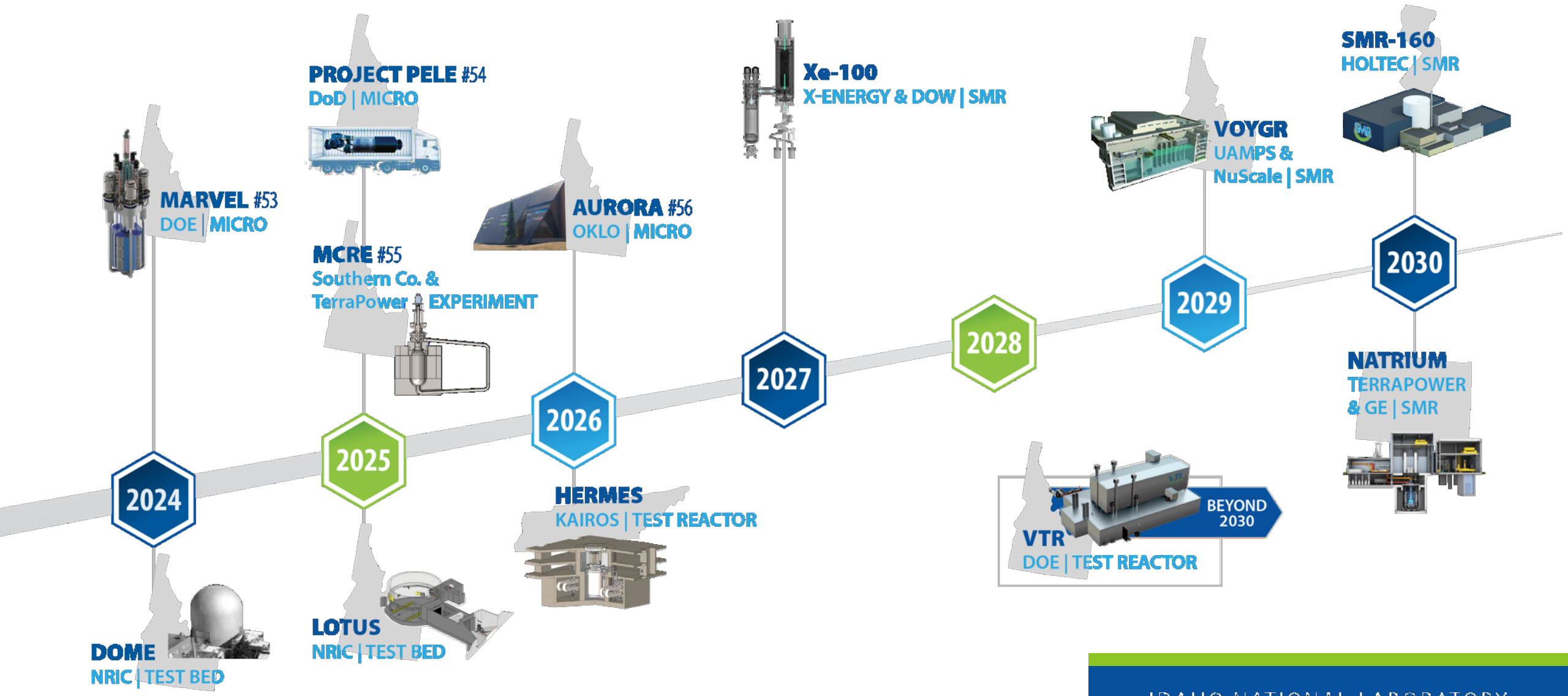
National & Homeland Security Science & Technology

Innovation for the clean energy future



INL strategic S&T initiatives support transforming the world's energy future and securing our critical infrastructure

Accelerating advanced reactor demonstration & deployment



FCS&T Division Strategy and Priorities

Mission

The Fuel Cycle Science & Technology Division delivers innovative leadership in the development and assessment of science and engineering-based solutions for the integrated nuclear fuel cycle, critical materials recovery, national security and space related applications through world-class staff and research capabilities.

Scope

Perform world-class aqueous and electrochemical separations research, from fundamentals to applied engineering demonstrations.

Leverage molten salt expertise to develop deeper understanding of molten salt chemistry and process monitoring in support of advanced reactor concepts.

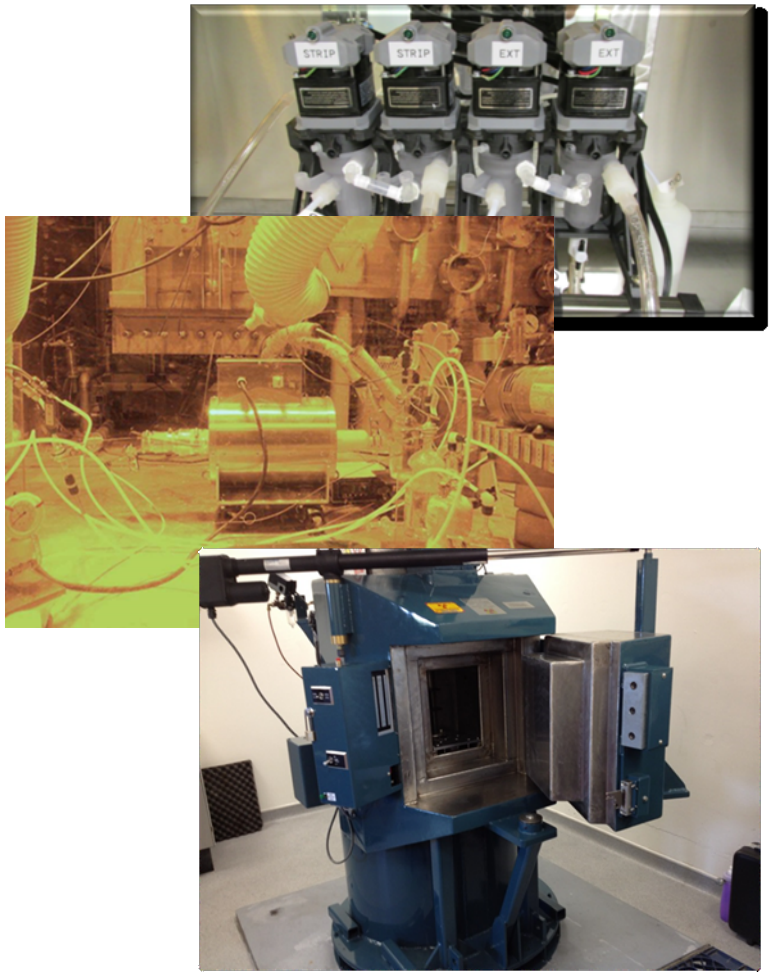
Provide comprehensive and innovative solutions to the challenges of storage, transportation, and disposition of used nuclear fuel.

Advance separation science, especially for lanthanides and actinides, supporting all three mission areas of the laboratory:

- NS&T – nuclear fuel cycle, waste management, feed for advanced reactors, isotopes and medical applications, and radiation chemistry
- N&HS – non-proliferation, signatures, training, and classified programs
- EES&T – critical materials (e.g., rare earth recovery and recycling)

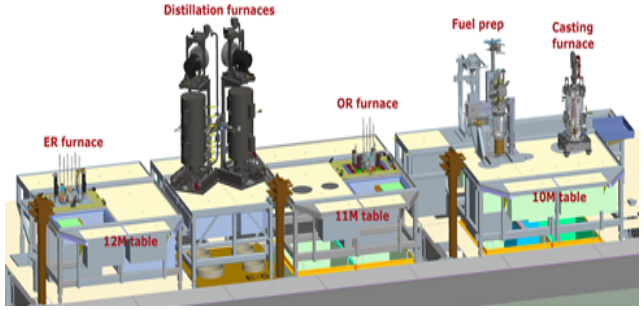
Aqueous Separations and Radiochemistry
Melissa Warner– Department Manager

- Flowsheet development and testing for advanced fuel cycles and critical materials recovery/separation
- Off-gas capture (I and Kr)
- Radiation chemistry
- Solvent degradation chemistry
- Complexation chemistry
- High-assay LEU recovery from zirconium and aluminum fuels
- HEU/HALEU polishing/down-blending/conversion
- National security missions
- Critical Materials Institute.



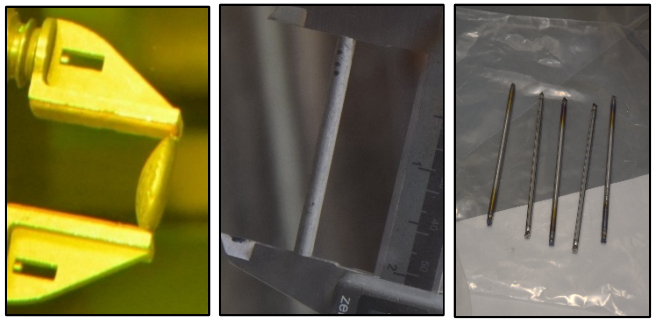
Pyrochemical Science
Ken Marsden – Acting Department Manager

- Pyrochemical recycling of oxide and metal fuels
- Immobilization processes and waste forms
- Base and strategic metal recovery/recycle/purification
- Safeguards and material accountancy in high temperature systems
- Process modeling
- EBR-II spent fuel processing technical support



Schematic of Scalable Pyrochemical Recycling (SPyRe) Testbed in HFEF

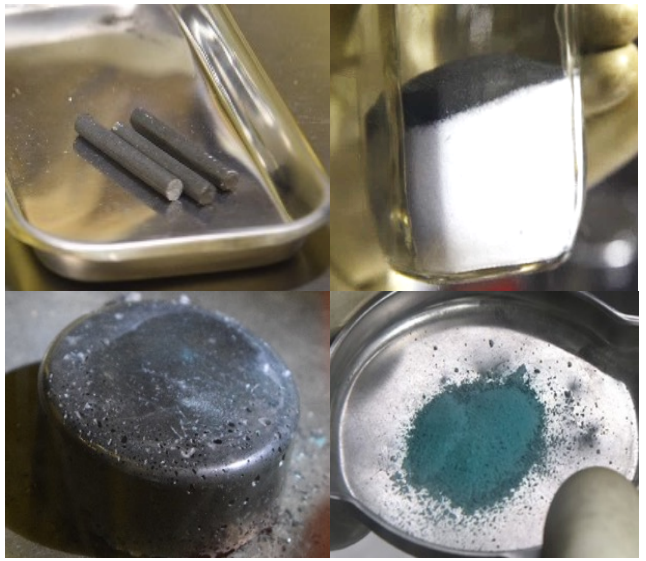
Modular Electrorefiner Test Station



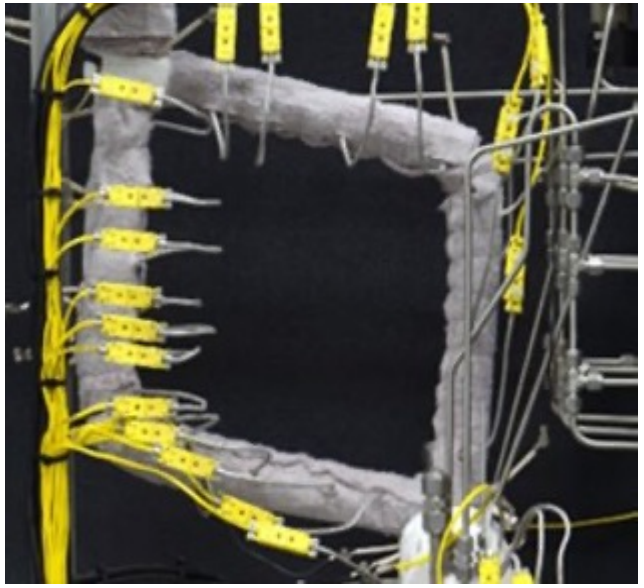
~100 gram U/TRU product, metallic fuel, and test rodlets produced from recycled oxide fuel

Advanced Technology of Molten Salts
John Carter – Department Manager

- Synthesis and purification of salts, specifically, proprietary fuel salt compositions needed for testing of novel advanced reactor concepts.
- Development of the world's first center for post-irradiation examination of molten fuel salts with the Molten Salt Thermophysical Examination Capability (MSTEC).
- Research facilities provide the nation with an experimental testbed for fundamental studies on corrosion, thermophysical properties, and speciation for solar, energy storage, uranium, transuranic, and irradiated salts at high temperatures.
- Team is actively supporting mission essential design and development for advanced reactor demonstrations, including the molten chloride reactor experiment (MCRE).
- Team actively engages with the broader molten salt community to support development of Multiphysics modeling and simulations, educate and grow the next generation of scientists, and maintain world leading expertise in molten salt technologies.



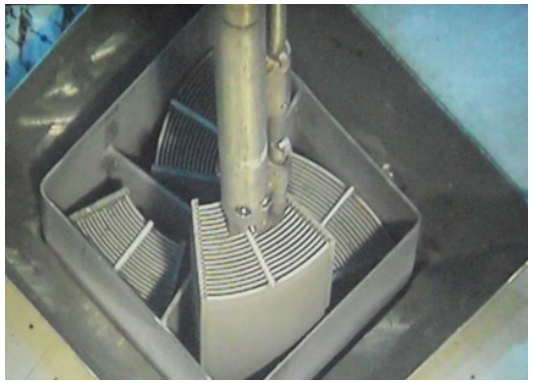
$PuCl_3$-NaCl fuel salt fabrication starting from plutonium metal rods.



Terra Power $PuCl_3$ Flow Test Loop

Used Nuclear Fuel Management
Dan Thomas – Department Manager

- Used nuclear fuel transportation, packaging, and interim storage
- Disposition of DOE-EM legacy materials
- Commercial and non-commercial used fuel disposition
- Used nuclear fuel monitoring and instrumentation



Advanced Test Reactor fuel elements

Building CPP-603 dry storage system at the INL site

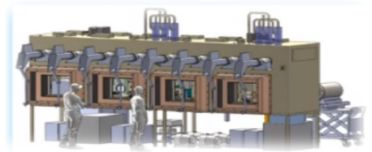
Integrated Fuel Cycle Solutions

Supports the safe, secure, and economic management of nuclear materials from inception to final disposition

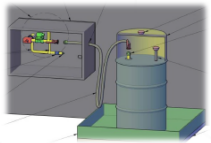
- Ensuring availability of special nuclear materials and strategic isotopes
- Reducing proliferation risk
- Managing radiological waste materials and used nuclear fuels
- Developing RD&D test beds

New and upcoming fuel cycle test bed capabilities at MFC-FCF

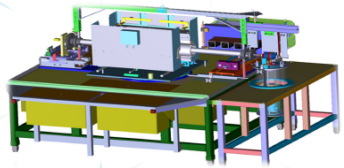
Strategic investments support development of new expertise and capabilities



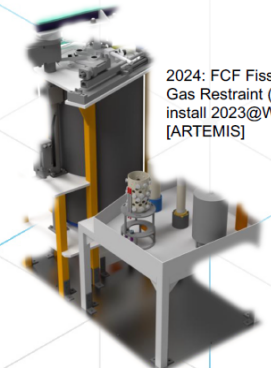
2023: Molten Salt Thermophysical Examination Capability (MSTEC) Room 35 A/B [NRIC]



2024: RLWTF Waste Drum Station [IFM]



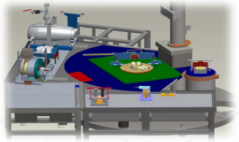
2023: FCF Air Cell Air/Moisture Ingress Experiment (AMIX); install 2022 @WA3 [AGR]



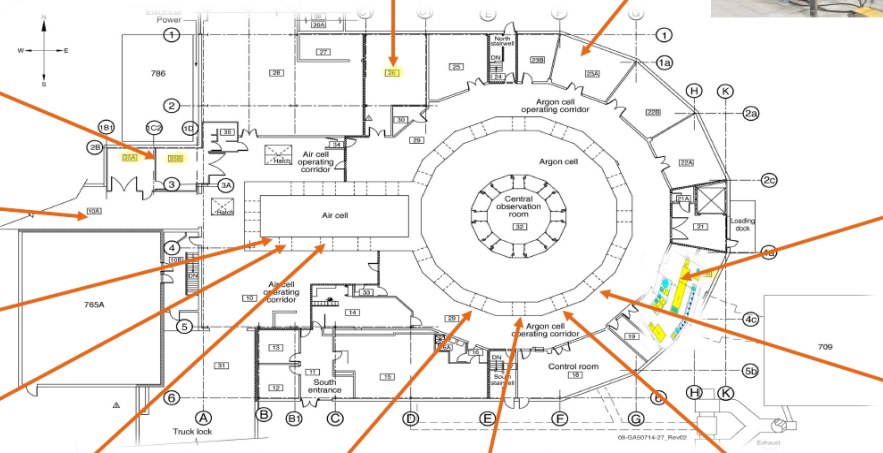
2024: FCF Fission Gas Restraint (FGR); install 2023@WA2&3 [ARTEMIS]

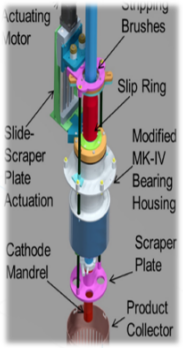
2023: FCF Air Cell VERSA Tele-manipulator @WA2 [IFM]

2018: FCF Fuel Cycle Glovebox (FCGB) Room 26 [JFCS/Materials Recovery Waste Form Development]



2022: FCF Fuel Bottle Inspection upgrade @W13 [IFM]



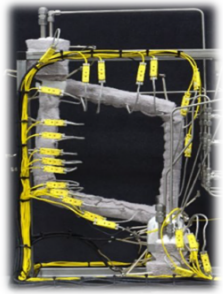


2022: Scraped Cathode Rod Assembly Prototype Equipment (SCRAPE) @ W12 [IFM]

2023: FCF Vitrification Laboratory/GeoMelt Room 23A/B [JFCS/Materials Recovery Waste Form Development]

2023: Multi-Function Furnace (MFF); install 2022 @W11 [IFM]

2024: Beartooth (modern test bed) Project Integrated Fuel Cycle solutions (IFCS) Strategy install 2023 Room 20 A/B [Fuel Cycle Science & Technology]

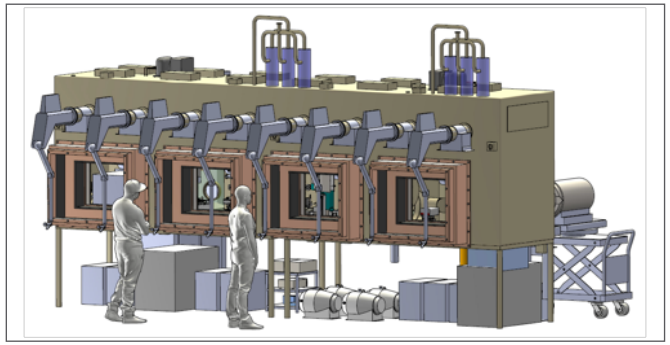


2022: FCF Terra Power PuCl3 Flow Test Loop @W10

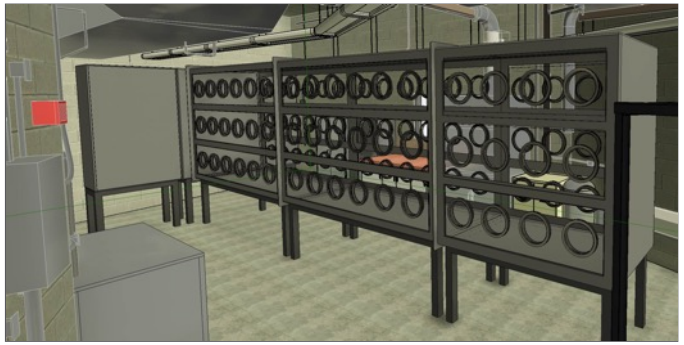
Upcoming test beds available at MFC starting 2023

Modern facilities to engage and train the next generation of fuel cycle experts

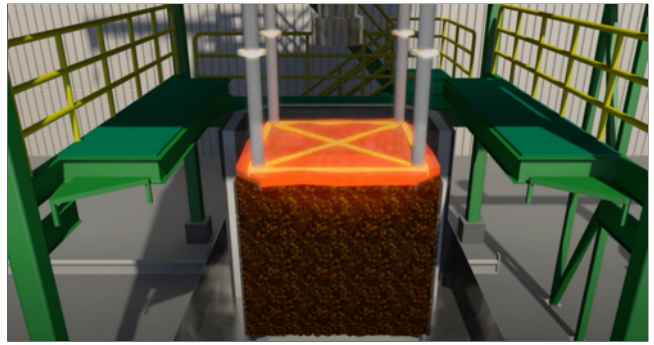
All new fuel cycle test beds are designed with the ability to demonstrate innovative safeguards and security concepts applicable to advanced reactors and their fuel cycles in support of national security objectives.



Molten Salt Thermophysical Examination Capability (MSTEC)
Platform to design, demonstrate, license, and operate MSRs



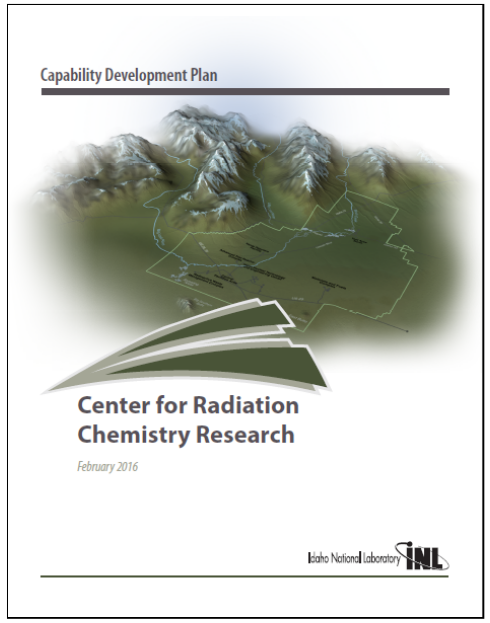
Beartooth - SNM Test Bed
Aqueous processing platform for demonstrating new safeguards and security concepts applicable to advanced fuel cycle operations

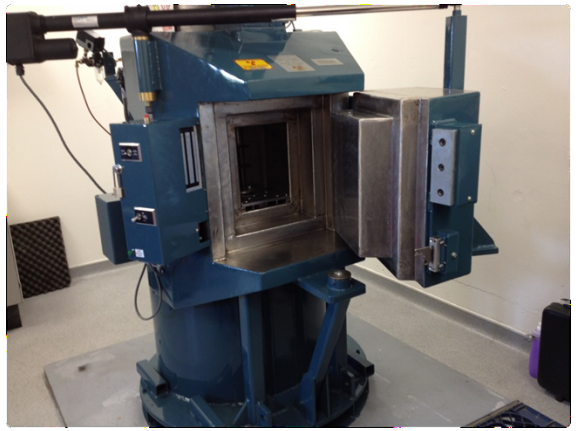


Sustainability – WM Test Bed
Platform to develop better more stable waste forms for final disposition in support of advanced reactor development and to address DOE legacy waste issues.

Center for Radiation Chemistry Research

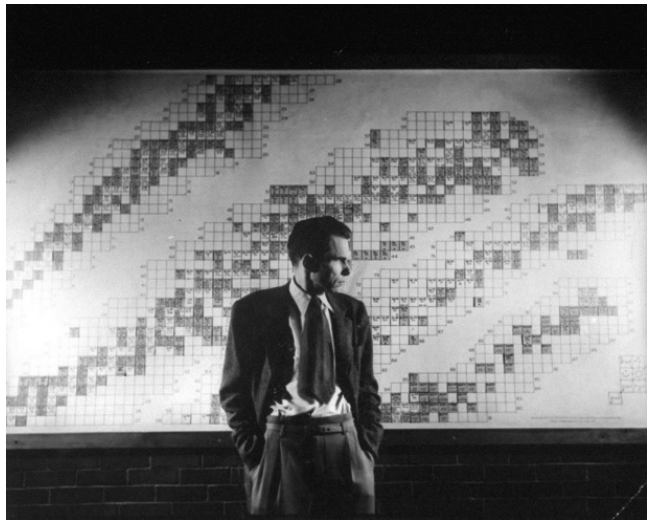
- **In 2016 we developed a Capability Development Plan to create the "Center for Radiation Chemistry Research" (CR2) to transfer and retain critical expertise in radiation chemistry related to the nuclear fuel cycle. The CR2:**
  - Transfers expertise to earlier career INL staff
  - Provides a plan to grow R&D in this field, within nuclear energy and with outside organizations
  - Defines staffing and equipment investment needs





Glenn T. Seaborg Institute

Glenn T. Seaborg
INSTITUTE
IDAHO NATIONAL LABORATORY



…to create a focus for actinide science in order to foster and develop U.S. pre-eminence in the science of the chemical, physical, nuclear, and metallurgical properties of the actinide elements.

- INL's Glenn T. Seaborg Institute kicked off in late 2017
- 9 Distinguished Post-docs hired to date
- 2 - 3 more expected to onboard in 2022
- The deputy director of the GTSI is from the FCS&T division (Don Wood)

Idaho National Laboratory

Battelle Energy Alliance manages INL for the U.S. Department of Energy's Office of Nuclear Energy. INL is the nation's center for nuclear energy research and development, and also performs research in each of DOE's strategic goal areas: energy, national security, science and the environment.