

April 15-18, 2024

FY 2023 NSUF ANNUAL PROGRAM REVIEW

Rongjie Song for Kelly Cunningham

Nuclear Science User Facilities Nuclear Fuels and Materials Library

Content

- Overview
- Materials acquisition
- Inventory
 - Ceramic
 - Fuel
 - Structure material/ fuel cladding
 - Sensor
- Utilization
- Data management planning

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Overview

- **The Nuclear Fuels and Materials Library (NFML)**
 - Owned by the U.S. Department of Energy's Office of Nuclear Energy (DOE-NE)
 - Curated by the Nuclear Science User Facilities (NSUF)
- **NFML samples are from**
 - NSUF-awarded projects
 - Experimental Breeder Reactor (EBR-II) shutdown in 1994
 - Real-world components retrieved from decommissioned and operating power reactors
 - Donations from other sources
- **Access to the NFML samples**
 - Publicly available via NSUF competitive award processes
 - Direct requests granted by the NSUF Director



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Receipt of FY 2022 Acquisition BWXT Core Shroud Samples



Shipments of NPP samples from BWXT (Virginia) to INL

- Three of five shipments received in FY 2023
- Last two shipments scheduled to be received in FY 2024
- All samples listed in library – availability updated as samples are received at INL

ID	Description	Material	Specimen	Available	Keywords	Code
22-BWXT-01	Piece A Base Metal	304 SS	remnant	Yes	In-S	
22-BWXT-02	Piece A Base Metal	304 SS	specimen	Yes	In-S	
22-BWXT-03	Piece A Base Metal	304 SS	remnant	Yes	In-S	
22-BWXT-04	Piece A Base Metal	304 SS	specimen	Yes	In-S	
22-BWXT-05	Piece A Base Metal	304 SS	specimen	Yes	In-S	
22-BWXT-06	Piece A Base Metal	304 SS	remnant	Yes	In-S	
22-BWXT-07	Piece A Base Metal	304 SS	TEM	Yes	In-S	
22-BWXT-08	Piece A Base Metal	304 SS	remnant	Yes	In-S	
22-BWXT-09	Piece A Base Metal	304 SS	TEM	Yes	In-S	
22-BWXT-10	Piece A Base Metal	304 SS	TEM	Yes	In-S	
22-BWXT-11	Piece A Base Metal	304 SS	remnant	Yes	In-S	
22-BWXT-12	Piece A Base Metal	304 SS	remnant	Yes	In-S	

Program	NSUF
Project	LWR 304 SS Core Shroud Samples
Reactor	LWR
Reactor Position	core shroud
Sample Id Code	22-BWXT-14
Material Code	Piece B1
Material Name	304 SS
Material Description	Piece B Base Metal
Specimen Type	remnant
Dimensions (mm)	1" x 0.7" x 0.65"
Number Of Samples	1
Samples Remaining	1
Available for Research	Yes
Anticipated Availability	August 8, 2023
Storage Facility	Hot Fuel Examination Facility
Notes	Irregular shaped piece contains uncracked material below tensile specimens. Weight 57 g. Estimated Dose Rate @1" = 25 R/hr
As Run Temp (°C)	288.00
As Run Dose (DPA)	3.25
As Run Fluence (n/cm ²)	2.3E+21
As Run Flux (n/cm ² /s)	1E+10
As Run Environment	LWR
Composition by Wt. (%)	Fe -17.7Cr -9.04Ni -1.3Mn -0.33Mo -0.26V -0.2Co -0.17Cu -0.09B -0.00Nb -0.002 -0.002 -0.002 -0.002 -0.002 -0.002



FY 2023 New Acquisition



Program-to-Program Transfer

CRADA - Ki-Jang Research Reactor (KJRR) Fuel Assembly Irradiation

- U-7Mo dispersed in Al-Si matrix, Al-clad fuel plates (Title transfer to DOE-ID was included in the Cooperative Research and Development Agreement (CRADA))
- Korea Atomic Energy Research Institute (KAERI) fabricated the KJRR fuel experiment and shipped to the INL, to run irradiation in the ATR, PIE in the HFEF, and irradiation conditions analyses.
- Primary purpose of the campaign was to provide data about the irradiation performance of the KJRR fuel assembly.



Lead Test Assembly



Fuel Plates

FY 2023 In-Process Acquisitions (REPOSITORY)



Program-to-Program Transfer

Zion Nuclear Power Plant Reactor Pressure Vessel Material

- NFML staff and LWRS staff discussing acquisition for years
- PIE completed in 2023
- List of samples and supporting documents assembled
- Need official statement of transfer from LWRS Program to NSUF Program

This project is critically important ... access to materials from active or decommissioned NPPs provide an invaluable resource for which there is limited operational data or experience to inform relicensing decisions and assessments of current degradation models to further develop the scientific basis for understanding and predicting long-term environmental degradation behavior. DOE: 10.2172/1471907



Program-to-Program Transfer

Microreactor Program Yttrium-Hydride Samples

- ATR-irradiated Yttrium Hydride samples
- Were tested as a moderator material for microreactors
- NSUF working with MFC staff to move samples to long-term storage
- Need official statement of transfer from the Microreactor Program to NSUF Program

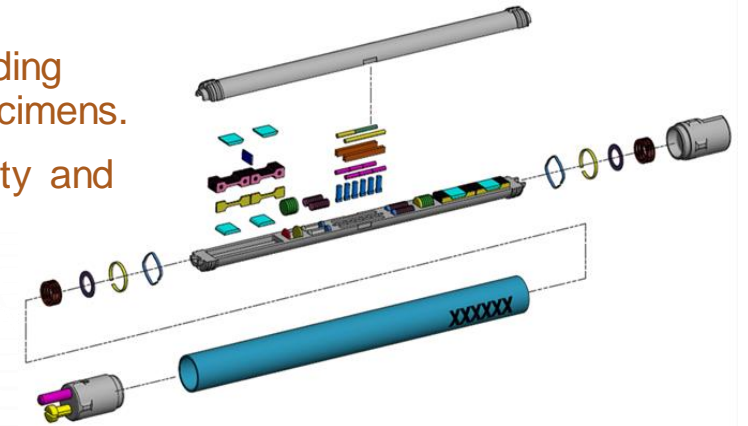
The emergence of microreactor technology has helped to drive supporting nuclear materials qualification and acceptance processes. ... While the behavior and performance of metal-hydride moderators go back to early advanced reactor development for nuclear-powered aviation ... there remains a knowledge gap in the understanding of hydrogen transport-related phenomena and irradiation performance for hydride moderators. 1080/00295450.2022.2121583 DOI: 10-

FY 2023 In-Process Acquisitions (REPOSITORY)



Tensile Testing Using the Standard Capsule (TTUSC) Irradiation

- Standard Capsule designed by SAM-2 team
 - ❖ Saves substantial time and money in experiments by providing investigators an approved design for irradiating tensile specimens.
- LDRD irradiation funding expended, NSUF assumed responsibility and ownership for remaining activities
- Multi-principal metal alloys (MPEA)
- Irradiated samples to be shipped from ATR to HFEF in FY 2024



Material Preservation Contract

University of California – Santa Barbara to University of California - Berkeley

- Residual NSUF experiment samples and small inventory of other neutron irradiated samples of interest stored at UCSB for years
- Current curator wants to ensure samples are preserved
- NSUF Samples to be inventoried and moved to UC-B for secure guardianship
- NSUF and UC-B agree that DOE-NE may secure ownership for NSUF curation and inclusion in the NFML

FY 2023 Domestic/International Activities

HARVESTING

- Halden Research Reactor
 - ❖ 304 & 316 samples irradiated in Russian Research Reactor
 - ❖ Title Transfer drafted
 - ❖ Shipment logistics agreed upon
 - ❖ End User Statement required from NSUF declaring samples will only be used for nuclear energy research
- Framatome (Germany)
 - ❖ Discussions regarding potential donation of RPV material from various NPPs
- SONGS Reactor Decommissioning
 - ❖ Collaborative efforts with AECOM, EPRI, SCE, SDS, WEC to harvest reactor core shroud segments

End User Statement sent to Russian officials for approval to import to INL. No response from Russia.

Discussions were halted due to international logistical issues.

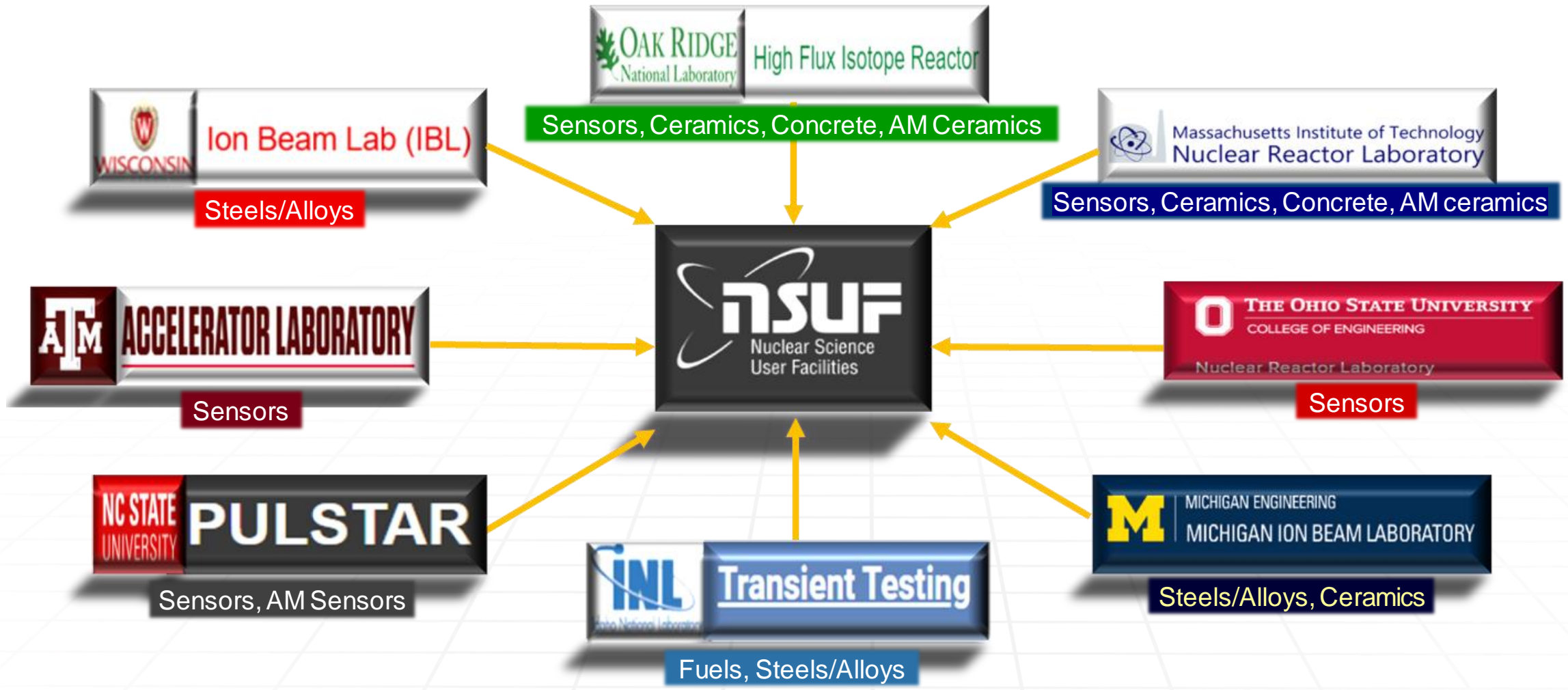
Discontinued efforts, critical path activities would have been affected.

COLLABORATION

- UK NNL Working Group (WG6) to archive NPP material in the UK
 - ❖ NSUF provided experience and advice about the conception and inception of the NFML
 - ❖ UK NNL gathered evidence for materials that could be archived
 - ❖ Created a Value Assessment Process (VAP) to determine which UK samples should be archived
 - ❖ Discussions regarding potential for the NFML to accept some UK historical samples of mutual interest.
- NIFT-E: Neutron Irradiation as a Function of Temperature – Experiment
 - ❖ NSUF-UK NNUF collaborative irradiation of Alumina-forming austenitic (AFA) stainless steel samples
 - ❖ Half the samples will be transferred to DOE (NSUF) for inclusion in the NFML

Ongoing

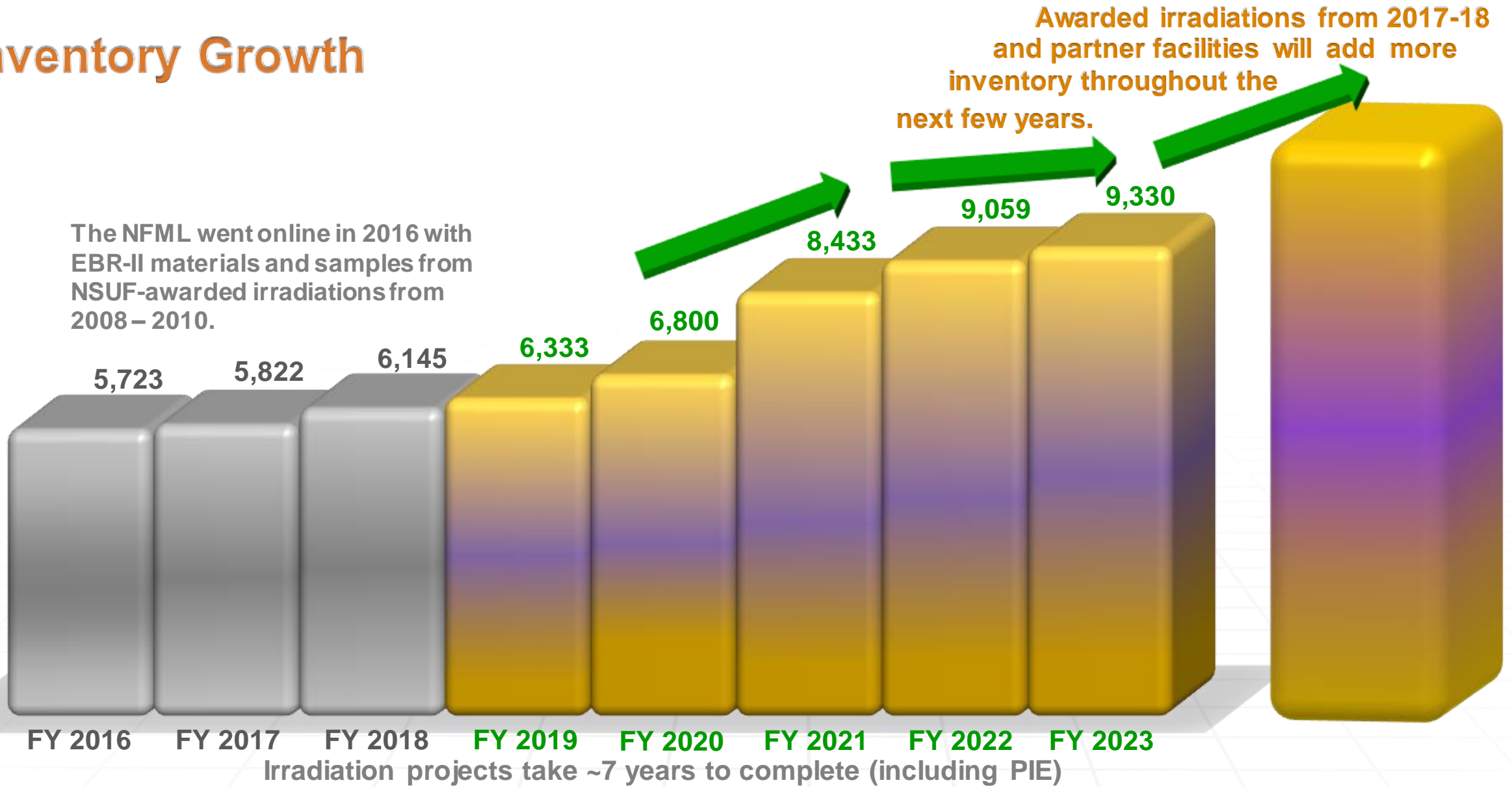
Partner and TREAT Irradiation Additions to the NSUF ... coming soon



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Inventory Growth



FY 2023 NFML Current and Future Ceramics Catalog

Irradiation/ Submission	Title	Material	Reactor
CINR	Advanced Damage Tolerant Ceramics: Candidates for Nuclear Structural Applications	Ceramics	INL ATR
CINR	Effect on Thermophysical Properties of Hf3Al-Al Composite: A Concept for Fast Neutron Testing at ATR	Ceramics	INL ATR
Nat'l Lab	Library Submission - Neutron-Interactions of Advanced Materials	Ceramics	ORNL HFIR
NSUF SAM	Neutron Transmutation Doping of High-Purity SiC	Ceramics	INL ATR
CINR	Nonstoichiometric Spinel as Inert Matrix	Ceramics	INL ATR

NSUF SAM	Neutron Transmutation Doping of High-Purity SiC (avail ~2025)		INL ATR
CINR	Radiation-Enhanced Diffusion of Ag, Ag-Pd, Eu, and Sr in Neutron Irradiated PyC/SiC Diffusion Couples		MIBL/HFIR
CINR	Irradiation of Advanced Neutron Absorbing Material to Support Accident Tolerant Fuel (Samarium Hafnate, Hafnium Carbide)		ORNL HFIR

NFML FUTURE SALTS Catalog

Irradiation/ Submission	Title	Material	Reactor
CINR	Integrated Effects of Irradiation and Flibe Salt on Fuel Pebble and Structural Graphites for Molten Salt Reactors	Salt	MTR

FY 2023 NFML Current and Future Fuels Catalog

Irradiation/ Submission	Title	Material	Reactor
CINR	Hydride LWR Fuel Rod	Fuel	INL ATR
DOE	Library Submission - KJRR Fuel Plates	Fuel	INL ATR
DOE	Library Submission - Peach Bottom Unit 2 Fuel Rod Sections and Remnants	Fuel	BWR NPP
DOE	Library Submission - Unirradiated TRISO Fuel	Fuel	n/a
CINR	Low Fluence Behavior of Metallic Fuels	Fuel	INL ATR
CINR	Measurement of Actinide Neutronic Transmutation Rates with Accelerator Mass Spectroscopy	Fuel	INL ATR

CINR	High Temperature In-Pile Irradiation Test of Single Phase U_3Si_2 , (avail ~early 2025 & ~2029)	ATR
CINR	Demonstration of a Methodology for Direct Validation of MARMOT Irradiation-Induced Microstructural Evolution & Physical Property Models Using $U-Zr$ (MVP) (avail ~2026-27)	ATR
CINR	Thermal Conductivity Measurement of Irradiated Metallic Fuel Using TREAT (THOR-EPIC) (EBR-II fuel pins, fresh $U-PU-Zr$) (avail ~2028)	TREAT
Nat'l Lab	Characterization-scale Instrumented Neutron Dose Irradiation (CINDI) ($U-Zr$, $U-Mo$) (avail ~May 2024)	TREAT
CRADA	Disc Irradiation for Separate Effect Testing with Control of Temperature (DISECT) ($U-Zr$, $U-Mo$)	BR2
CINR	Fission Product Transport in TRISO	MBL
CINR	High Power Irradiation Testing of TRISO Fuel Particles with UCO and UO_2 Kernels in Miniature Fuel Specimen Capsules in HFIR	ORNL HFIR

FY 2023 NFML Current Steels and Alloys Catalog

Irradiation/ Submission	Title	Material	Reactor
CINR	Characterization of the Microstructures & Mechanical Properties of Advanced Structural Alloys for Radiation Service: A Library of ATR Irradiated Specimens	Steels/Alloys	ATR
EBR-II	EBR II-Surveillance	Steels/Alloys	EBR-II
EBR-II	EBR-II Legacy Hexblocks and Assemblies	Steels/Alloys	EBR-II
EBR-II	EBR-II SS Creep	Steels/Alloys	EBR-II
CINR	Enhancing Irradiation Tolerance of Steels via Nanostructuring by Innovative Manufacturing Techniques (N-SERT)	Steels/Alloys	ATR
CINR	High Fluence Embrittlement Database and ATR Facility for LWR Vessel Life Extension	Steels/Alloys	ATR
CINR	Influence of Fast Neutron on the Mechanical Properties and Microstructure of Nanostructured Metals/Alloys	Steels/Alloys	ATR
CINR	Irradiation Influence on Alloys Fabricated by Powder Metallurgy and Hot Isostatic Pressing for Nuclear Applications	Steels/Alloys	ATR
CINR	Irradiation Performance of Fe-Cr Base Alloys	Steels/Alloys	ATR
CINR	Irradiation Performance Testing of Specimens Produced by Commercially Available Additive Manufacturing Techniques	Steels/Alloys	ATR
CINR	Irradiation Test Plan for the Advanced Test Reactor National Scientific User Facility/University of Wisconsin Pilot Project	Steels/Alloys	ATR
CINR	Irradiation Testing of LWR Additively Manufactured Materials	Steels/Alloys	ATR
CINR	Irradiation Testing of Materials Produced by Additive Friction Stir Manufacturing a.k.a. AeroProbe Test of Additively Manufacture Materials (ATAMM)	Steels/Alloys	ATR
Nat'l Lab	LANSCE APT 1996/1997/1999	Steels/Alloys	LANL APT
Industry	Library Submission - Baffle-former Bolt Donation to NSUF Nuclear Fuels and Materials Library	Steels/Alloys	PWR NPP
DOE	Library Submission - High Fidelity Ion Beam Simulation of High Dose Neutron	Steels/Alloys	BOR-60
Industry	Library Submission - LWR 304 SS Core Shroud Samples	Steels/Alloys	LWR NPP
DOE/AECL	Library Submission - The Effects of Irradiation on Inconel X-750	Steels/Alloys	CANDU
CINR	Nanodispersion Strengthened Metallic Composites with Enhanced Neutron Tolerance FY23 NEW ADDITION	Steels/Alloys	HFIR

NFML Future Steels/Alloys Catalog

Irradiation	Title	Reactor	Add Mfg
CINR	Nuclear Operations Effect on Mobility and Accelerated Diffusion (NOEMAD) Zr-(CR,NB, Ta, Mo), (Zry-Cr), Cr-(Nb, Ta, Mo) (avail mid 2024)	TREAT	
CINR	Irradiation Influence on Alloys Fabricated by Powder Metallurgy and Hot Isostatic Pressing for Nuclear Applications [High Entropy Alloys (HEAs)] (avail ~mid 2024)	ATR	AM
CINR	Irradiation Testing of LWR Additively Manufactured Materials (Alloys 316L, Inconel 718) (avail ~mid 2024)	ATR	AM
CINR	Aeroprobe Test of Additively Manufacture Materials (ATAMM) (316L) (avail ~mid 2025)	ATR	AM
CINR	NuScale SMR Materials Irradiation and Testing (SA 508, F6NM) (avail ~late 2027)	ATR	
CINR	Investigation of Degradation Mechanisms of Cr coated Zirconium Alloy Cladding in Reactive Initiate Accidents (RIA) (avail ~late 2026)	TREAT	
CINR	Assessment of Irradiated Microstructure and Mechanical Properties of FeCrAl Alloy Fabrication Routes (GENIE) (avail ~late 2027)	ATR/MIBL	AM
LDRD	Tensile Testing Utilizing the Standard Capsule Irradiation (TTUSC) (HEAs) (avail ~late 2024)	ATR	AM
CINR	Enhancing Irradiation Tolerance of Steels via Nanostructuring by Innovative Manufacturing Techniques (N-SERT) (HEAs) (avail ~late 2024 & ~early 2026)	ATR	AM
CINR	Role of Minor Alloying Elements on Long Range Ordering in Ni-Cr Alloys	WIBR	
CINR	Capacitive Discharge Resistance Welding of 14YWT and Ferritic ODS Alloys for Cladding Applications	WIBL/MIBL	
CINR	High-dose Ion Irradiation Testing and Relevant Post-Irradiation Examination of Friction-Stir-Welded ODS MA956 Alloy	TAMU	
CINR	Irradiation-Assisted Stress Corrosion Cracking of PWR-Irradiated Type 347 Stainless Steel	MIBL	
CINR	Machine Learning on High-Throughput Databases of Irradiation Response & Corrosion Properties of Selected Compositionally Complex Alloys for Structural Nuclear Materials (FeCrMnNi, FeCrMoNi, MoNbTiV, MoNbTaW Quaternary Systems)	WIBL	

FY 2023 NFML Current and Future Sensor Catalog

Irradiation	Title	Material	Reactor	Add Mfg
IRRAD	Transducers for In-pile Ultrasonic Measurements of Fuels and Materials Evolution	Sensor	ATR	

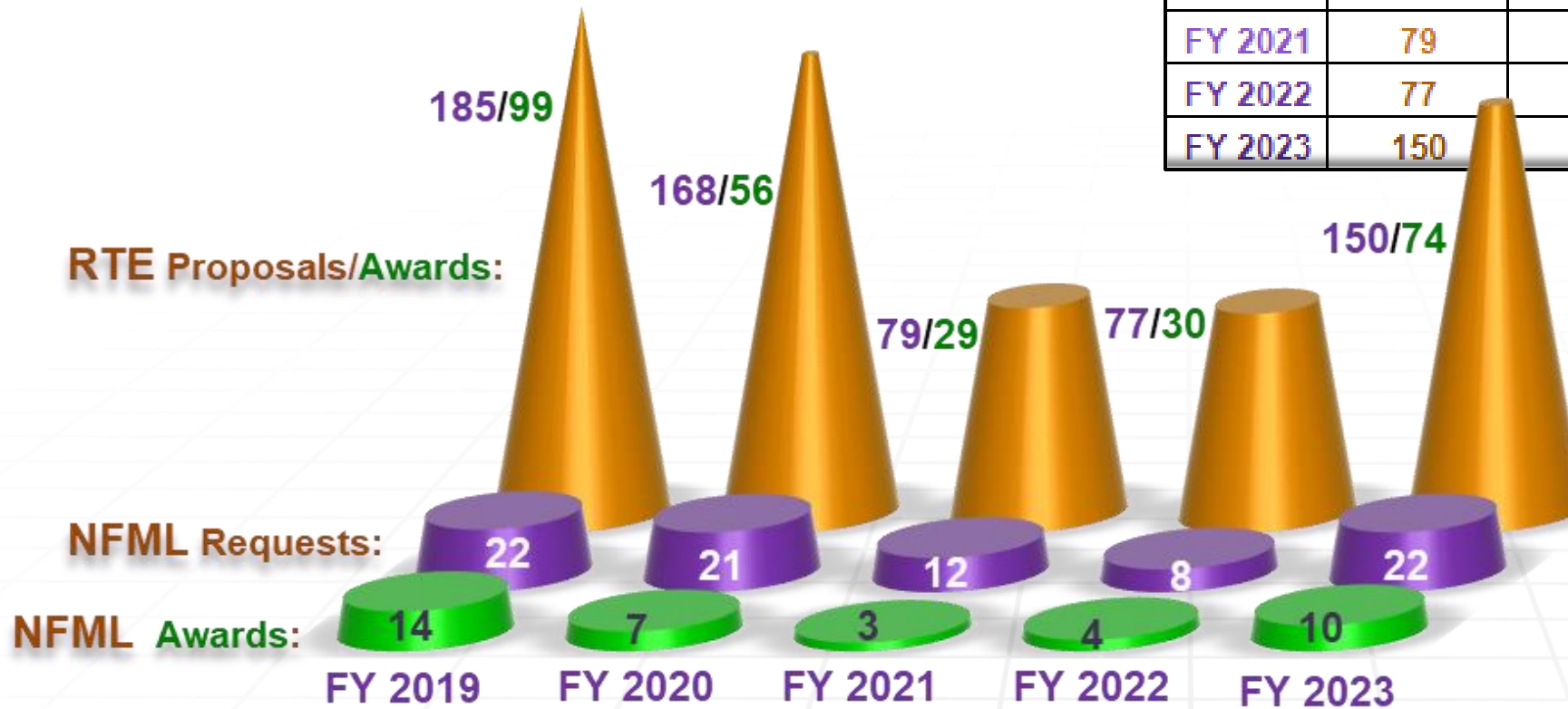
CNR	<i>Additive Manufacturing Of Thermal Sensors For In-Pile Thermal Conductivity Measurement</i>	Sensor	NCSUR/MITR	AM
CNR	<i>Radiation Effects On Optical Fiber Sensors Fused Smart Alloy Parts With Graded Alloy Composition Manufactured By Additive Manufacturing Processes</i>	Sensor	MITR	AM
CNR	<i>High-Performance Nanostructured Thermoelectric Materials And Generators For In-Pile Harvesting</i>	Sensor	MITR/MBL	
CNR	<i>High Fluence Active Irradiation And Combined Effects Testing Of Sapphire Optical Fiber Distributed Temperature Sensors</i>	Sensor	MITR/OSUR	
CNR	<i>Irradiation Of Optical Components Of In-Situ Laser Spectroscopic Sensors For Advanced Nuclear Reactor Systems</i>	Sensor	OSURR	
CNR	<i>Integral Fuel Rod Real-Time Wireless Sensor & Transmitter Irradiation Test And Post Irradiation Examination</i>	Sensor	ORNL HFIR	
CNR	<i>Irradiation Of Sensors And Adhesive Couplants For Application In Lwr Primary Loop Piping And Components</i>	Sensor	NCSUR	
CNR	<i>Demonstration Of Self Powered Neutron Detectors Performance And Reliability</i>	Sensor	MITR	
CNR	<i>Integral Fuel Rod Real-Time Wireless Sensor & Transmitter Irradiation Test And Post Irradiation Examination</i>	Sensor	HFIR	
CNR	<i>Understanding Irradiation Behaviors of Ultrawide Bandgap Ga2O3 High Temperature Sensor Materials for Advanced Nuclear Reactor Systems</i>	Sensor	NCSUR	
CNR	<i>Deployment And In-Pile Test Of An Instrument For Real-Time Monitoring Thermal Conductivity Evolution Of Nuclear Fuels</i>	Sensor	MITR	

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Utilization in Rapid Turnaround Experiments Proposals, Sample Requests, Awards

RTE Proposals/NFML Requests/Awards					
FY	Proposals	NFML Requests	% NFML Requests	NFML Request Awards	% NFML Request Awards
FY 2019	185	22	11.89%	14	63.64%
FY 2020	168	21	12.50%	7	33.33%
FY 2021	79	12	15.19%	3	25.00%
FY 2022	77	8	10.39%	4	50.00%
FY 2023	150	22	14.66%	10	45.00%

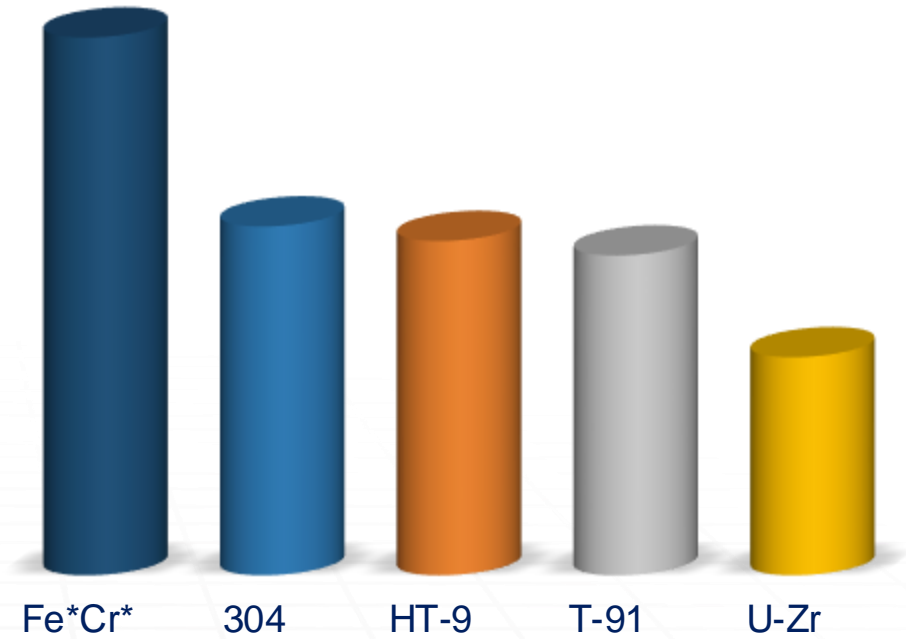
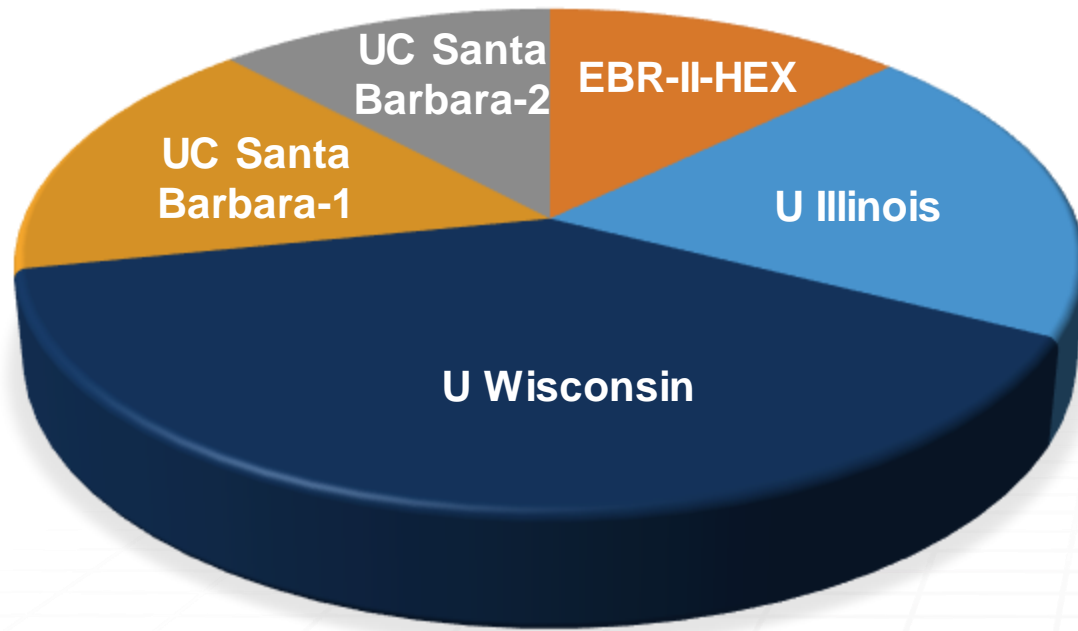


Only 2 Calls in FY 2020, only 1 Call in FYs 2021 and 2022

FY 2023 Awarded RTEs Sample Utilization

FY 2023 Awarded Institution	FY 2023 Awarded RTE Proposal Title	NSUF Irradiation Project Samples	
	High-Resolution Characterization of Neutron-Irradiated Cr-Fe-Mn-Ni-(Al,Ti) High-Entropy Alloys	2016 ISU	
	Deconvoluting Void and Bubble Effects on Deformation-Induced Martensitic Transformations in Austenitic Stainless Steel Using 4D STEM Strain Mapping	EBR-HEX	
	Assessment of Local Thermal Conductivity and Microstructure of Irradiated U-20 wt% Pu-10 wt% Zr alloy	DISECT CRADA	
	Serial Sectioning to Quantify Fission Induced Microstructural Evolution in U-Zr Alloys	DISECT CRADA	
	Atom probe characterization of HT-9 as a function of neutron irradiation temperature	2008 UW	
	Post Incubation Void Swelling in Tempered Martensitic Steels	UCSB-2	
	Understanding the Origin of Irradiation-Induced Yield Drop Phenomena in Grade 91	2015 BSU	
	Room Temperature Tensile Properties of ATR Neutron Irradiated T91	2008 UI	
	Recovery of Irradiated Tantalum, a Pre-Cursor to Understanding Ferritic (BCC) Steels	EBR-SUR	
	Characterization of Manganese-Nickel Rich Precipitates and Their Interaction with Dislocations in Irradiated Reactor Pressure Vessel Steels	UCSB-2	

Top Five Requested Projects and Materials (2010-2023)



U Wisconsin: Irradiation Test Plan for the Advanced Test Reactor National Scientific User Facility/University of Wisconsin Pilot Project

UCSB-1: Characterization of the Microstructures and Mechanical Properties of Advanced Structural Alloys for Radiation Service: A Comprehensive Library of ATR Irradiated Alloys and Specimen

U Illinois: Irradiation Performance of Fe-Cr Base Alloys

UCSB-2: High Fluence Embrittlement Database and ATR Irradiation Facility for LWR Vessel Life Extension

EBR-II-HEX: EBR-II Legacy Hexblocks and Assemblies

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FY 2023 NSUF Preparations for Data Management Planning



The NSUF is in the early stages of reviewing data management practices to increase public access to appropriate scientific data:

➤ **Data considerations under review:**

- ❖ Underlying data from NSUF supported projects in publications, reports, and projects which may include data from:
 - Charts
 - Graphs
 - Tables
 - Various forms of raw or analyzed experimental data

➤ **Development of the Nuclear Research Data System (NRDS)**

- ❖ Aiming to be a long-term data repository to preserve appropriate NSUF funded scientific data and virtual user workspace environment

➤ **Key considerations requiring coordination and collaboration across program stakeholders (PIs, users, instrument scientists) include:**

- ❖ Data embargo periods
- ❖ Data attribution
- ❖ Persistent identifiers

The Nuclear Fuels and Materials Library



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