Brenden Heidrich,
Director

NSUF TEM Data Workshop

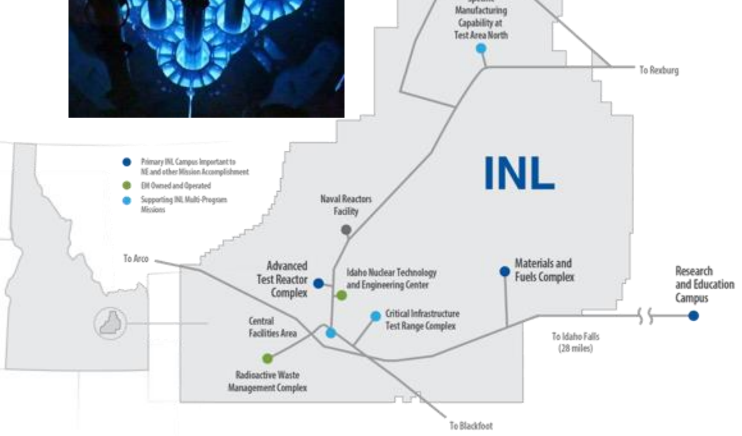
August 26, 2025

NSUF Program Overview

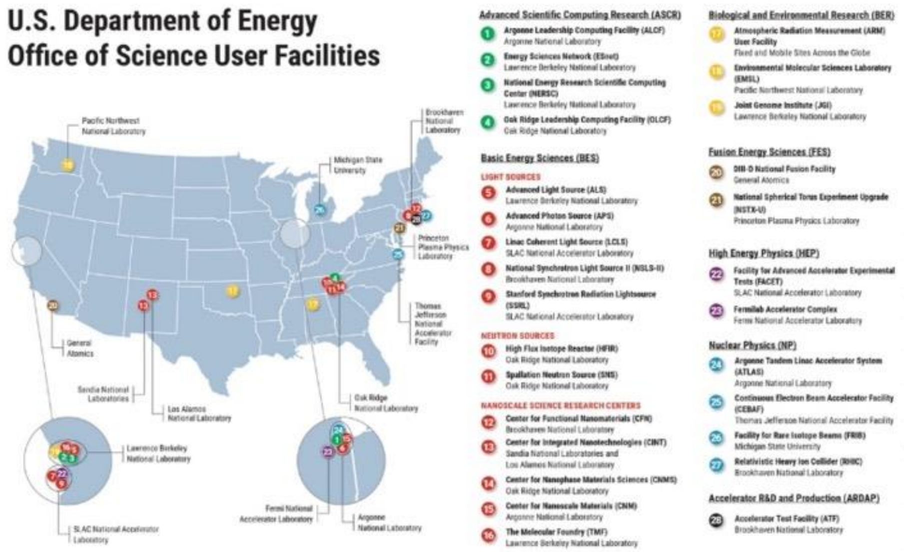
Nuclear Science User Facilities

INL/MIS-25-83964

The Nuclear Science User Facilities Program



- **Established in 2007**
  - To be the U.S. Department of Energy Office of **Nuclear Energy's** first & only dedicated user facility
  - To open the national laboratories to university researchers
- **Founded at Idaho National Laboratory (INL)**
  - INL remains the lead and primary institution
- **NSUF operates similarly to other user facilities in the United States**
  - **Fundamental Research** - basic and applied research in science and engineering, intended to be published and shared broadly with the scientific community
  - Competitive proposal processes for access
  - No cost to user for accessing capabilities
  - No travel funding to users, etc.



The Nuclear Science User Facilities (NSUF) Program

Unique aspects of NSUF

Consortium of facilities/capabilities

- 21 institutions across the United States
- >50 major facilities and laboratories
- NSUF efficiently leverages existing investment in physical capabilities by utilizing excess capacity.
- Funding to partners covers only the costs for the awarded access project

NSUF offers multiple capabilities to a single scientific area

- Fundamental irradiation effects in nuclear fuels and materials important to US nuclear energy development

Large projects can last up to 7 years

- Major projects can include design, fabrication, transport, neutron irradiation, post-irradiation examination, and final disposition.
- All projects are fully forward funded at the start.

NSUF research areas cover all technical readiness levels

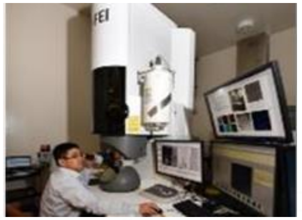
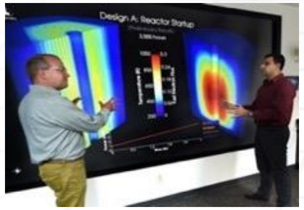
NSUF offers the **best** capabilities across the nation

Cutting-Edge Resources: Access to infrastructure and associated capabilities across 21 partner sites

Open access: Available to industry, academia, and national labs for non-proprietary R&D

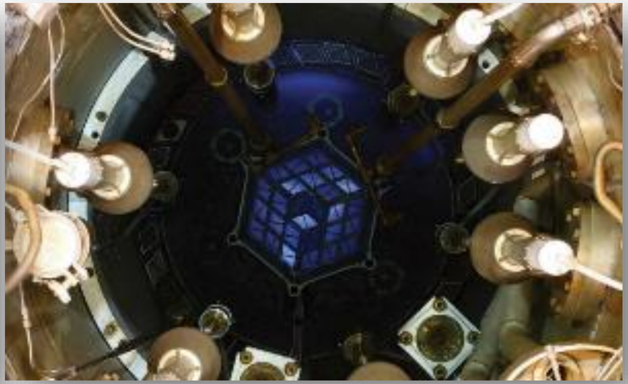
Education and training: Workshops, webinars, and hands-on skill development

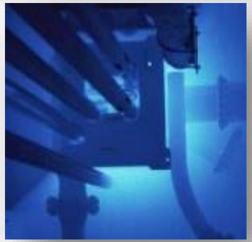
Impact: Increase understanding to drive innovation across nuclear energy technologies

Neutron Reactors		12 reactor facilities at national laboratories and universities including the Advanced Test Reactor at INL
Gamma & Ion Irradiation		7 gamma irradiation facilities and 7 ion beam facilities at national laboratories and universities
Post-Irradiation Examination		Multiple hot cell and broad post-irradiation examination facilities including advanced characterization methods
Beamlines		Synchrotron and neutron beamlines for nuclear fuel and materials studies
Computational Resources		Scientific high-performance computing capabilities for advanced modeling and simulation at INL

Simulated Reactor Environments: Neutron Irradiation



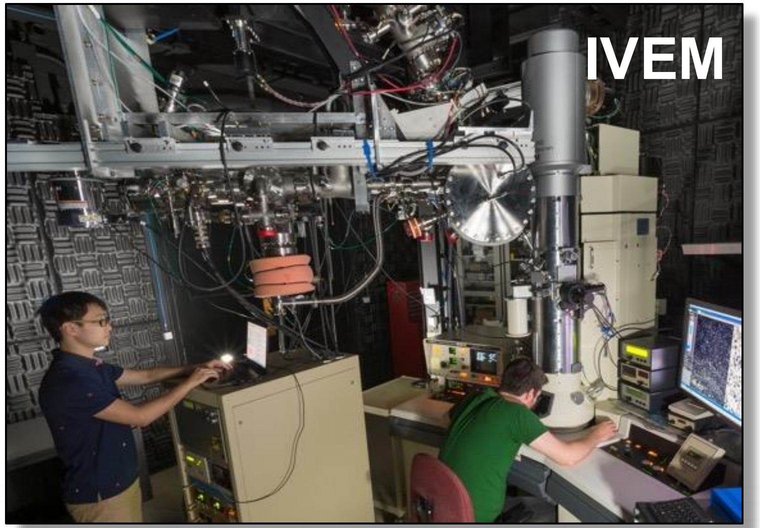





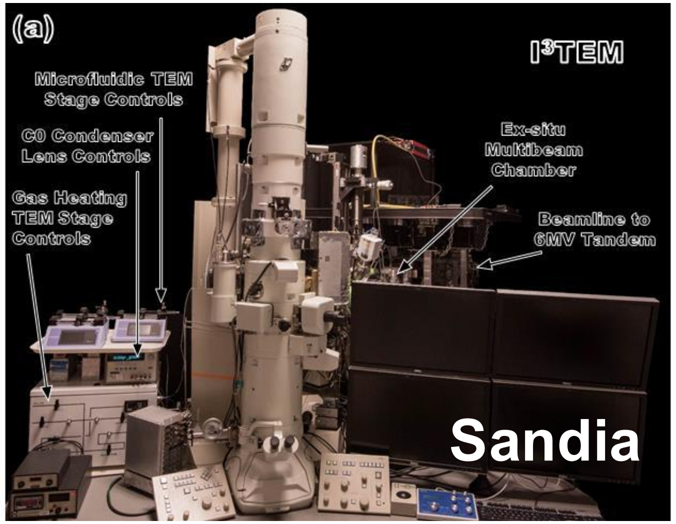


Simulated Reactor Environments: Ion Irradiation

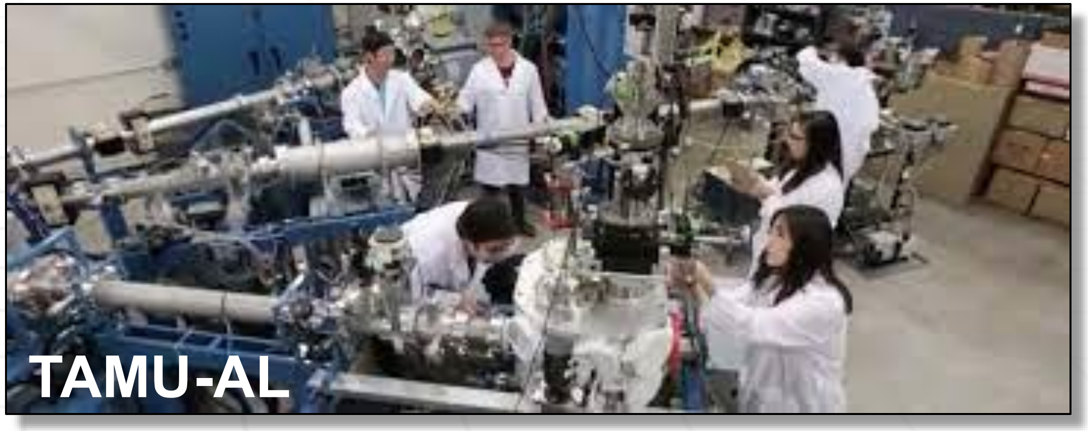
In Situ TEM



In Situ TEM



In Situ TEM



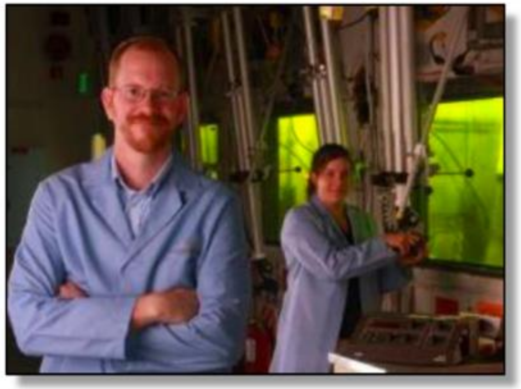
Hot Cells

INL Idaho National Laboratory

Oak Ridge National Laboratory

Westinghouse

MIT Massachusetts Institute of Technology



PNNL

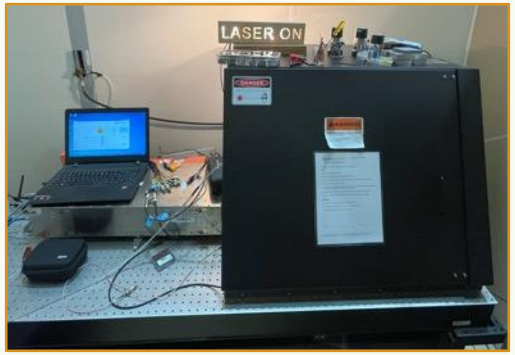
Argonne National Laboratory

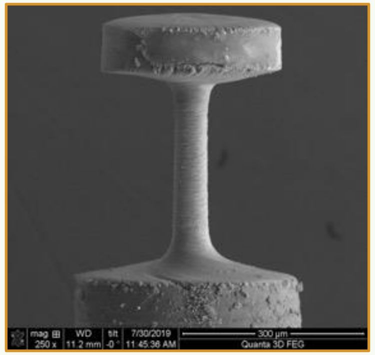
PennState

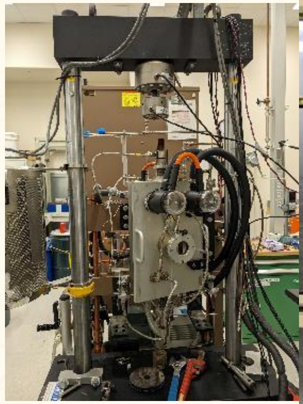
NC State University

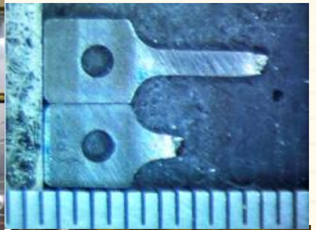
Simulated Reactor Environments: Mechanical Testing

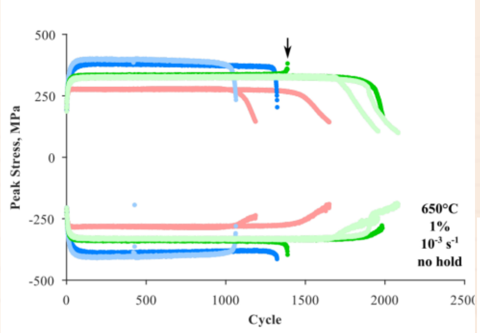
- Hardness/ Bend test/ Tensile/ Creep/ Fatigue/ Compact tension/ Charpy impact (toughness)

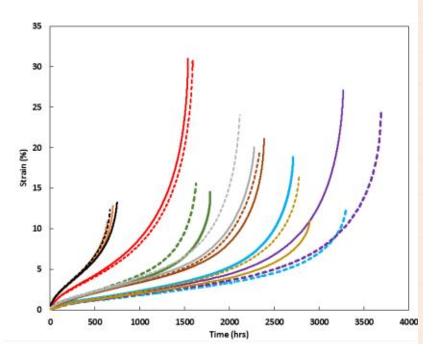






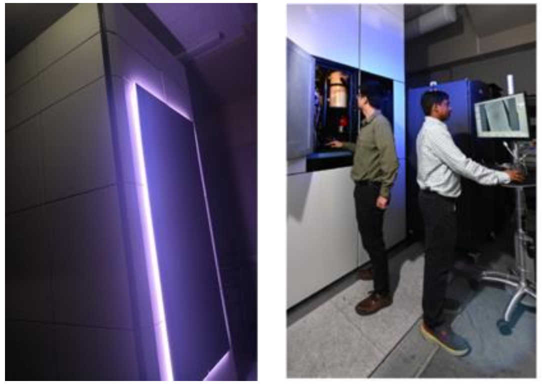






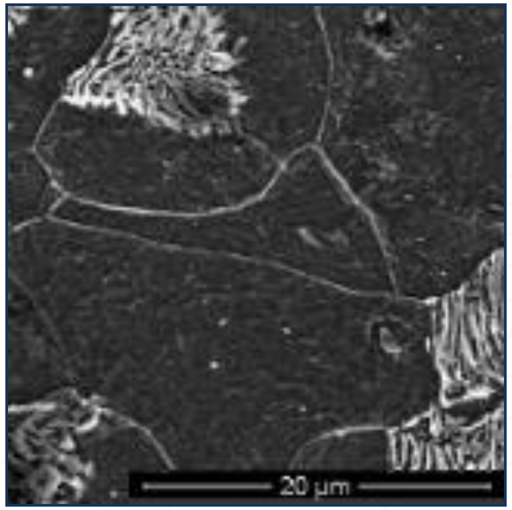
Advanced Microstructure Characterization Capabilities

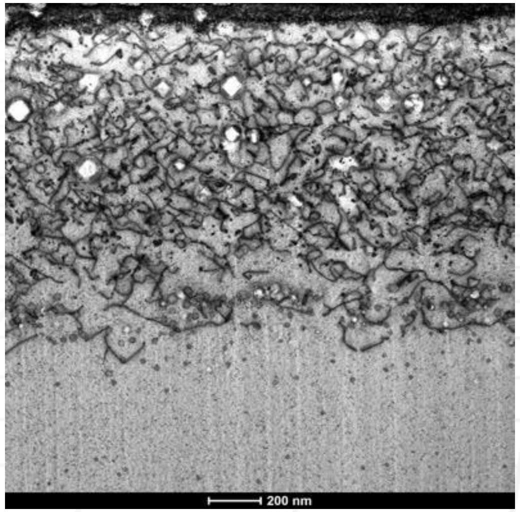
- Optical metallography
- Scanning electron microscopy (SEM)
  - BSE/EBSD/FIB
- Transmission electron microscopy (TEM)

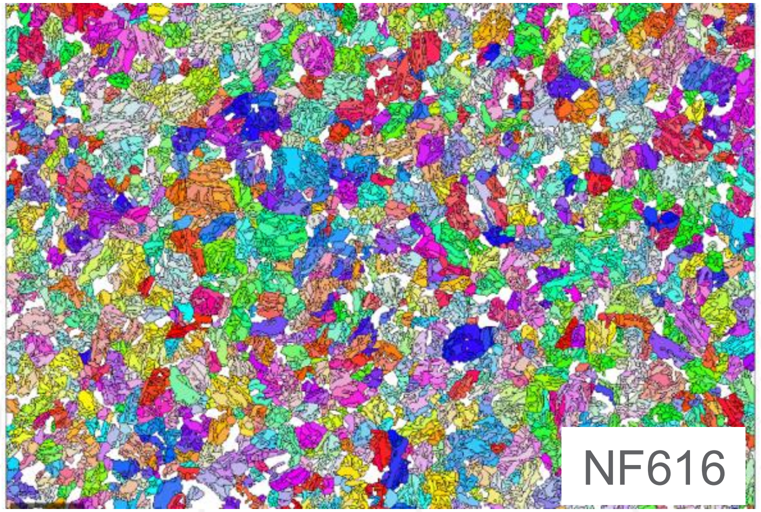


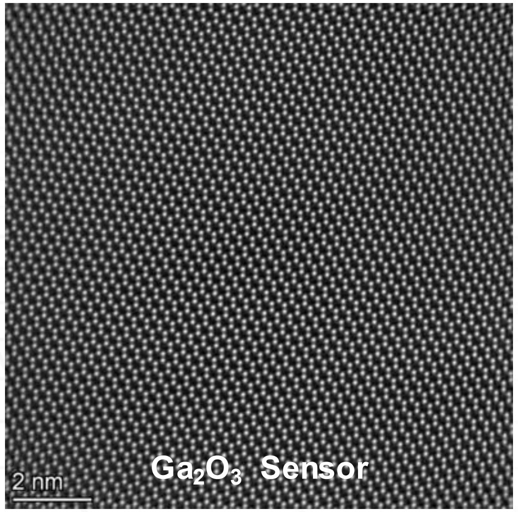
Spectra 300 STEM

STEM resolution 50 pm
(125 pm at 30kV)





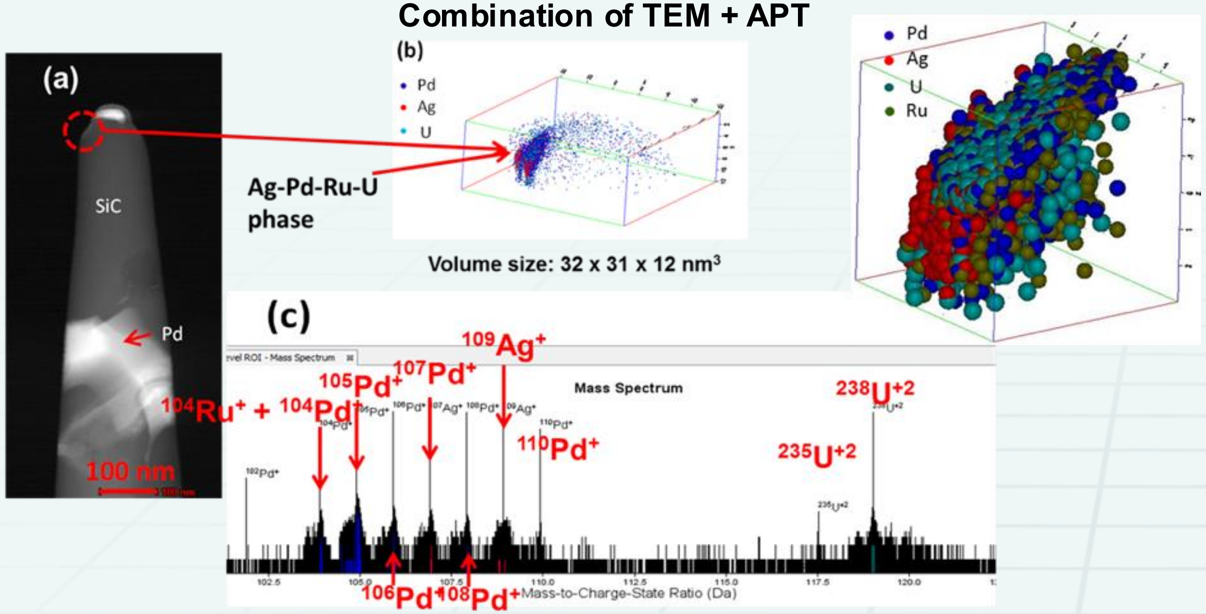




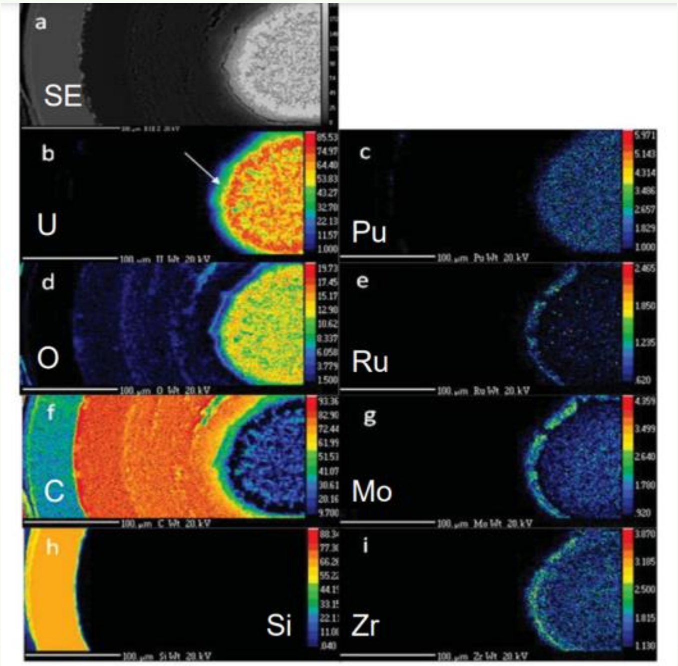
Advanced Microstructure Characterization Capabilities

- Atom probe tomography (APT)
- Electron Probe MicroAnalysis (EPMA)
- Energy Dispersive Spectroscopy (EDS)
- Electron Energy Loss Spectroscopy (EELS)

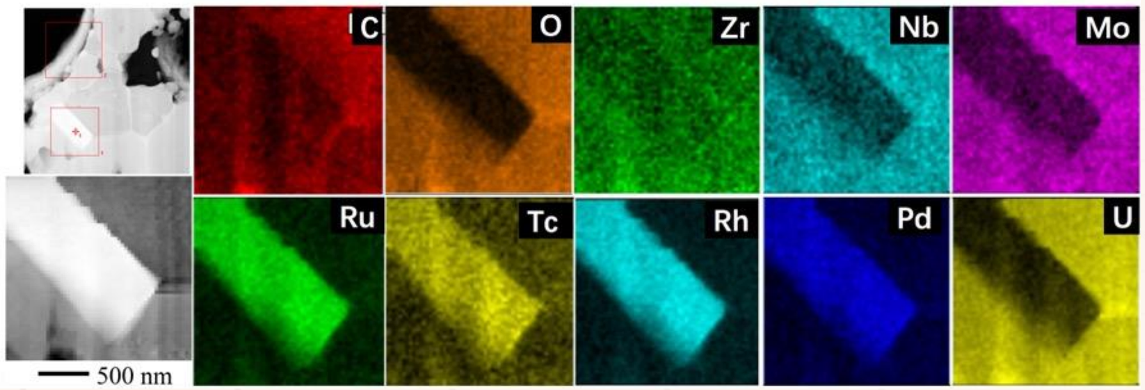
Combination of TEM + APT



STEM HAADF image of an irradiated TRISO APT sample tip (a), corresponding reconstructed three-dimensional APT maps showing a Ag-Pd-Ru-U - rich phase in a volume size of 32 nm x 31 nm x 12 nm (b) and mass spectrum showing detected isotopes of Ag, Pd, Ru and U (c).



WDS maps of a TRISO fuel particle



TEM images and EDS maps of irradiated fuel particle

Center for Advanced Energy Studies

University of Florida

NSUF Nuclear Science User Facilities

High Performance Computing (HPC) resources

NSUF HPC systems support a wide range of users and programs

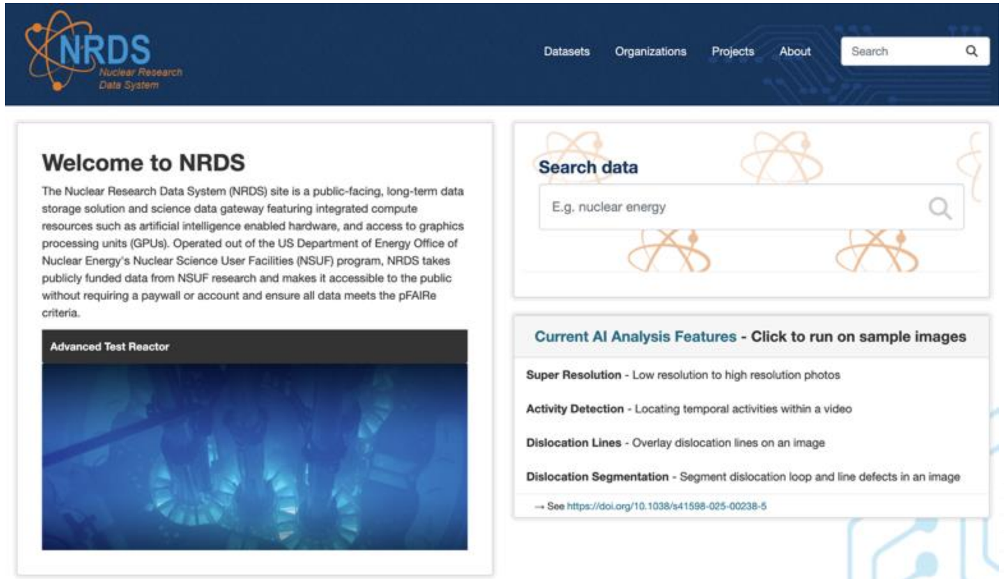
- **Teton (2026)**
  - 15.6 Petaflops performance
  - 393,216 AMD 9965 Turin cores
  - 1024 nodes - 384 cores/node – 768GB/node memory
- **Windriver (2025)**
  - 5.4 Petaflops performance
  - 94,416-core Dell CTS-2 system
  - 211 TB total memory
- **Bitterroot (2024)**
  - 2 Petaflops performance
  - 43,008-core Dell CTS-2 system
  - 90 TB total memory
- **Hoodoo (2021)**
  - Machine Learning Cluster with 108 A100 GPUs
- **Sawtooth (2020)**
  - 5.6 Petaflops performance (was #37 on Top 500 list in 2020)
  - 99,972 compute cores HPE SGI 8600 system
  - 395 TB total memory

Teton

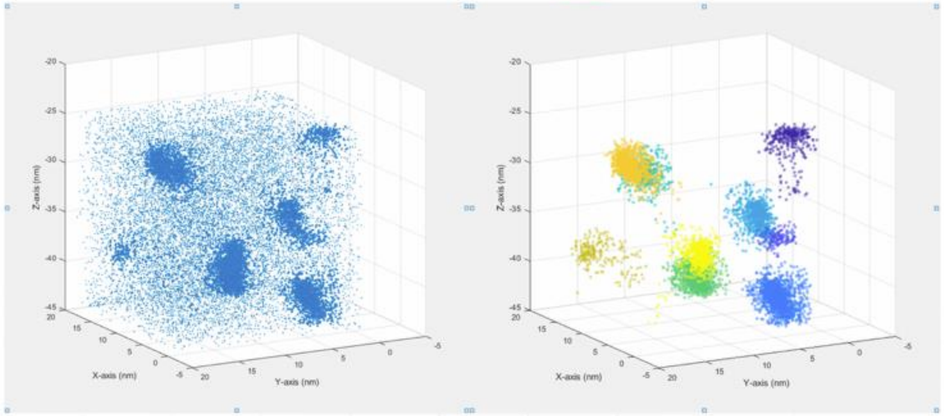
Bitterroot & Windriver

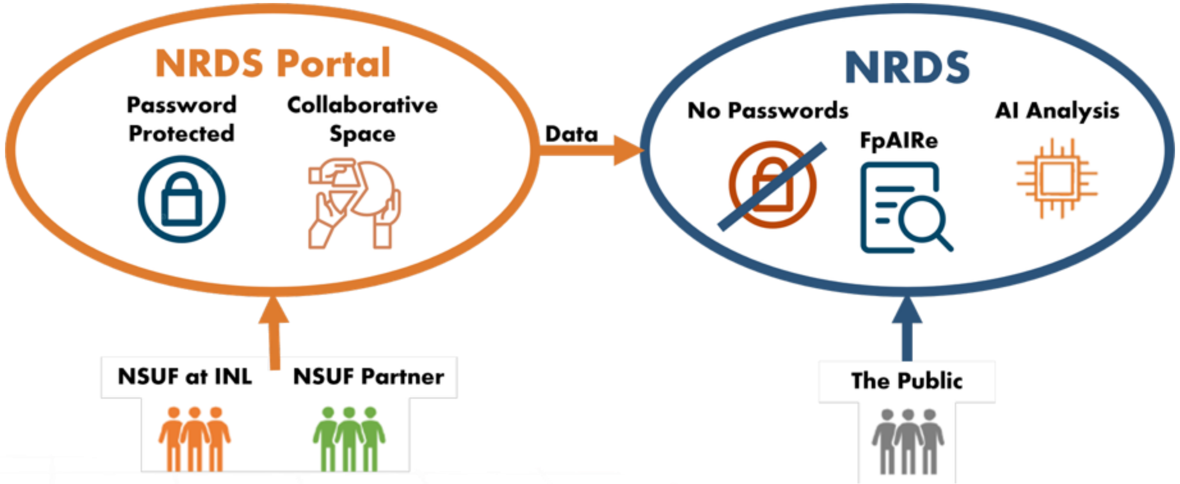
Sawtooth

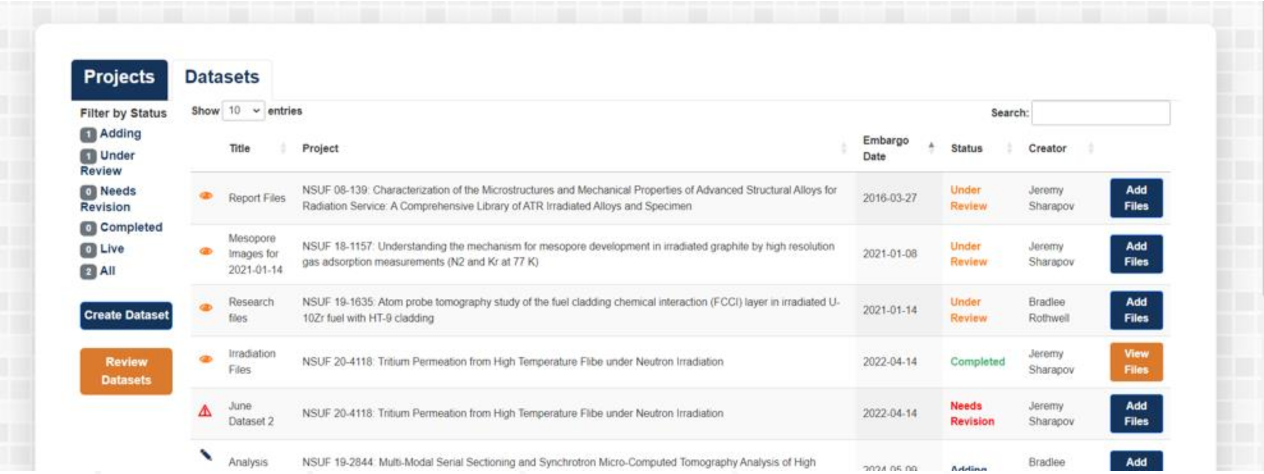
Nuclear Research Data System (NRDS)



Atom Probe Tomography Clustering Analysis via AI courtesy Yalei Tang







Title	Project	Embargo Date	Status	Creator	
Report Files	NSUF 08-139: Characterization of the Microstructures and Mechanical Properties of Advanced Structural Alloys for Radiation Service: A Comprehensive Library of ATR Irradiated Alloys and Specimen	2016-03-27	Under Review	Jeremy Sharapov	Add Files
Mesopore Images for 2021-01-14	NSUF 18-1157: Understanding the mechanism for mesopore development in irradiated graphite by high resolution gas adsorption measurements (N2 and Kr at 77 K)	2021-01-08	Under Review	Jeremy Sharapov	Add Files
Research files	NSUF 19-1635: Atom probe tomography study of the fuel cladding chemical interaction (FCCI) layer in irradiated U-10Zr fuel with HT-9 cladding	2021-01-14	Under Review	Bradlee Rothwell	Add Files
Irradiation Files	NSUF 20-4118: Tritium Permeation from High Temperature Flibe under Neutron Irradiation	2022-04-14	Completed	Jeremy Sharapov	View Files
June Dataset 2	NSUF 20-4118: Tritium Permeation from High Temperature Flibe under Neutron Irradiation	2022-04-14	Needs Revision	Jeremy Sharapov	Add Files
Analysis	NSUF 19-2844: Multi-Modal Serial Sectioning and Synchrotron Micro-Computed Tomography Analysis of High			Bradlee	Add

Images from NRDS Portal

NSUF Access Award Projects Summary: FY07-FY25

- Total NSUF Access Award Funding: **$138M**
- **838** total projects awarded
  - **45** CINR type projects executed
  - **32** CINR type projects currently ongoing
  - **689** RTEs executed
  - **73** RTEs ongoing
- Awards distribution by institution type
  - **507** projects to **55** U.S. universities
  - **260** projects to **10** national laboratories
  - **37** projects to **15** industrial users*
  - **42** projects to **21** international researchers

* All NSUF access awards support non-proprietary **fundamental science** and are intended for **full public release**

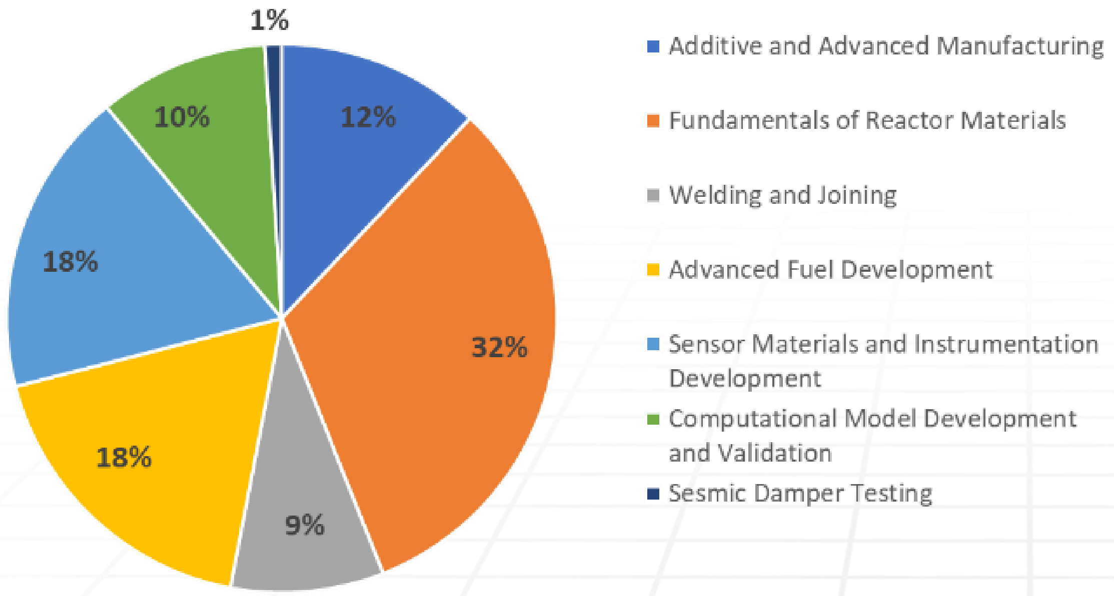
NSUF Funding Calls

- **Consolidated Innovative Nuclear Research (CINR NOFO)**
  - One call per year
  - Projects include design, analyses, fabrication, transport, irradiation, disassembly, PIE, disposition
  - Possibility to also receive user R&D funding on university topic areas
  - Guidance on project costs and timelines

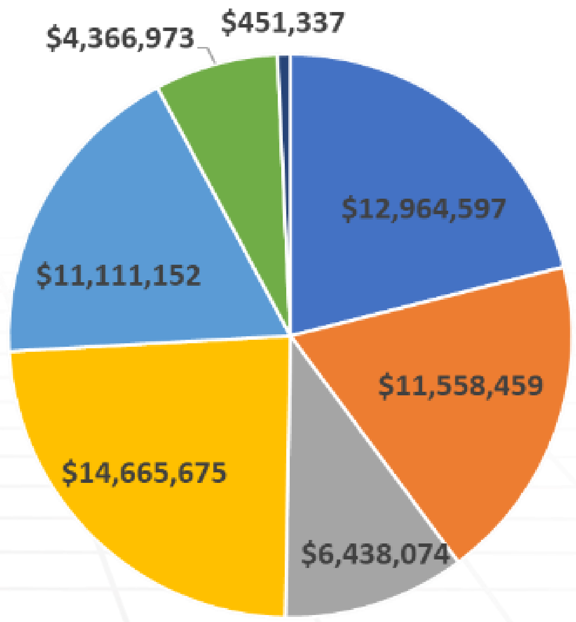
Neutron Irradiation + PIE	$0.5M - $4.0M	≤7 years
Neutron Irradiation only	up to ~$750K	3 years
PIE only	up to $250K	3 years
Ion or Gamma Irradiation + PIE	up to $250K	3 years
Ion or Gamma Irradiation only	up to $100K	3 years
Beamlines at other user facilities	(cost included)	3 years

CINR awarded projects up to FY24 by research field

Number of awards by field

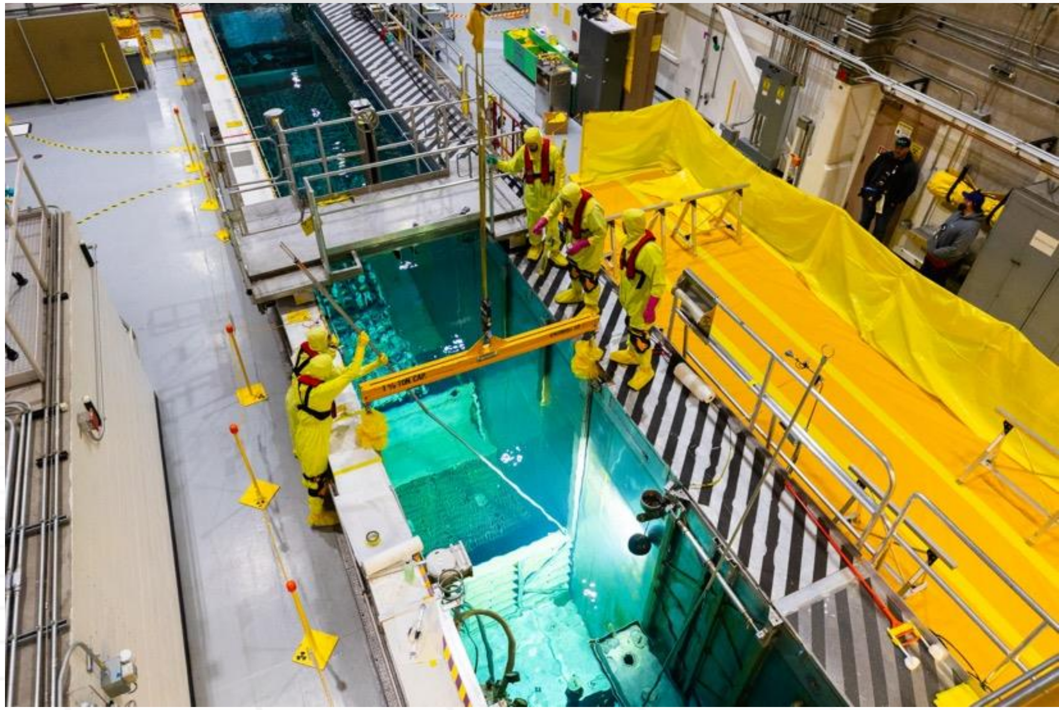


Value of awards by field



NSUF User Access Opportunities: Rapid Turnaround Experiments

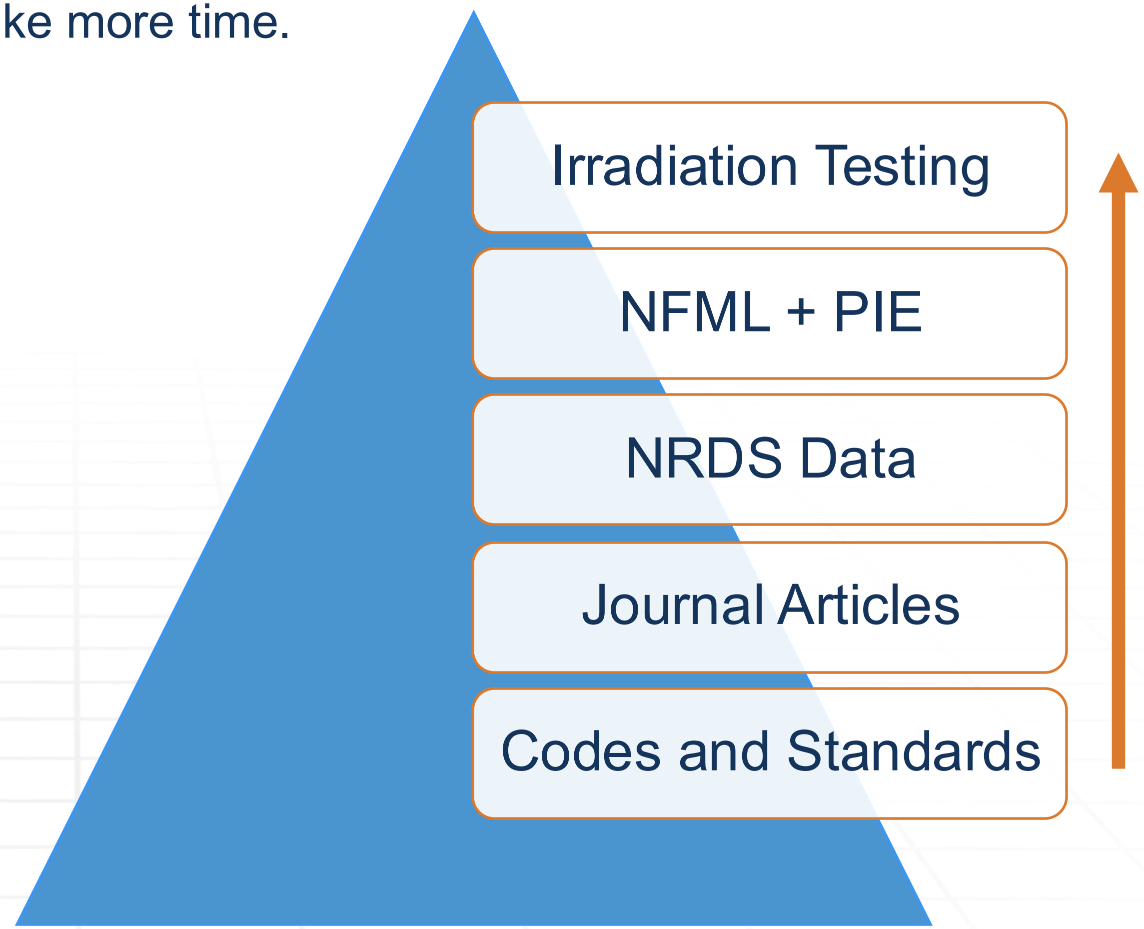
- **Rapid Turnaround Experiments (RTEs) historically have had up to 3 calls/year and 1 SuperRTE (new in FY 24)**
  - Limited funding, executed within 9 months (or 12 months for the SuperRTE)
  - Projects are selected through open competitive proposal processes
  - Proposals welcome from university, government laboratory, industry, and small business researchers
  - Only non-proprietary projects accepted. All awarded projects are fully forward funded



Answering the need for a nuclear energy material

If you need a material for a nuclear energy system, start at the bottom and work upward. Activities higher up the pyramid are costlier and will take more time.

1. The material might already be in the marketplace. Search for ASME code cases.
2. Perhaps there is not a qualified material, but there has been research. Do a search of the academic literature.
3. Maybe there has been research, but it doesn't answer your questions, find the project data at NSUF's Nuclear Research Data System and do your own analyses.
4. If you need to create your own data, find material specimens in the Nuclear Fuels and Materials Library.
5. Finally, if all else has failed, get your data from performing a new neutron irradiation test.



NSUF User Data Workshops

This is planned to be the first of many similar efforts to cover NSUF capabilities

Desired Workshop Outcome

- Materials Characterization Best Practices
  - Metadata
  - Data structures
  - Data quality
  - Suitability for benchmarking/model training

What isn't covered here

- Data Management Policies
  - Exclusivity
  - Publishing
  - Proprietary protections

NSUF Partners (2023) and Users Organization (2025)

Questions?

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Nuclear Science User Facilities

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