Brenden Heidrich,
Director

NSUF Program Review Meeting

April 15, 2024

NSUF FY24 Program Overview and Updates

Nuclear Science User Facilities

INL/MIS-24-77373

- **NSUF Overview**
  - Program Office
  - Partners
  - Outreach
- **Competitive Access Awards**
  - Rapid Turnaround Experiments (RTE)
  - Consolidated Innovative Nuclear Research (CINR)
  - Research Areas
- **Capability Development**
  - Nuclear Fuels and Materials Library (NFML)
  - Collaborations and SAM
  - Instrument Scientist Support

The Nuclear Science User Facilities (NSUF)

- **Established in 2007 as the United States Department of Energy Office of Nuclear Energy (DOE-NE)'s first & only user facility**
- **Founded at Idaho National Laboratory (INL)** (initially intended as a single institution user facility)
  - INL remains lead and primary institution

- **NSUF operates similarly to other U.S. user facilities** (no cost to user, competitive proposal processes, no travel funding to users, etc.)

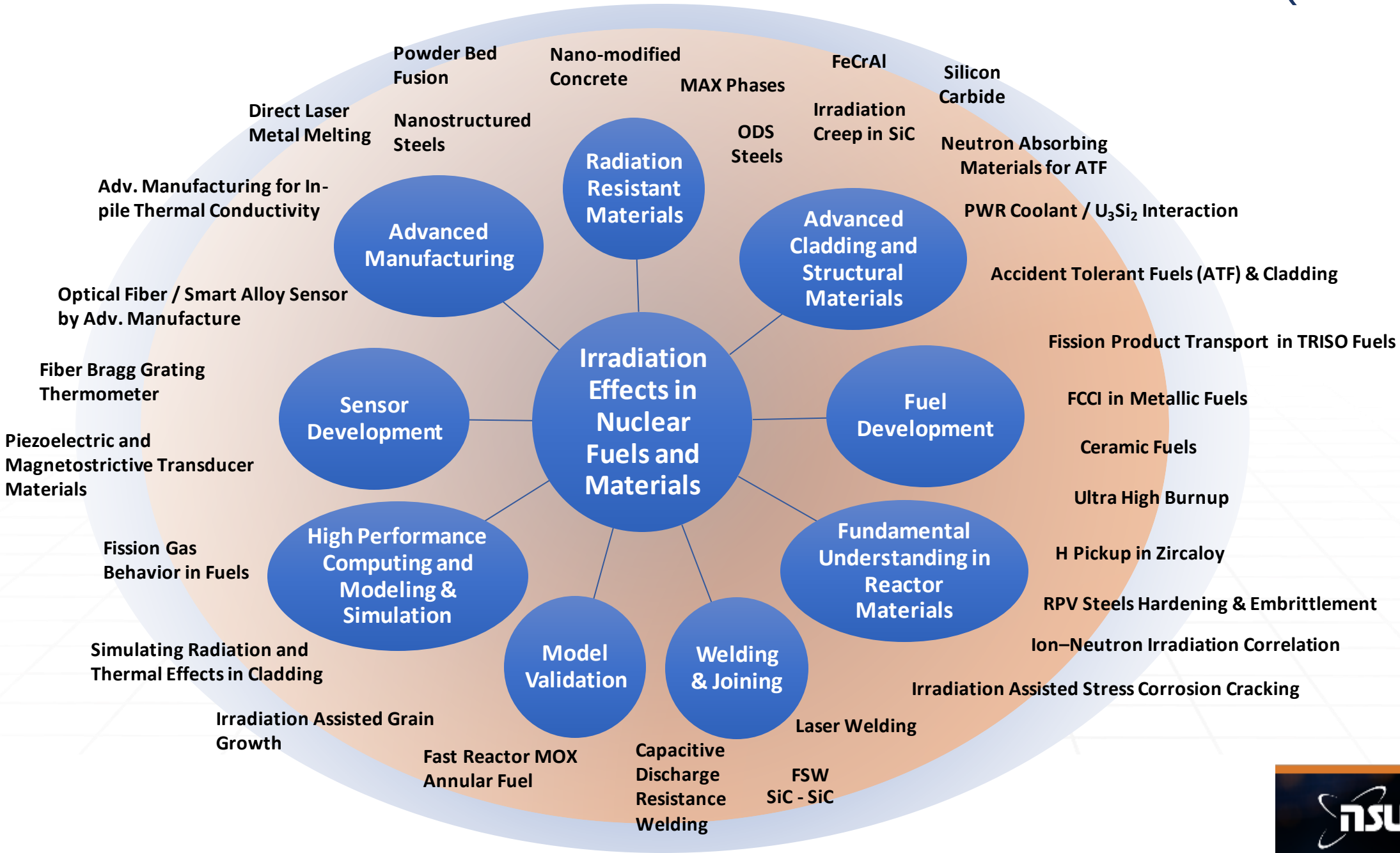
Unique aspects of NSUF

- **Consortium of facilities/capabilities, not single institution (21 Institutions)**
  - 11 Universities + 3 Univ. in CAES, 8 National Laboratories, 1 industry partner
- **NSUF offers multiple capabilities to a single scientific area**
  - Irradiation effects in nuclear fuels and materials
- **Projects can last many years or have a short duration**
  - Largest projects include design, fabrication, transport, irradiation, post irradiation examination (PIE), and final disposition
- **No base funding to facilities**
  - Funding to facility is for project cost and is fully forward funded

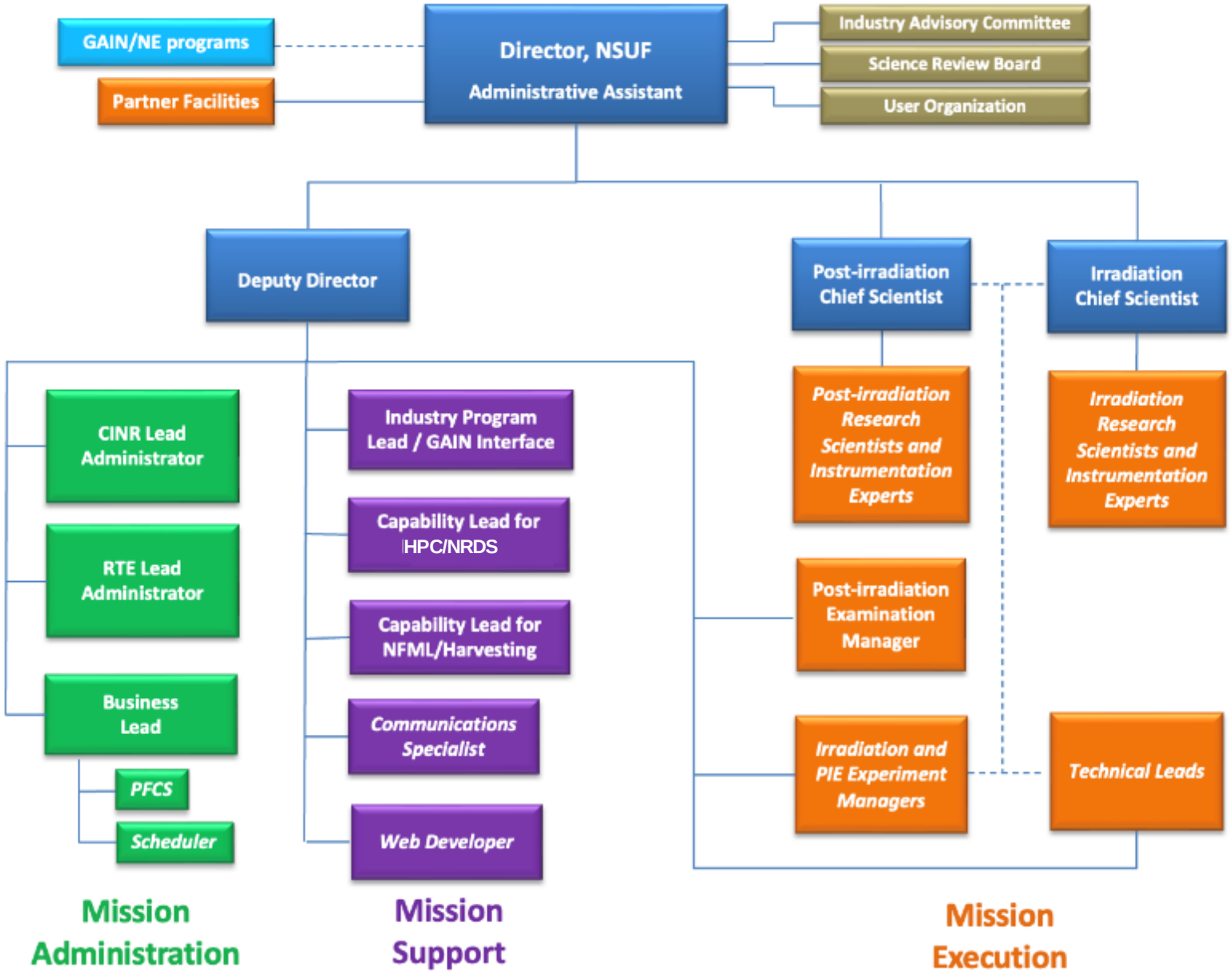
The Nuclear Science User Facilities (NSUF)

- **Vision**
  - Continue U.S. leadership in nuclear energy research with cutting edge resources.
- **Mission**
  - Coordinate a consortium of institutions to provide no-cost access to unique and highly specialized nuclear research facilities and technical expertise.
- **Goal**
  - Produce the highest quality research results that increase understanding of advanced nuclear energy technologies important to DOE-NE and industry while creating new innovative concepts.
- **Strategy: Strategic Research and Development (R&D) Support**
  - Provide mechanisms for research organizations to conduct irradiations and post irradiation analyses and utilize computing and experimental resources not normally accessible to these organizations.

NSUF Research Areas Cover all Technical Readiness Levels (TRLs)



NSUF Program Office Structure



The Best Capabilities across the Nation

NSUF Capabilities Offer Research Opportunities

Neutron Irradiations	Ion Irradiations	Gamma Irradiations	Hot Cells & Shielded Cells	Low Activity Laboratories	Beamlines	High Performance Computing
INL	Wisconsin	INL	INL	INL	Brookhaven National Laboratory	INL
ORNL	Michigan	ORNL	ORNL	CAES	Argonne ✓	
MIT	Argonne	Sandia	PNNL	ORNL	NC State University	
NC State University	Sandia	Texas ✓	Los Alamos	Berkeley	Los Alamos	
Ohio State	Texas A&M		Westinghouse	PNNL		
Sandia	Lawrence Livermore		Michigan	Los Alamos		
PennState ✓			SCK•CEN	NC State University, Michigan, Purdue, Wisconsin, Florida, SCK•CEN		

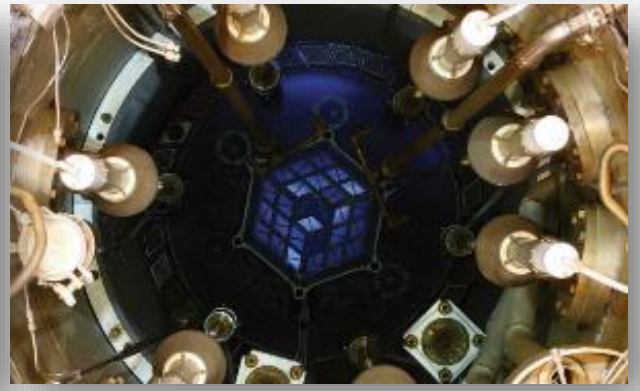
- **Penn State: Radiation Science and Engineering Center 2023**
- **Texas Austin: Prompt Gamma Neutron Activation Analysis 2023**
- **ANL: APS AML HEXM beamline 2024**

Visit nsuf.inl.gov for details of individual facilities

NSUF Nuclear Science User Facilities

Neutron Irradiation Capabilities










Hot Cell Capabilities

Idaho National Laboratory

Idaho National Laboratory

Massachusetts Institute of Technology

Westinghouse Churchill Laboratories

Oak Ridge National Laboratory

Pacific Northwest National Laboratory

New Partner Capabilities: Activated Materials Laboratory at APS-U

- NSUF funded construction of the Activated Materials Laboratory (AML) in FY 2022 as part of the Advanced Photon Source Upgrade (APS-U) project to create a new capability for NSUF users.
- The collaboration is planned to provide access to NSUF users at the High-Energy X-ray Microscope beam station for **irradiated fuels and materials** research.
- AML staff at APS held a workshop, sponsored by NSUF for potential AML users in November 2023.
- This capability is planned to be ready for users in early FY 2025.

Credit: Argonne National Laboratory

New Partner Capabilities: Penn State Reactor Facility

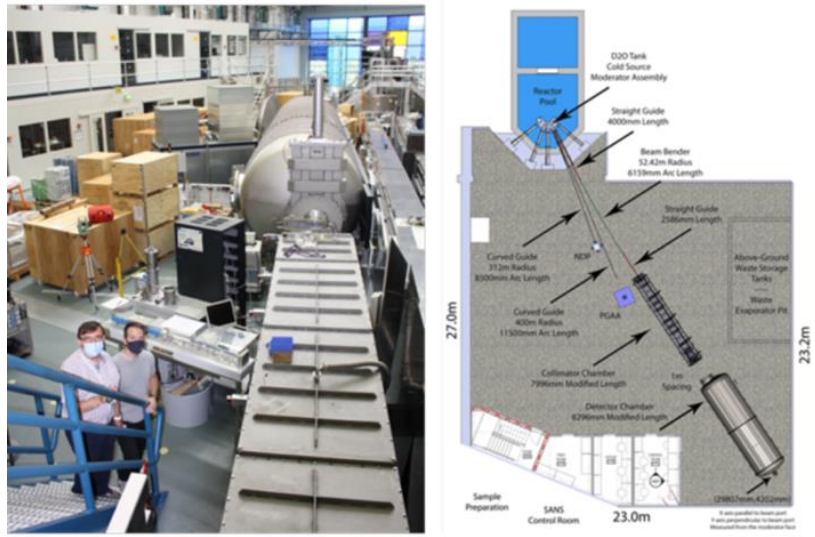
Radiation Science & Engineering Center (RSEC) Neutron Beam Laboratory

Five core neutron beam ports provide seven new neutron beam lines for the beam experimental facilities.

- BP#1 is an epithermal neutron beam facility
- BP#2 is thermal beam that will be used for exploratory research projects
- BP#3 is designated for neutron transmission projects
- BP#4 is dedicated for Neutron Imaging Facility
- Cold Neutron Beam port (three beam lines)

The Small Angle Neutron Scattering facility (SANS) has three overarching themes:

- Materials under extreme conditions (e.g., nuclear fission/fusion materials, radiation hardening, corrosive-resistant materials, etc.)
- Design of complex soft and hard matter (e.g., glassy metals, non-crystalline solids, porous metals, natural biopolymers, radiation-hardened high-entropy alloys, and electronic materials)
- Dynamics of biological matter (e.g., cell-material interactions, protein-surface interactions, neuron cell-water interactions)



Credit: Penn State University

"The addition of new neutron beam port facilities including a SANS instrument that is donated by The Helmholz-Zentrum Berlin, time-of-fight neutron depth profiling, new prompt gamma activation analysis system and new neutron imaging system in the existing RSEC capabilities, will expose students to a range of important applications."

New Partner Capabilities: University of Texas at Austin Reactor

Nuclear Engineering Teaching Laboratory

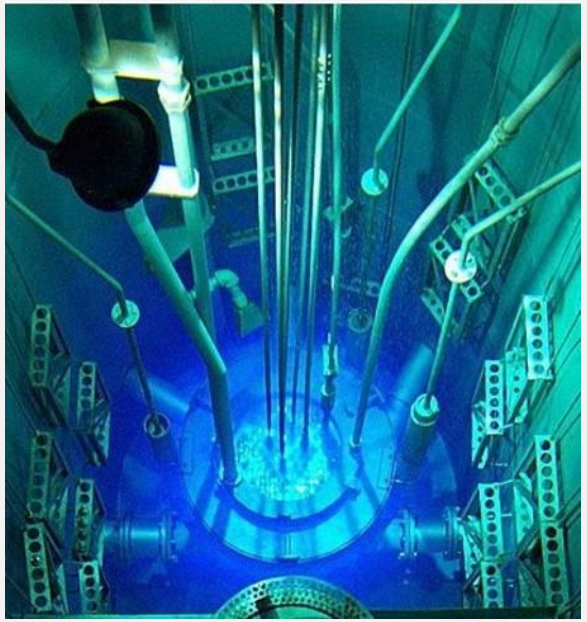
Prompt Gamma Neutron Activation Analysis Capability (PGNAA)

The PGNAA facility is currently being used to:

- Assay boron concentration for an ongoing research project
- Determine mercury content in scale and corrosion layers inside steel pipe
- Measure hydrogen content in steel for correlation to stress cracking phenomena
  - Hydrogen concentrations less than 20 ppm in steel have been measured to date

- Plans for PGNAA upgrades:
  - Automated (sample) motion controls
  - Shielding optimization
  - Environmental chamber for reduction of humidity (in progress)
  - Development of fluorine-based neutron (detector) shielding (in progress)

A proposal to acquire equipment supporting cross calibration for measurements of hydrogen in metal is in review.



Credit: University of Texas at Austin

High Performance Computing (HPC) Resources

- NSUF HPC systems support a wide range of users and programs as a shared-use resource for national laboratories, universities, and industry
- **Bitterroot (2024)**
  - 374 nodes, 41,888 cores
  - Will be delivered March 16, 2024
- **Hoodoo (2021)**
  - **Machine Learning Cluster**
  - **108 A100 GPUs**
- **Sawtooth (2020)**
  - 6 Petaflops performance
  - 2,079 compute nodes, 99,972 compute cores
  - #37 on November 2019 TOP500 list
- **Lemhi (2018)**
  - 1 Petaflop performance
  - 504 compute nodes, 20,160 compute cores
  - #427 on November 2018 TOP500 lst

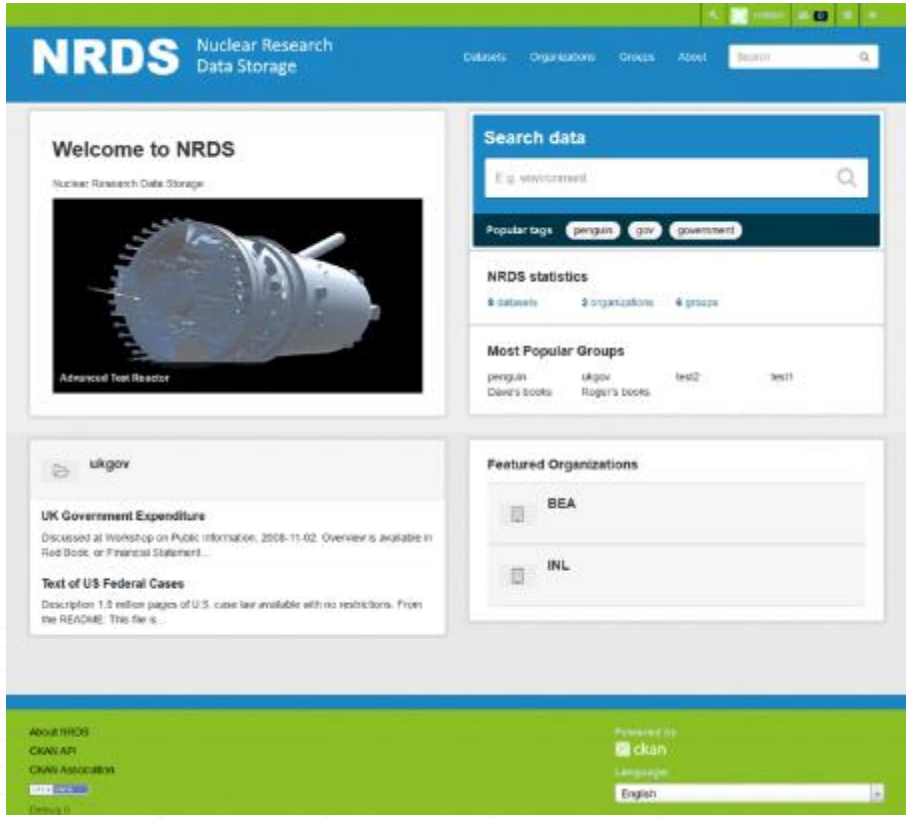
Bitterroot

Sawtooth

Lemhi

NSUF Nuclear Research Data System (NRDS): https://nrds.inl.gov

- **NRDS:** a place for public data to be stored and accessible in perpetuity
- **Near real-time analysis**
  - Stored close to HPC systems, allows data to be analyzed in near real time
- **Artificial Intelligence/Machine Learning (AI/ML) analysis toolsets**
  - Super resolution
  - Active detection
- **Publicly available**
  - Data co-located with projects
  - Easy to find via search and tags
  - Traceable
  - Digital Object Identified (DOI) for projects
  - Variety of licenses for PIs to choose for their data
- **FpAIRe data**
  - Findability, Peekable, Accessibility, Interoperable, Reusable, Extensible



Nuclear Science User Facilities

NSUF Points of Contact

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Ms. Suibel Schuppner
Ms. Rebecca Onuschak
Dr. Christopher Barr
Ms. Willettia Amos (ID)

Ion Beams/Gamma Irradiation

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Prof. Adrien Couet (UW)
Dr. Wei-Ying Chen (IVEM, ANL)
Dr. Michael Starr (SNL)
Prof. Lin Shao (TAMU)
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Dr. Tarik Saleh (LANL)
Dr. Jon Almer (ANL)
Prof. William Charlton (UTA)

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Dr. Colin Judge (INL)
Dr. Rongjie Song (INL)
Dr. Jeffrey Giglio (INL)
Mr. Kory Linton (ORNL)
Dr. Yaqiao Wu (CAES)
Dr. Stu Maloy (PNNL)
Prof. Ahmed Hassanein (Purdue)
Prof. Peter Hosemann (UCB)
Ms. Catou Cmar (Westinghouse)
Dr. Alexander Long (LANL)
Prof. Yong Yang (UFla)
Prof. Kumar Sridharan (UW)
Prof. Ayman Hawari (NCSU)
Prof. Kevin Field (UM)
Dr. Joris Van den Bosch (BNRC)

… and many more scientists, engineers, and technical staff at INL and all partner facilities

NSUF Program Office with Partner Representatives

NSUF Minority Serving Institution Pilot Project

Mission: In order to increase the diversity and expertise of the scientists utilizing NSUF facilities, the **MSI Pilot Project** seeks to build long term relationships between NSUF and the Partner Facilities (PFs) and MSI university faculty in nuclear material science.

- For FY 2024, NSUF PFs include the University of Michigan, the Ohio State University, the University of Wisconsin, Cal Berkley and NC State University
- Currently NSUF Partners are engaging the MSI faculty to form teams
- NSUF PF /MSI Teams will generate a RTE type proposal
- The Pilot Project Workshop will be held at INL from May 19–23
- Finalize the RTE proposals at workshop, along with some hands-on work.
- Teams are strongly encouraged to submit their proposals into the FY24 3rd RTE Call.

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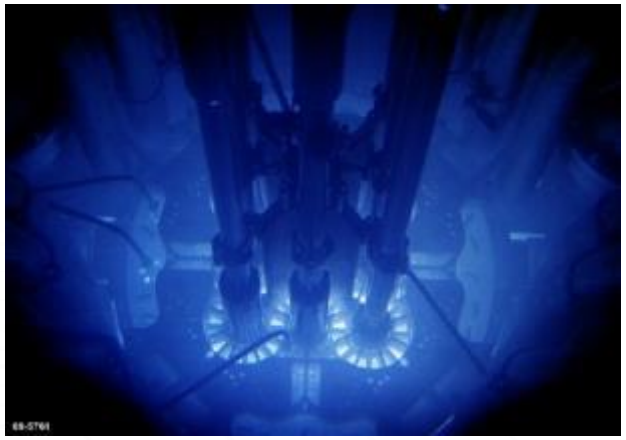
NSUF Funding Calls

- **Consolidated Innovative Nuclear Research (CINR FOA, 1 call/year)**
  - Projects include design, analyses, fabrication, transport, irradiation, disassembly, PIE, disposition
  - Possibility to also receive user R&D funding on limited number of work scopes

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



- **Rapid Turnaround Experiments (RTE, 3 calls/year +1 special call)**
  - Limited funding, executed within 9 months
- 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

NSUF Projects Summary (FY 2007 – 2023)

- **Total NSUF Access Award Funding: $124M**
- **751 total projects awarded**
  - 77 CINR type projects executed
  - 24 CINR type projects currently ongoing
  - 553 RTEs executed
  - 71 RTEs ongoing
- **Awards distribution by institution type**
  - 449 projects to 67 U.S. universities
  - 233 projects to 8 national laboratories
  - 30 projects to 14 industrial users
  - 39 projects to 13 international users

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NSUF Rapid Turnaround Experiments FY 2023

The 1st RTE call opened in October 2022. Awards were made in February 2023.
The 2nd RTE call opened in February 2023. Awards were made in June 2023.
The 3rd RTE call opened in June 2023. Awards were made in September 2023.

The NSUF awarded 74 of the 150 proposals evaluated (49%).

- The RTE budget estimate for the 74 awarded proposals for FY 2023 is $4,719,961 (52%).
  - The average cost of the awarded RTEs in FY 2023 is $63,783
- The RTE budget estimate to award all 150 proposals for FY2023 is $8,996,909.
  - The average cost of all proposed RTEs in FY 2023 is $59,979

The metrics for the three FY 2023 RTE Calls are as follows:

- 43 awards (out of 88 submitted) to PIs from **U.S. universities** (49%)
- 27 awards (out of 45 submitted) to PIs from **U.S. national laboratories** (60%)
- 2 awards (out of 11 submitted) to PIs from **U.S. Industry** (18%)
- 2 awards (out of 10 submitted) to PIs from **international institutions** (20%)
- 3 awards (out of 5 submitted) to **minority serving institutions** (60%)
- 17 awards (out of 37 submitted) to **female PIs** (46%)

NSUF Rapid Turnaround Experiments FY 2024

The 1st RTE call opened in October 2023.	Awards were made in February 2024.
The 2nd RTE call opened in February 2024.	Awards are predicted for June 2024.
The Super-RTE call opened in April 2024.	Awards are predicted for July 2024.
The 3rd RTE call will open in June 2024.	Awards were made in September 2024.

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FY 2023 RTE Highlights

Awards Valuation of $4.7M

150 proposals submitted from 58 institutions

(77/28 in FY 2022, 79/32 in FY 2021, 168/44 in FY 2020, 185/51 in FY 2019)

- 34 US Universities
- 8 National Laboratories
- 10 Foreign Institutions
- 6 Industry

74 experiments awarded PIs from 37 institutions

(30/20 in FY 2022, 29/20 in FY 2021, 56/29 in FY 2020, 99/38 in FY 2019)

- 27 US Universities
- 6 National Laboratories
- 2 Foreign Institutions
- 2 Industry

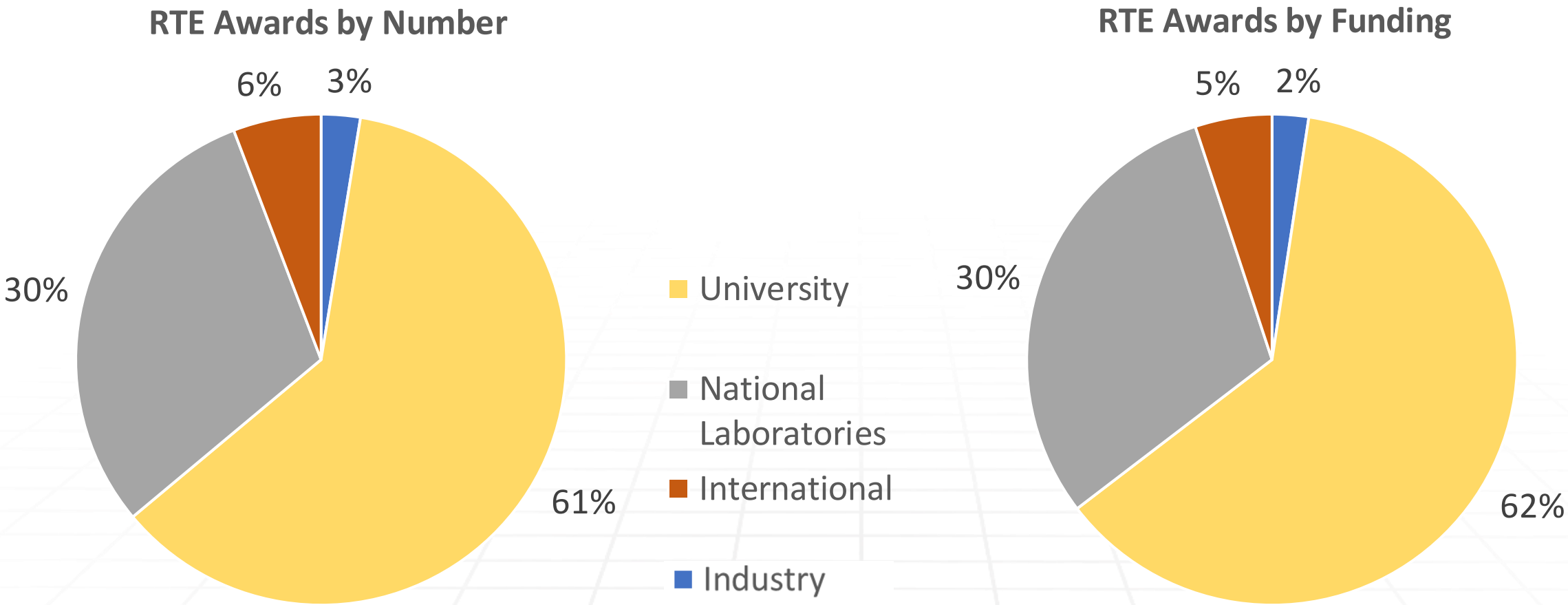
17 NSUF facilities to perform experiments

(9 in FY 2022, 10 in FY 2021, 14 in FY 2020, 12 in FY 2019)

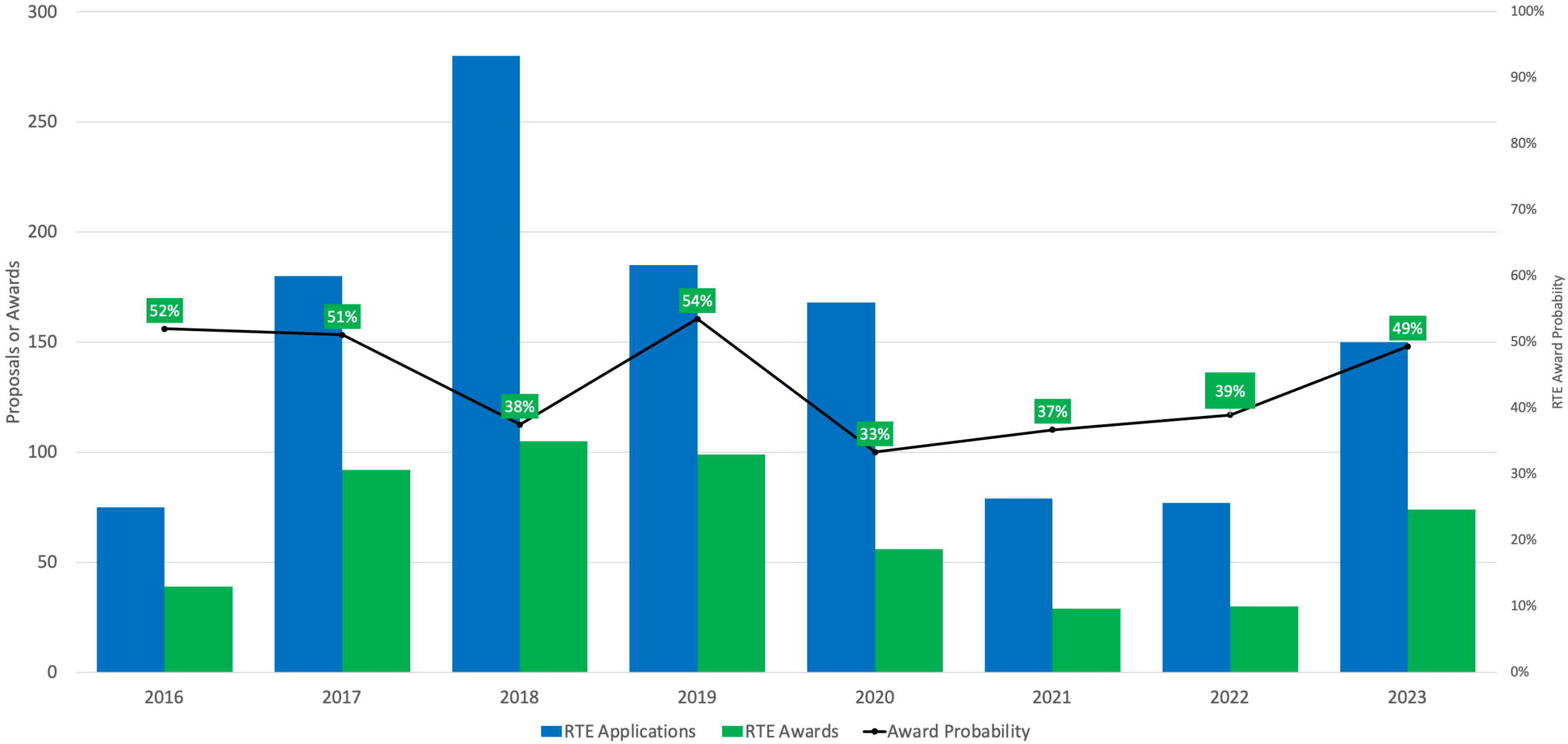
- 24 INL
- 13 ORNL/LAMDA, 12 ANL/IVEM, 3 PNNL, 1 BNL/NSLS-II, 2 LANL, 1 LLNL, 1 SNL
- 9 OSU, 8 Michigan, 7 TAMU, 3 MIT, 2 NCSU, 1 UCB, 1 UF, 1 UW
- 9 CAES

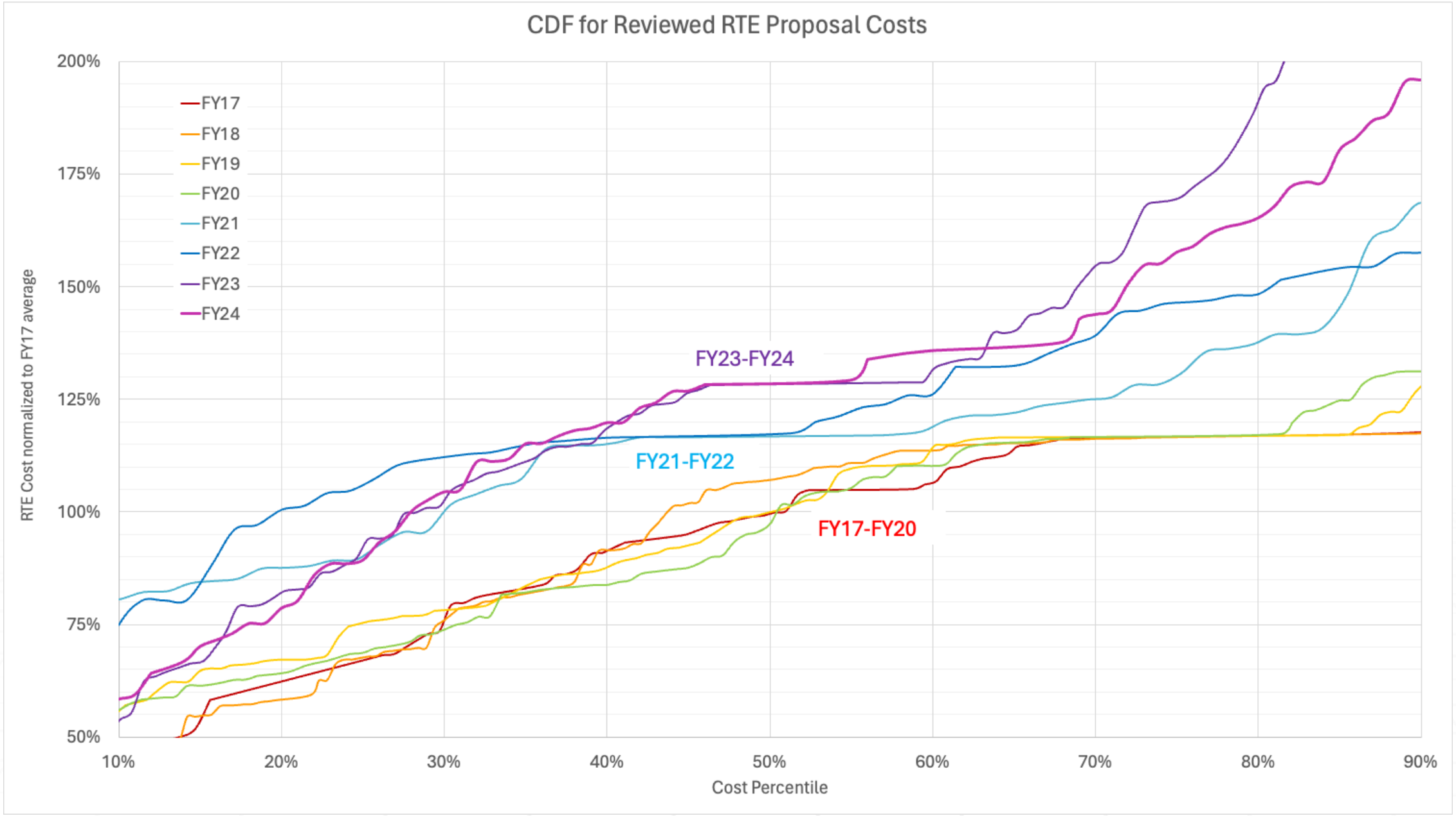
Center for Collaborative Computing (C3) and the Center for Advanced Energy Studies (CAES) in Idaho Falls

RTE Awarded Projects up to FY 2023: by Institution Type



NSUF Rapid Turnaround Experiments (small projects)




CDF for Reviewed RTE Proposal Costs
RTE Cost normalized to FY17 average
200%
175%
150%
125%
100%
75%
50%
FY17
FY18
FY19
FY20
FY21
FY22
FY23
FY24
FY23-FY24
FY21-FY22
FY17-FY20
10%
20%
30%
40%
50%
60%
70%
80%
90%
Cost Percentile

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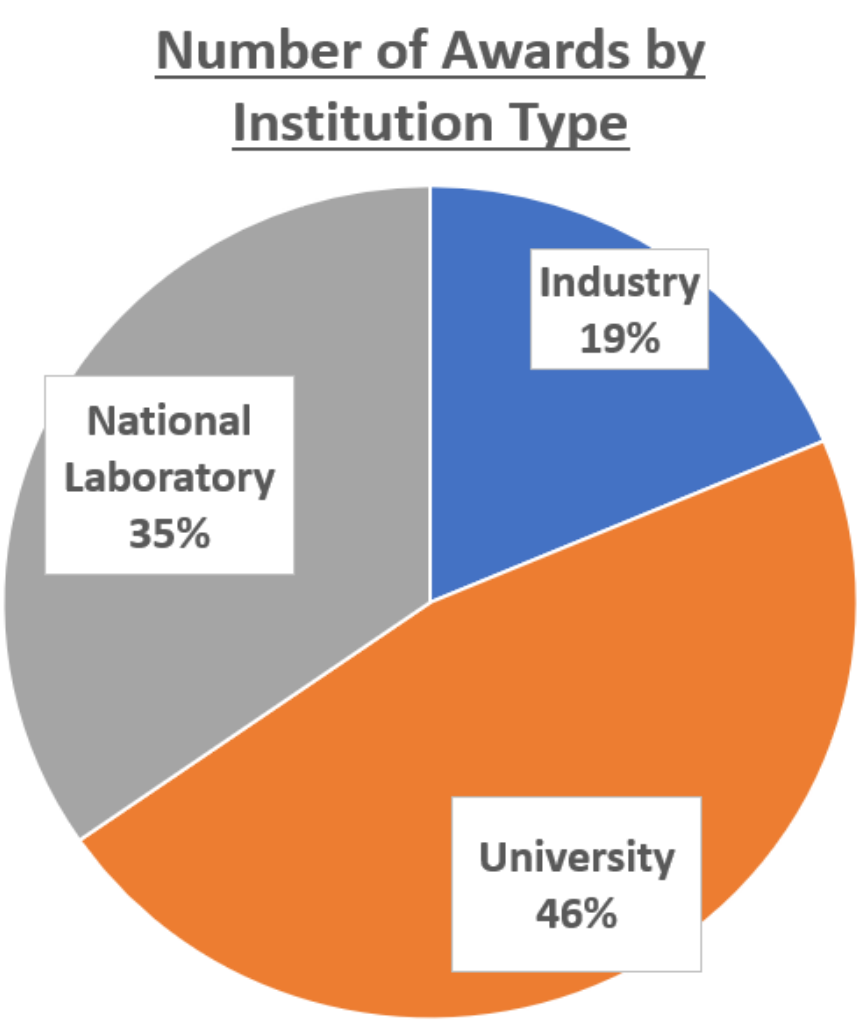
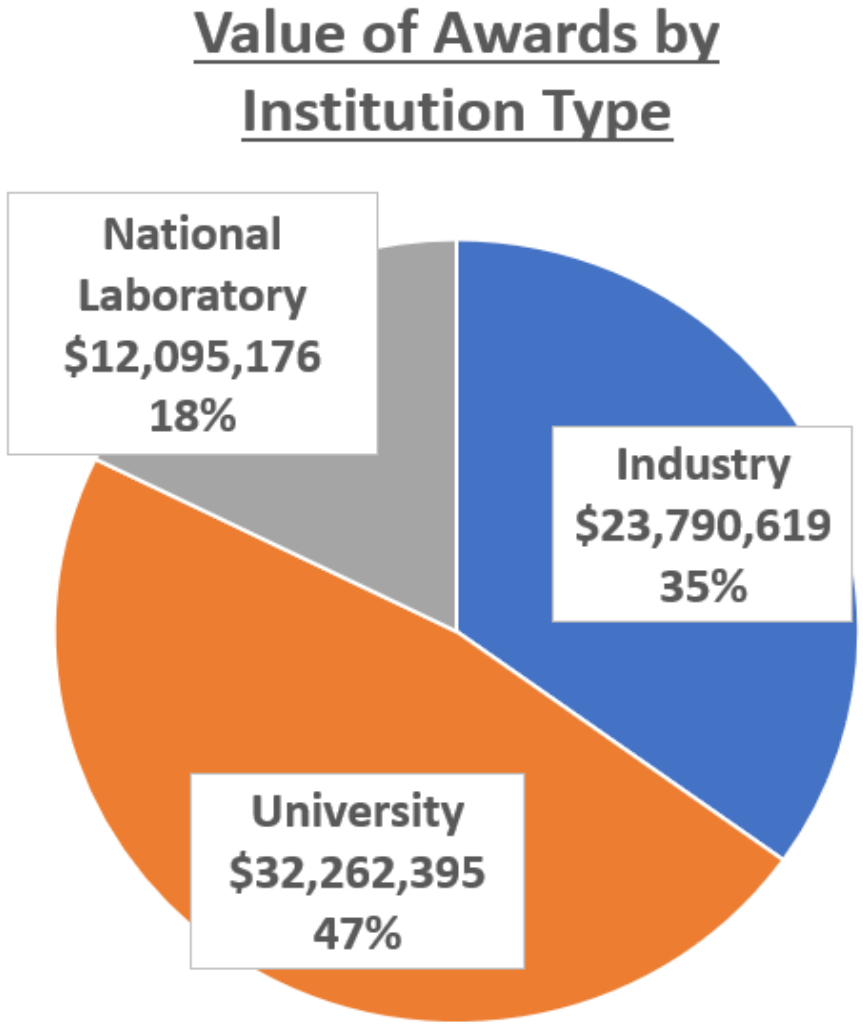
NSUF CINR Awards FY 2022–2023: Projects

FY	PI	Title	Institution	NSUF Capabilities	Award Budget
2023	Janelle Wharry	Irradiation-Corrosion of Alumina-Forming Austenitic Stainless Steels in Static Lead	Purdue University	ORNL/HFIR irradiation, ORNL PIE, Purdue surface science lab	$2,288,974
	Elizabeth Sooby	UN multi-design irradiation campaign: a critical assessment of accelerated burnup and main correlations for mechanistic fuel performance modeling	University of Texas at San Antonio	ORNL/HFIR irradiation, ORNL PIE	$2,498,000
	Maxim Gussev	Investigation of intergranular cracking of highly irradiated austenitic stainless steels – materials of pressurized water reactors – in ambient conditions	Oak Ridge National Laboratory	ORNL PIE, Michigan PIE, WCLS PIE	$1,575,111
2022	Maria Okuniewski	Mechanical response and chemical effects at the fuel-cladding interface of HT-9 and metallic fuel	Purdue University	INL/MFC PIE	$651,854
	Junhua Jiang	Accelerated Irradiation and Evaluation of Ultra-strong and Elastic Glassy Carbon	Idaho National Laboratory	TAMU Ion Beam Lab, CAES	$256,423
	Gabriel Meric	Integrated Effects of Irradiation and FLiBe Salt on Fuel Pebble and Structural Graphite for Molten Salt Reactors	Kairos Power	MITR irradiation, INL/MFC PIE	$833,191
	Andrew Whittaker	Gamma irradiation effects on the mechanical behavior of seismic protective devices	University at Buffalo	INL Gammacell, INL/MFC PIE	$451,337

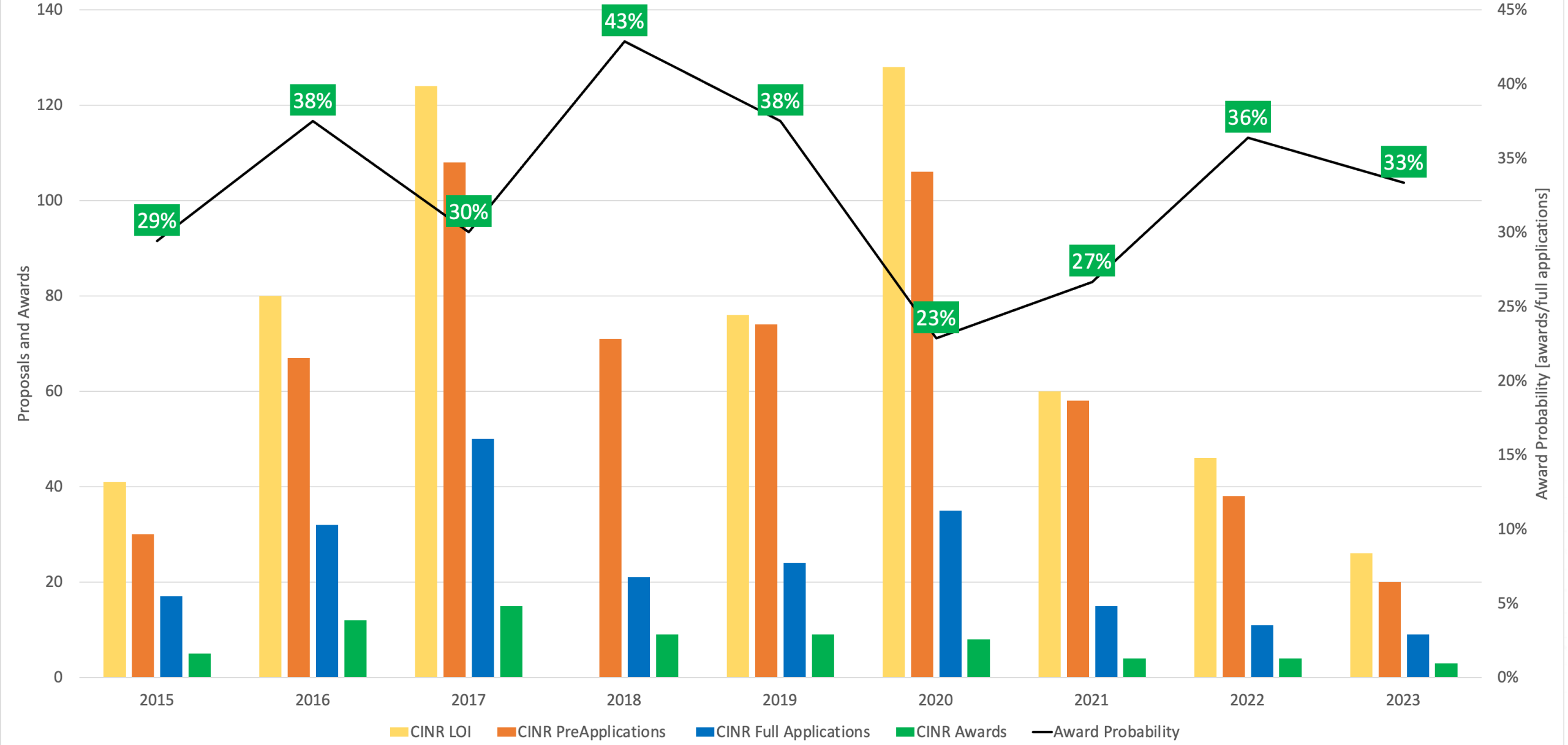
CINR Awarded Projects FY 2015–FY 2023





Graphics created by Lindy Bean

NSUF Consolidated Innovative Nuclear Research (large) Projects



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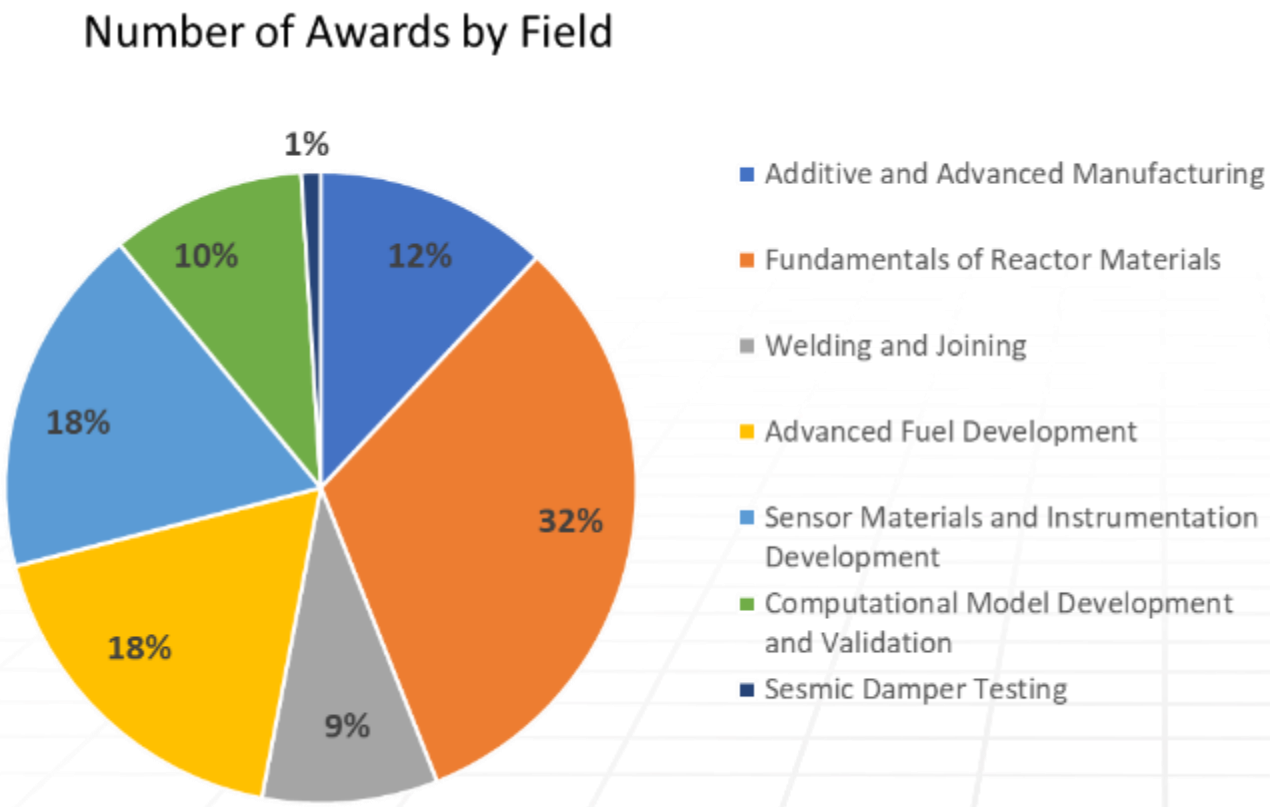
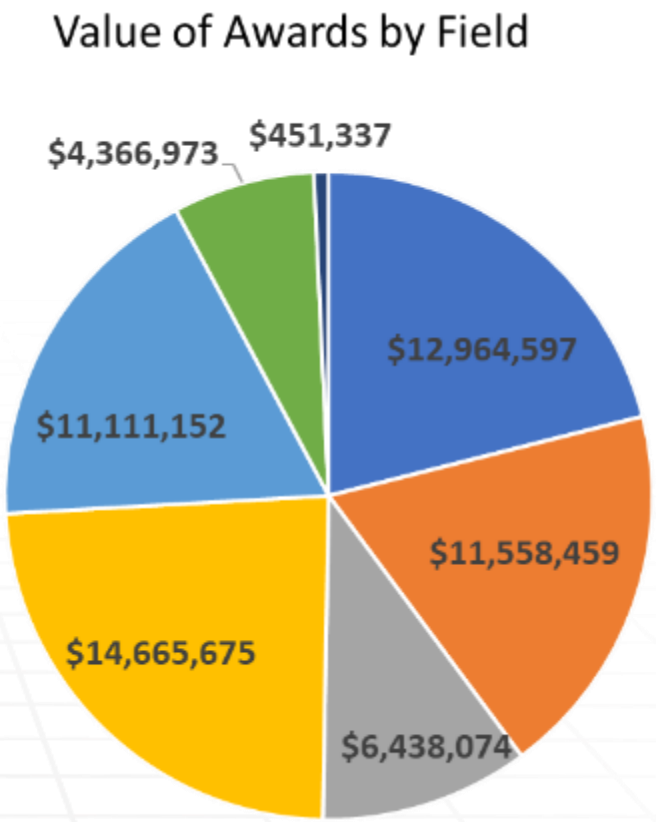
NSUF CINR Awarded Projects up to FY 2023: by Research Field





Summary of CINR work in various technical areas

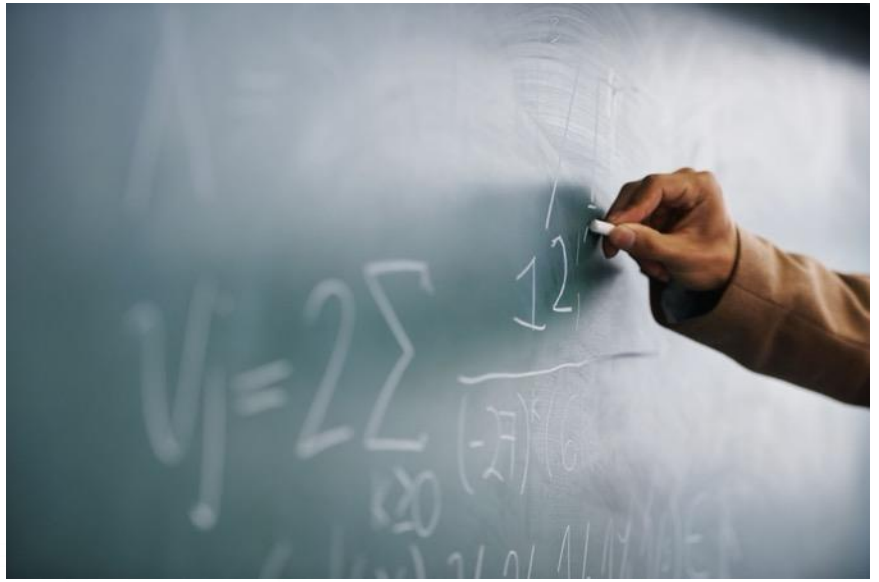
Technical Areas	Number of CINR Awards	Award Years	Access Funding
Fundamentals for Reactor Materials	30	FY15, 16, 17, 18, 19, 20, 21,22, 23	$22,450,554
Additive / Advanced Manufacturing	10	FY15, 16, 17, 18, 19, 21	$15,264,025
Advanced Fuel Development	11	FY15, 16, 17, 19, 20, 23	$14,494,994
Sensor Development	13	FY15, 17, 18, 19, 20, 21	$8,571,664
Computational Model Development and Validation	6	FY17, 18	$4,714,455
Welding & Joining Advanced Cladding	3	FY16, 17	$1,656,984
Nuclear Materials Discovery & Qualification Initiative	2	FY20, 21	$995,514

NSUF Awards Related to Advanced Manufacturing

- **24 awarded projects**
  - 14 of RTE awards
  - 10 of CINR awards
- **Awards related to types of advanced manufacturing**
  - 11 projects related to LPBF
  - 8 projects related to DED
  - 6 projects related to PM-HIP
  - 1 project related to electron beam welding
  - 2 projects related to cold spray
- **Awards related to materials**
  - ODS, Fe-based, Ni-based, Zircaloy, Fiber sensor embedded titanium components
- **NIFT-E "Neutron Irradiation as a Function of Temperature – Experiment**
  - Alumina-forming austenitic (AFA) steels, Al_2O_3 coated, Oxide coated F/M, AM Grade 91, HEAs, Hetero Nano-composites

Research Output

- In terms of scientific output, publications are one of the best tangible demonstrations of our impact in the field of nuclear science.
- Our team manually tracks NSUF publications monthly. Your NSUF-supported research is only accounted for when NSUF is accurately credited in the acknowledgments section of your publications. When publishing your work, please be sure to utilize the approved language, which is provided in. Going forward, please be sure to also identify what award you received, and the award number.
- The better we can demonstrate our impact, the better positioned we are to justify our presence in the nuclear science community, which ultimately benefits our ability to obtain funding and resources for NSUF, and inevitably, the funding and resources to support you, our users.



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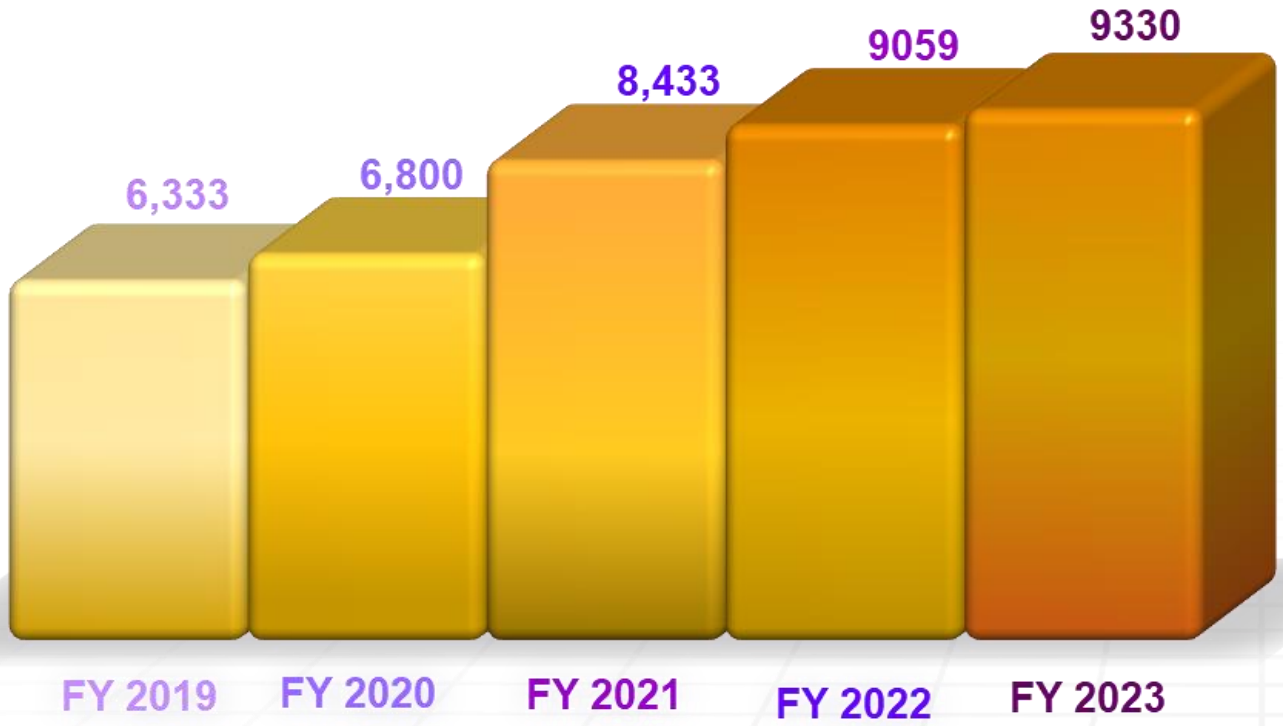
  - Instrument Scientist Support

The NSUF Nuclear Fuels and Materials Library



The NFML is the largest global open archive of high-value irradiated fuels and material from test, commercial, and decommissioned power reactors, and valuable donations from other sources.

Most samples in the library are neutron irradiated:

- **EBR-II** (INL), **ATR** (INL), **HFIR** (ORNL), **FFTF** (PNNL)
- José Cabrera Nuclear Power Station, commercial NPPs (in process)

A smaller number were proton irradiated:

- LANSCE (Los Alamos National Laboratory)

In the past, NSUF was in ***acquisition mode***.

Now we are in ***curation mode***.

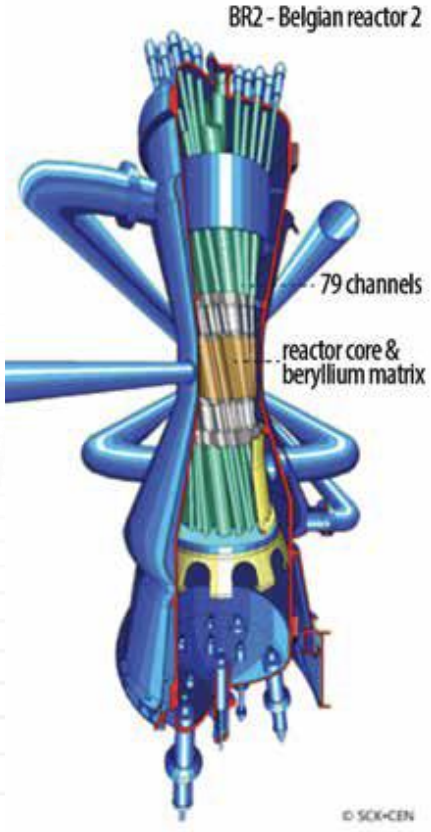
Future plans include:

- Forming a working group to inform new acquisitions. Tied in with UK collaborators.
- Planning for specific irradiation campaigns to populate the NFML with desirable material.

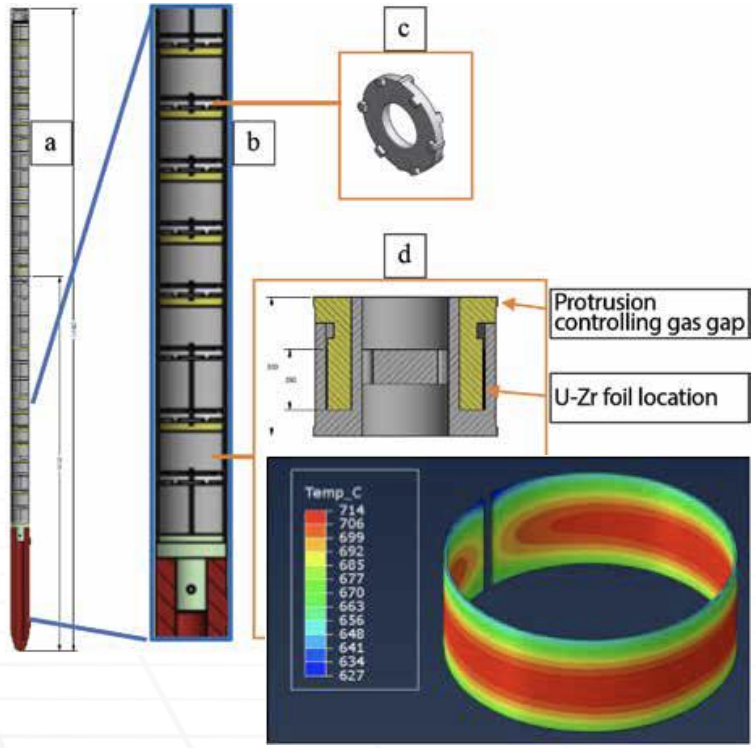
International Collaborations – NSUF BR-2 Project

DISECT "*Disc Irradiation for Separate Effects testing with Control of Temperature*"

- The research involves a collaborative effort with the **SCK-CEN in Belgium** and the NSUF utilizing capabilities at INL and the Belgian Nuclear Research Center.
- The DISECT project includes the design and fabrication of a uniquely instrumented, separate effects testing vehicle; specimen fabrication and pre-characterization; irradiation; and post-irradiation examination to enable a more comprehensive understanding of in-pile phenomena.
- **Uranium-Zirconium** (U-Zr) alloy fuel is the reference fuel for any future U.S. fast test reactors.
- Furthering the understanding of the U-Zr system can be used to provide the basis for increasing fuel burn-up beyond the current 10 atomic percent (at%) for fuels and 20 at% for experiments or extrapolating the effect of minor design modifications.



The Belgian BR2 reactor at SCK-CEN.



a) In-core portion of the test vehicle.
b) Enlarged section of vehicle illustrating the stack-up of specimen holders separated by insulators.
c) Insulators utilizing gas gaps to isolate specimen holders.
d) Specimen holders for the U-Zr alloy foils.

International Collaborations – NSUF ATR Project

NIFT-E "**N**eutron **I**rradiation as a **F**unction of **T**emperature – **E**xperiment

Strategic Objectives

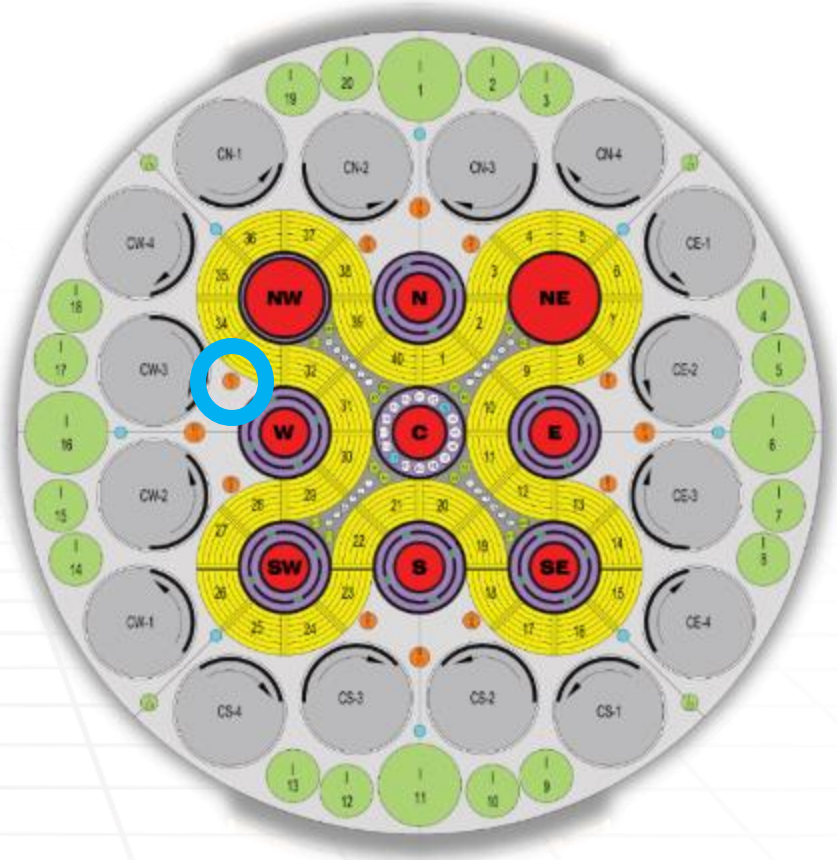
- Explore sharing of nuclear facilities between the United States and the UK
- Further nuclear energy research collaboration

Technical Objectives

- Capture effects of neutron irradiation as a function of temperature on dose on nuclear graphite and on alumina-forming austenitic (AFA) steels
- Targets microstructure and mechanical property plus corrosion behavior

Stakeholders

- **U.S.:** NSUF plus INL, PNNL, Purdue University, Westinghouse
- **UK:** NNUF plus UK NNL, Univ. of Manchester, Univ of Oxford, Univ. of Sheffield, UKAEA

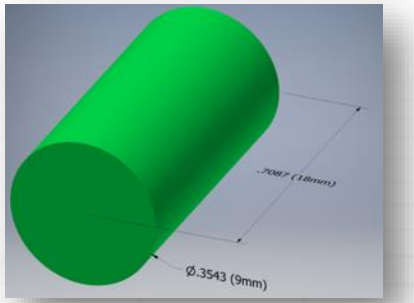


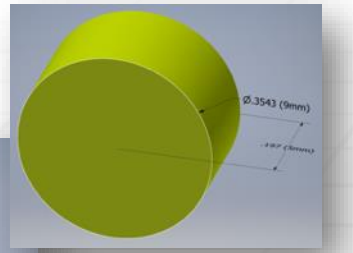
Specimens & Capsules

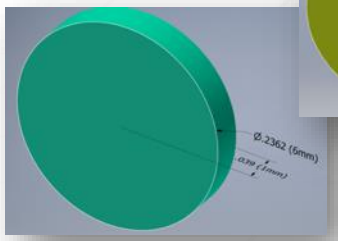
Alumina-Forming Alloys
GA05 SA
GA05 HT
GA05 20Ni SA
GA05 20Ni HT
AISI Type 304L SS 3 µm Al2O3 coated
AISI Type 304L SS 1.5 µm FeCrAl 1.5 µm Al2O3 coated

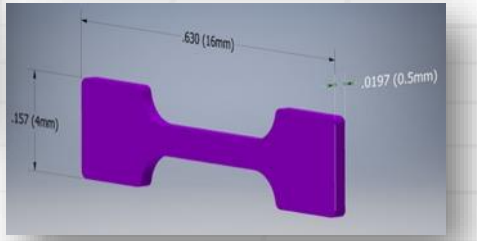
Miscellaneous Material
Oxide-Coated F/M Steels 3µm Al2O3 coated
Oxide-Coated F/M Steels 1.5 µm FeCrAl 1.5 µm Al2O3 coated
Adv Mfg Grade 91
HEAs
Hetero Nano-composites

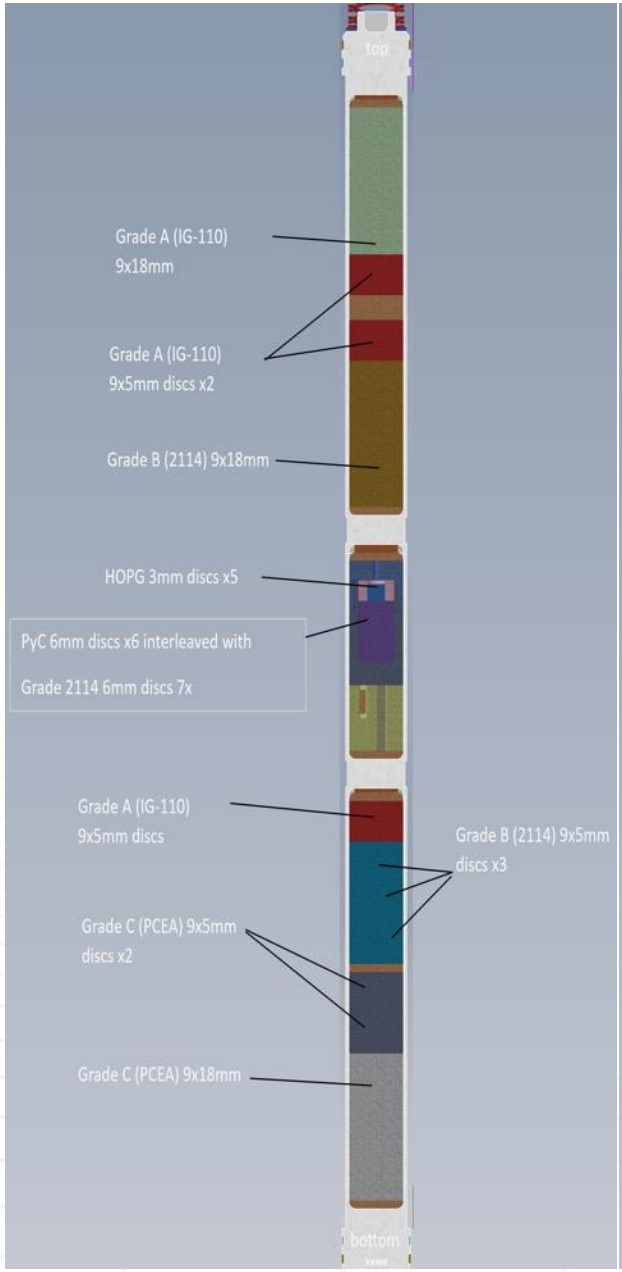
Graphite
IG110
HOPG
PyC
NBG18

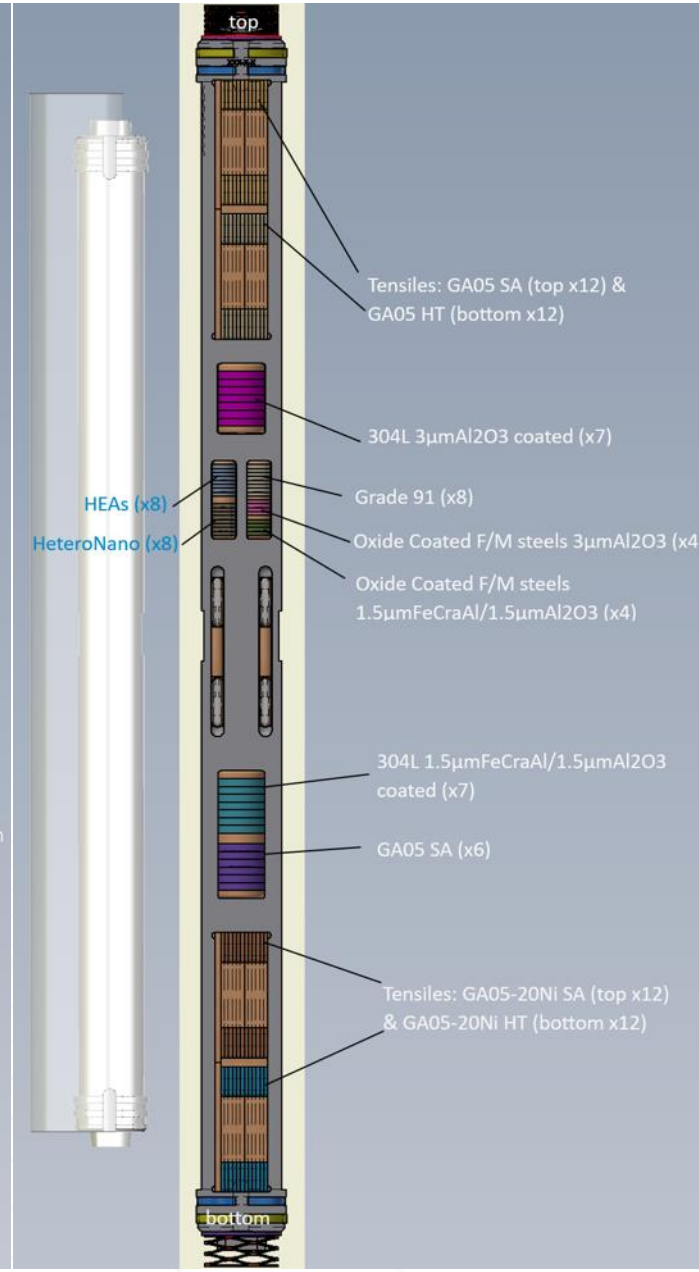












US-UK Project Timeline & Strategy

Activity	Finish Date
Final Design Complete	September 2023
Assembly Complete	late 2024
Commence Irradiation	September 2025

Capsule	DPA Target	Temperature
C1	1.0 dpa minimum	750 ± 50°C
C2	2.0 dpa minimum	750 ± 50°C
C3	3.0 dpa minimum	750 ± 50°C
AFA1	1.0 ± 0.3 dpa	400 ± 50°C
AFA2	1.0 ± 0.3 dpa	650 ± 50°C
AFA3	8.0 dpa nominal	400 ± 50°C
AFA4	4.0 dpa nominal	400 ± 50°C
AFA5	4.0 dpa nominal	650 ± 50°C

ATR Position B-7		Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 6	Cycle 7	Cycle 8	Cycle 9	Cycle 10	Cycle 11	Cycle 12	Cycle 13
CAPSULE POSITION	A	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE
	B	AFA1	AFA4	AFA4	AFA4	AFA4	AFA4	AFA4	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE
	C	C1	C1	C1	C2	C2	C2	C2	C2	C2	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE
	D	AFA5	AFA5	AFA5	AFA5	C3	C3	C3	C3	C3	C3	C3	C3	C3
	E	AFA2	AFA3	AFA3	AFA3	AFA3	AFA3	AFA3	AFA3	AFA3	AFA3	AFA3	AFA3	AVAILABLE
	F	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE

NFML SAM-2 – NSUF Directed Project

SiC Interest and Applications

- Monolithic SiC – high temperature, low activation structural material
- Wide bandgap semiconductor – 3.26 eV
- Fuel applications (TRISO, accident tolerant cladding)
- Passive metrology – well characterized volumetric swelling (both fluence and temperature)

ATR Irradiation

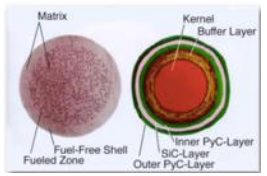
- Small B position (NW) 0.875” diameter
  - Thermal Flux: 2.5E+14 Fast Flux: 8.1E+13
- Insertion Cycle: 169A (DEC 2020) 12 Cycles (4-5 years)

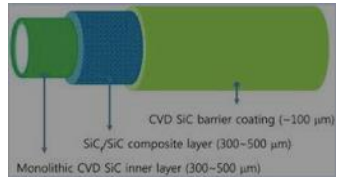
PIE and Data Results

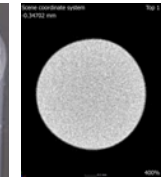
- Mechanical, thermal, and electrical properties
- Measurements repeated after annealing above irradiation temperature (158°C) to remove fast neutron damage.

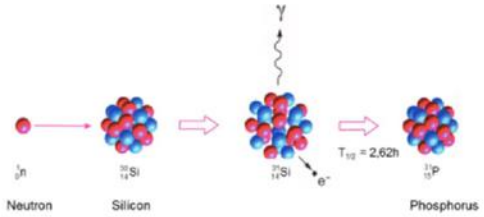
Schedule

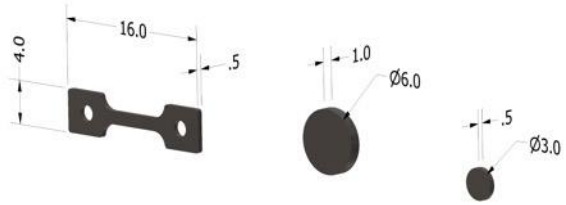
- First 3 capsules removed and disassembled
- Started tensile testing on baseline unirradiated and irradiated specimens from first 3 capsules-complete in summer 2023
- Every year another 1-3 capsules removed, and PIE performed.
- Re-utilizing the irradiation space with other drop in capsules experiments (GENIE-AH)

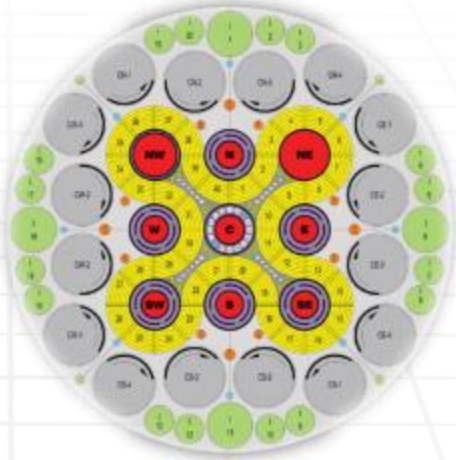


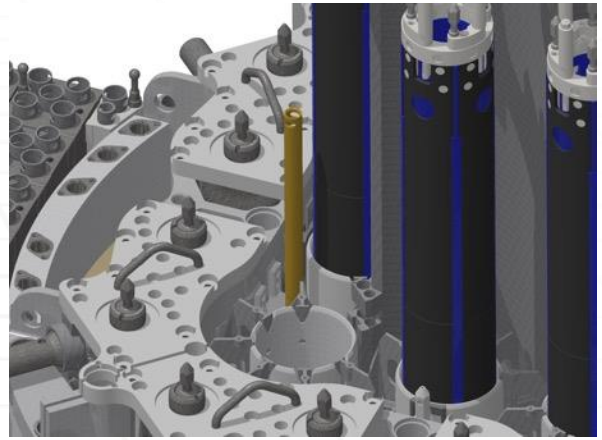








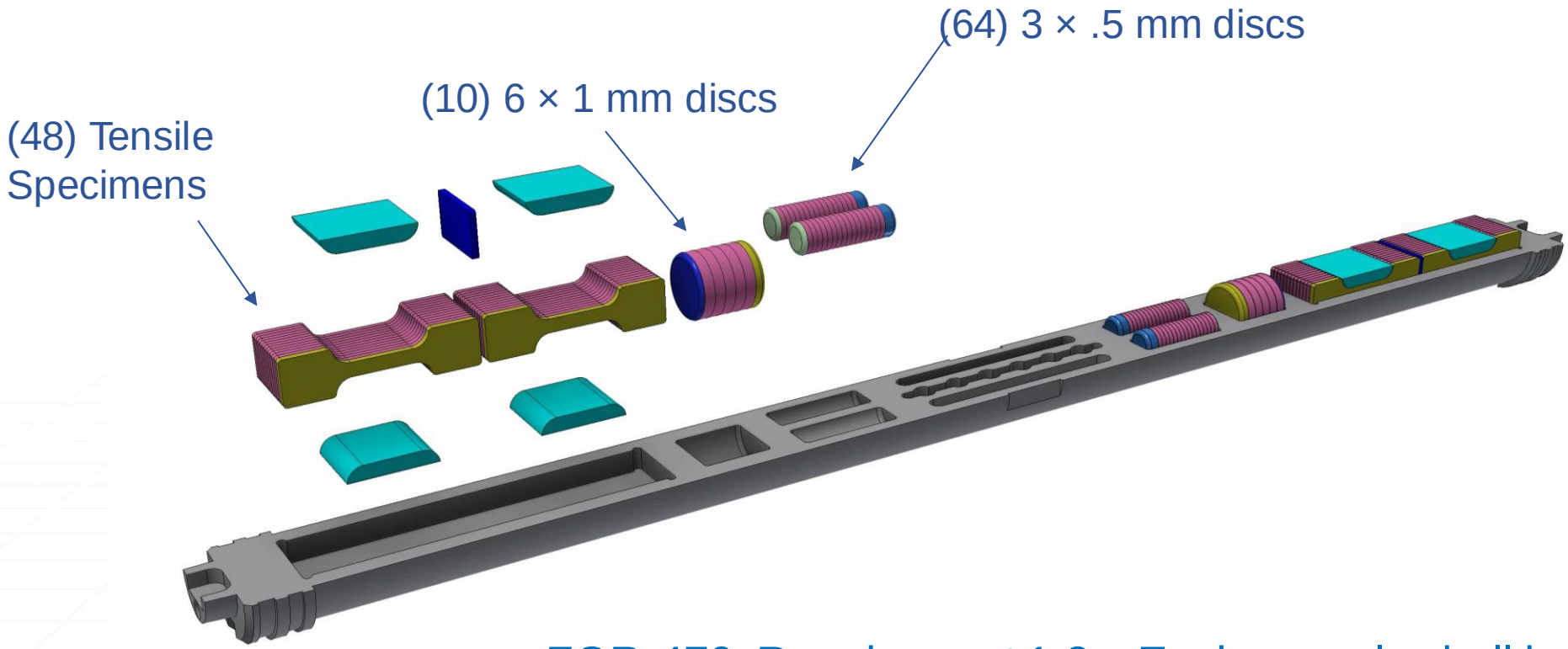




Rory Kennedy – Idaho National Laboratory
Keith Jewell – Idaho National Laboratory

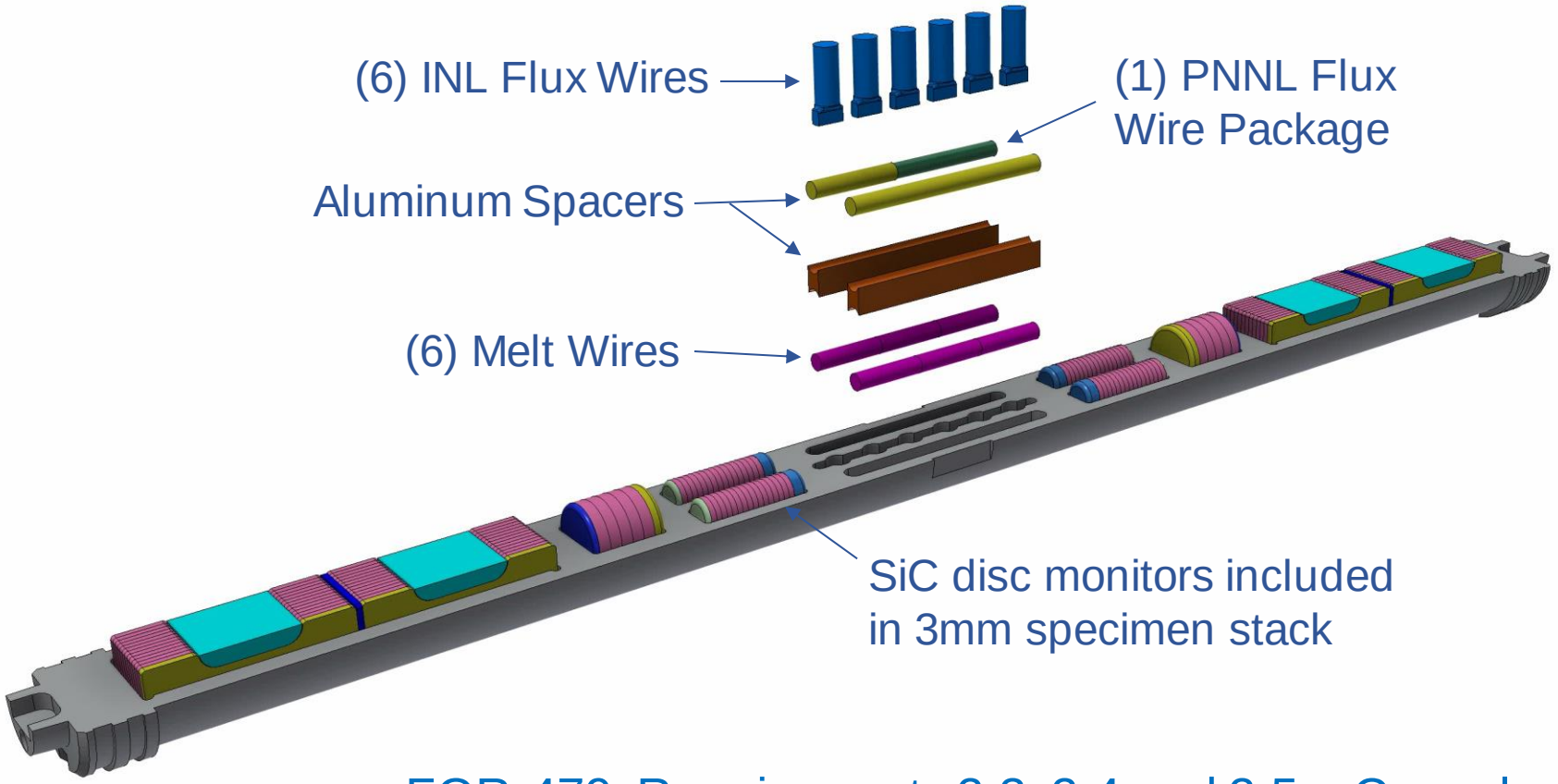
NSUF Nuclear Science User Facilities

5/8” Standard Capsule Fixture



- FOR-479, Requirement 1.2 – Each capsule shall be designed to contain a minimum of (30) 3 × .5 mm discs, (10) 6 × 1 mm discs and (15) 16 × 4 × .5 mm tensile specimens.

Standard Dosimetry Package



- FOR-479, Requirements 2.3, 2.4 and 2.5 – Capsules shall be designed to include melt wires, flux wires and SiC monitors.

The NSUF Instrument Scientist (IS) Support

- **A User Facility needs to invest in both physical infrastructure and in trained scientific staff**
- Started in FY 2018, the NSUF offered up to 20% of a scientist's time based on a competitive process that includes:
  - Technical merit
  - Amount of NSUF work at that facility/instrument
  - Potential to expand or improve capabilities at that facility/instrument
- IS support effort was designed to provide additional funding to INL scientific staff who support NSUF awards which will improve instrumentation, enhance data collection methods and improve experimental methods .
  - In FY 2024 the NSUF IS project was expanded to include IS from NSUF national laboratory Partner Facilities
- Instrument Scientist support funding has continued to increase.
  - FY 2024 call: 24 proposals submitted from all eight NSUF national laboratories.
    - Proposals funded at INL/MFC, BNL/NSLS-II, ORNL/LAMDA, and LANL/LANCE
    - 5 funded trips to national/international conferences
    - Money to support publications

NSUF

Nuclear Science User Facilities

CINR Awarded Projects

Focus on Key Technologies and Understanding

Additive / Advanced Manufacturing

Completed in:
FY17
FY18
FY19
FY20
FY21
FY22
FY23

FY	Title	Institution	Funding
2015	Irradiation Influence on Alloys Fabricated by Powder Metallurgy and Hot Isostatic Pressing for Nuclear Applications	BSU	$1,598
2016	Enhancing irradiation tolerance of steels via nanostructuring by innovative manufacturing techniques	ISU	$2,459
	Irradiation performance testing of specimens produced by commercially available additive manufacturing techniques	CSM	$2,030
	Irradiation Testing of LWR Additively Manufactured Materials	GEH	$1,982
2017	Radiation Effects on Zirconium Alloys Produced by Powder Bed Fusion Additive Manufacturing Processes	WCLS	$830
2018	High-dose ion irradiation testing and relevant post-irradiation examination of friction-stir-welded ODS MA956 alloy	PNNL	$182
	Irradiation Testing of Materials Produced by Additive Friction Stir Manufacturing	Aeroprobe	$1,837
	Nanodispersion Strengthened Metallic Composites with Enhanced Neutron Irradiation Tolerance	MIT	$2,046
2019	Irradiation studies on electron beam welded PM-HIP pressure vessel steel	Purdue	$2,072
2021	Effect of neutron irradiation on friction stir welded Ni-based ODS MA754 alloy	PNNL	$227
			$15,264

CINR Awarded Projects table created by Lindy Bean

CINR Awarded Projects
Focus on Key Technologies and Understanding

Advanced Fuel Development

Completed in:
FY17
FY18
FY19
FY20
FY21
FY22
FY23

FY	Title	Institution	Funding
2015	Microstructural Evolution in Low Fluence Irradiated Metallic Fuels	INL	$663
2016	Fission Product Transport in TRISO	UMich	$22
	Radiation-Enhanced Diffusion of Ag, Ag-Pd, Eu, and Sr in Neutron Irradiated PyC/SiC Diffusion Couples	ORNL	$518
2017	Irradiation of Advanced Neutron Absorbing Material to Support Accident Tolerant Fuel	AREVA	$630
	Irradiation, Transient Testing and Post Irradiation Examination of Ultra High Burnup Fuel	EPRI	$3,588
	Disc Irradiation for Separate Effects Testing with Control of Temperature (DISECT)	SCK-CEN/INL	
	Accident Tolerant fuel Test for the Interaction of Coolant with Uranium Silicide (ATTICUS)	SCK-CEN/INL	
2019	High power irradiation testing of TRISO fuel particles with UCO and UO2 kernels in miniature fuel specimen capsules in HFIR	Kairos	$2,997
	Thermal Conductivity Measurement of Irradiated Metallic Fuel Using TREAT	UPitt	$1,895
2020	Investigation of Degradation Mechanisms of Cr coated Zirconium alloy cladding in Reactive Initiate Accidents (RIA)	UWisc	$1,683
2023	UN multi-design irradiation campaign: a critical assessment of accelerated burnup and main correlations for mechanistic fuel performance modeling	UTSA	$2,498
			$14,495

CINR Awarded Projects table created by Lindy Bean

CINR Awarded Projects
Focus on Key Technologies and Understanding

Fundamentals for Reactor Materials

Completed in:
FY17
FY18
FY19
FY20
FY21
FY22
FY23

FY	Title	Institution	Funding
2015	Advanced Characterizations of Low-dose Neutron Irradiated T91 and HT9 Alloys	UIll-Urbana	$219
	In-situ Synchrotron Wide-Angle X-ray Scattering (WAXS) Tensile Investigation of Neutron Irradiated Ferritic Alloys	UIll-Urbana	$765
2016	Beamline Examination of a Hf-Al Metal-Matrix Composite Material	INL	$342
	Correlative Atom Probe and Electron Microscopy Study of Radiation Induced Segregation at Low and High Angle Grain Boundaries in Steels	ORNL	$150
	Effect of Gamma Irradiation on the Microstructure and Mechanical Properties of Nano-modified Concrete	Vanderbilt	$185
	Feasibility of Combined Ion-Neutron Irradiation for Accessing High Dose Levels	UMich	$187
	Radial Heat Flux – Irradiation Synergism in SiC ATF Cladding	ORNL	$843
	Role of minor alloying elements on long range ordering in Ni-Cr alloys	OrStU	$90
	Understand the phase transformation of thermal aged and neutron irradiated duplex stainless steels used in LWRs	UFla	$579
2017	Correlation between Microstructure and Mechanical Properties of Neutron-Irradiated Ferritic-Martensitic and Austenitic Steels	ORNL	$652
	Improved Understanding of Zircaloy-2 Hydrogen Pickup Mechanism in BWRs	EPRI	$817
	Positron Annihilation Studies of Neutron Irradiated Ferritic Alloys	UIll-Urbana	$203
	X-ray Characterization of Atomistic Defects Causing Irradiation Creep of SiC	ORNL	$150

CINR Awarded Projects table created by Lindy Bean

CINR Awarded Projects
Focus on Key Technologies and Understanding

Fundamentals for Reactor Materials

Completed in:
FY17
FY18
FY19
FY20
FY21
FY22
FY23

FY	Title	Institution	Funding
2018	Rapid Simulation of Irradiation Damage in PWR Internals	ORNL	$323
	Understanding Swelling-Related Embrittlement of AISI316 Stainless Steel Irradiated in EBR-II	INL	$1,077
2019	Integral Fuel Rod Real-Time Wireless Sensor & Transmitter Irradiation Test and Post Irradiation Examination	WCLS	$3,097
	Irradiation-assisted Stress Corrosion Cracking of PWR-irradiated Type 347 Stainless Steel	WCLS	$927
	NuScale SMR Materials Irradiation and Testing	NuScale	$2,482
2020	Improving Lifetime Prediction of Electrical Cables in Containment	PNNL	$22
	Effect of neutron irradiation on microstructure and mechanical properties of nanocrystalline nickel	NSCU	$204
	X-ray diffraction tomography analysis of SiC composite tubes neutron-irradiated with a radial high heat flux	ORNL	$50
	Synergy of radiation damage with corrosion processes through a separate effect investigation approach	NSCU	$175
	Demonstration of Self Powered Neutron Detectors Performance and Reliability	INL	$705
2021	Assessment of Irradiated Microstructure and Mechanical Properties of FeCrAl Alloy Fabrication Routes	GE Research	$2,149

CINR Awarded Projects table created by Lindy Bean

CINR Awarded Projects
Focus on Key Technologies and Understanding

Fundamentals for Reactor Materials

Completed in:
FY17
FY18
FY19
FY20
FY21
FY22
FY23

2022	Mechanical response and chemical effects at the fuel-cladding interface of HT-9 and metallic fuel	Purdue	$652
	Accelerated Irradiation and Evaluation of Ultrastrong and Elastic Glassy Carbon	INL	$256
	Integrated Effects of Irradiation and Flibe Salt on Fuel Pebble and Structural Graphites for Molten Salt Reactors	Kairos	$833
	Gamma irradiation effects on the mechanical behavior of seismic protective devices	SUNY-Buffalo	$451
2023	Irradiation-Corrosion of Alumina-Forming Austenitic Stainless Steels in Static Lead	Purdue	$2,289
	Investigation of intergranular cracking of highly irradiated austenitic stainless steels – materials of pressurized water reactors – in ambient conditions	ORNL	$1,575
			$22,451

CINR Awarded Projects table created by Lindy Bean

CINR Awarded Projects

Focus on Key Technologies and Understanding

Sensor Development

Completed in:	
	FY17
	FY18
	FY19
	FY20
	FY21
	FY22
	FY23

FY	Title	Institution	Funding
2015	Ultrasound-Based Sensors for Enhanced Monitoring of Irradiation Testing	INL	$957
2017	Additive manufacturing of thermal sensors for in-pile thermal conductivity measurement	BSU	$536
	Radiation Effects on Optical Fiber Sensor Fused Smart Alloy Parts with Graded Alloy Composition Manufactured by Additive Manufacturing Processes	UPitt	$775
	Monitoring Of Temperature Of Reactor Experiments – MOTORE	SCK-CEN/INL	$100
	Benchmarking of Ultrasonic Thermometer and Fiber Bragg Grating Thermometer	SCK-CEN/INL	$140
2018	High-performance nanostructured thermoelectric materials and generators for in-pile harvesting	UND	$655
	Irradiation Behavior of Piezoelectric Materials for Nuclear Reactor Sensors	OSU	$458
2019	High Fluence Active Irradiation and Combined Effects Testing of Sapphire Optical Fiber Distributed Temperature Sensors	INL	$1,206
	Irradiation of Optical Components of In-Situ Laser Spectroscopic Sensors for Advanced Nuclear Reactor Systems	UMich	$406
	Neutron Radiation Effect on Diffusion between Zr (and Zircaloy) and Cr for Accurate Lifetime Prediction of ATF	OSU	$1,134
2020	Irradiation of Sensors and Adhesive Couplants for Application in LWR Primary Loop Piping and Components	EPRI	$635
2021	Understanding irradiation behaviors of ultrawide bandgap Ga2O3 high temperature sensor materials for advanced nuclear reactor systems	NCSU	$490
	Deployment and In-Pile Test of an Instrument for Real-Time Monitoring Thermal Conductivity Evolution of Nuclear Fuels	INL	$1,080
			$8,572

CINR Awarded Projects table created by Lindy Bean

CINR Awarded Projects
Focus on Key Technologies and Understanding

Completed in:
FY17
FY18
FY19
FY20
FY21
FY22
FY23

Computational Model Development and Validation

FY	Title	Institution	Funding
2017	HPC Access to Advance Understanding of Fission Gas Behavior in Nuclear Fuel	UTenn	$890
	In-Situ Ion Irradiation to Add Irradiation Assisted Grain Growth to the MARMOT Tool	PennSt	$125
	Simulation of Radiation and Thermal Effects in Advanced Cladding Materials	PNNL	$45
	Study of the Irradiation Behavior of Fast Reactor Mixed Oxide Annular Fuel with Modern Microstructural Characterization to Support Science Based Model Validation	INL	$773
2018	Demonstration of a Methodology for Direct Validation of MARMOT Irradiation-Induced Microstructural Evolution and Physical Property Models Using U-10Zr	TAMU	$2,080
	Facilitating MARMOT Modeling of Radiation Phenomena in U-Pu-Zr fuels through experiments (MORPH experiment)	UFla	$801
			$4,714

CINR Awarded Projects
Focus on Key Technologies and Understanding

Completed in:	
	FY17
	FY18
	FY19
	FY20
	FY21
	FY22
	FY23

Welding & Joining Advanced Cladding

FY	Title	Institution	Funding
2016	Effects of High Dose on Laser Welded, Irradiated AISI 304SS	BSU	$613
2017	Capacitive Discharge Resistance Welding of 14YWT for Cladding Applications	LANL	$59
	Performance of SiC-SiC Cladding and Endplug Joints under Neutron Irradiation with a Thermal Gradient	GA	$985
			$1,657

Nuclear Materials Discovery & Qualification Initiative

FY	Title	Institution	Funding
2020	Machine Learning on High-Throughput Databases of Irradiation Response and Corrosion Properties of Selected Compositionally Complex Alloys for Structural Nuclear Materials	UWisc	$502
2021	Computer vision and machine learning for microstructural qualification	Carnegie Mellon	$494
			$996

CINR Awarded Projects table created by Lindy Bean