The US Nuclear Science User Facilities (NSUF)

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nsuf.inl.gov

NSUF Nuclear Science User Facilities

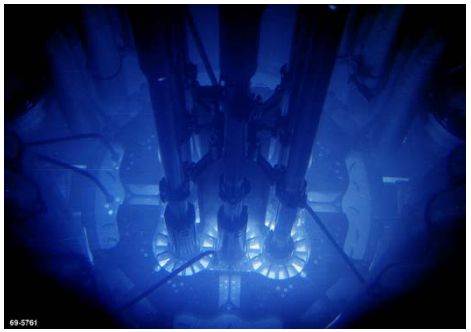
The US User Facility Model

- The goal is to connect intellectual capital with investigative capabilities.
- Typically large single structure, government supported facilities with unique capabilities located at a single institution.
- Access is typically offered at no cost to the user through a competitive proposal process.
- Principle is to offer advanced, cutting edge capabilities to single investigators or teams.
- Generally the user facility offers a single type of capability to a broad range of technological or research areas.
- User facilities do not fund salaries or other user costs, such as travel.
  - They provide access and support with funding used at the user facility institution.
- Currently ~50 user facilities in US
  - Synchrotron X-ray sources (e.g. APS, NSLS-II)
  - Neutron spallation sources (e.g. SNS)
  - Advanced scientific computing
  - Nano-scale sciences
  - etc.

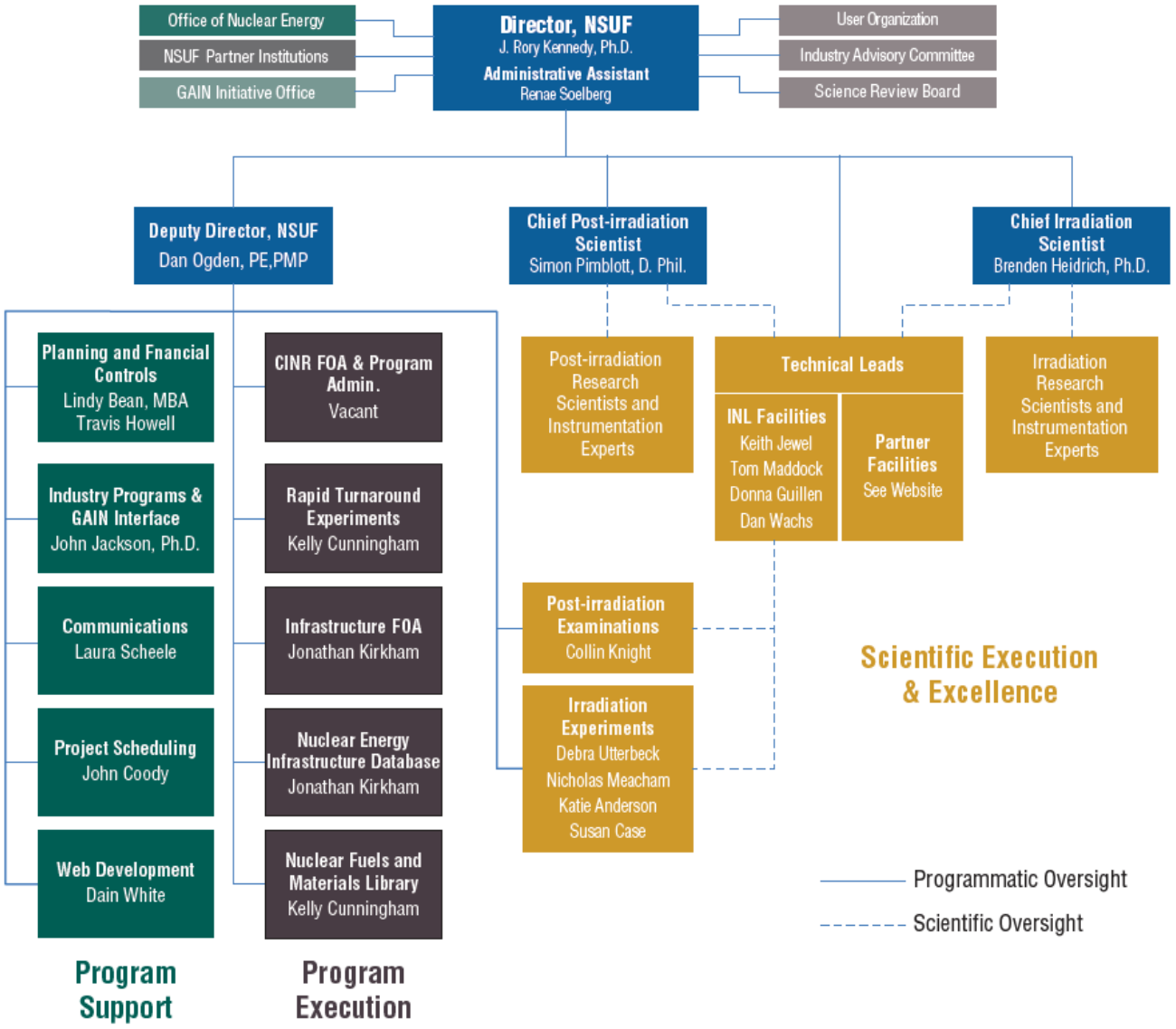
Advanced Photon Source, ANL

The Nuclear Science User Facilities

- **Established 2007 as US DOE Office of Nuclear Energy first & only user facility.**
- **Founded at Idaho National Laboratory initially intended as a single institution user facility. INL remains lead and primary institution.**
- **NSUF operates as typical US user facility (no cost to user, competitive proposal processes, no funding to users) but also some unique aspects.**
- **<u>Unique aspects of NSUF</u>**
  - **Consortium of facilities/capabilities, not single institution (currently 11 Universities + 4 Universities in CAES, 8 National Laboratories, 1 industry)**
  - **NSUF offers multiple capabilities to a single scientific area:**
    - **irradiation effects in nuclear fuels and materials.**
  - **Projects can last many years or be short duration.**
    - **Largest projects include design, fabrication, transport, irradiation, PIE, and final disposition.**
  - **No base funding to facilities.**
    - **Funding to facility is for project cost and is fully forward funded.**



NSUF Organization Chart



NSUF Support Structure Points of Contact

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Prof. Kumar Sridharan (UW)
Prof. Ayman Hawari (NCSU)
Prof. Gary Was (UM)
Dr. Mitch Meyer (INL)
Dr. Sven Van den Berghe (BNRC)

And many more scientists, engineers and technical staff at all partner facilities to help get things done

The Nuclear Science User Facilities

- **Generally select projects through open competitive proposal processes**
  - **Consolidated Innovative Nuclear Research (CINR FOA, 1 call/year)**
    - **Irradiation + PIE ($1.0M - $4.0M, up to 7 years) includes design, analyses, fabrication, transport, irradiation, disassembly, PIE, disposition**
    - **PIE only (~$500K, up to 3 years)**
    - **Irradiation only ($500K - $3.5M)**
    - **Beamlines at other user facilities**
    - **Possibility to also receive user R&D funding on limited work scopes**
  - **Rapid Turnaround Experiments (RTE, 3 calls/year, limited $$, executed within 9 months)**
- **Proposals welcome from university, government laboratory, industry, and small business researchers. Only non-proprietary projects accepted. All awarded projects are fully forward funded.**

FY2019 CINR NSUF Access Workscopes

- **NSUF-2 (Access only, Industry Led Only)**
  - **NSUF-2.1: Core and Structural Materials**
  - **NSUF-2.2: Nuclear Fuel Behavior and Advanced Nuclear Fuel Development**
  - **NSUF-2.3: Advanced In-reactor Instrumentation**
- **NSUF-1 (Access + R&D, Industry, University, Nat'l Lab Led)**
  - **NSUF 1.1: Testing of Advanced Materials or Advanced Sensors for Nuclear Applications**
  - **NSUF 1.2: Irradiation Testing of Materials Produced by Innovative Manufacturing Techniques**
- **FC-2.5: Separate Effects Testing in TREAT using Standard Test Capsules (Access + R&D, University Led Only)**
- **NEAMS-2 Separate Effects Irradiation Testing for Validation of Microstructural Models in Marmot (Access + R&D, University Led Only)**

NSUF Capabilities Offer Research Opportunities

Neutron Irradiations	Ion Irradiations	Gamma Irradiations	Hot Cells & Shielded Cells	Low Activity Laboratories	Beamlines	High Performance Computing
INL Idaho National Laboratory	Wisconsin University of Wisconsin-Madison	INL Idaho National Laboratory	INL Idaho National Laboratory	INL Idaho National Laboratory	125 Illinois Tech Since 1890	INL Idaho National Laboratory
Oak Ridge National Laboratory	University of Michigan	Oak Ridge National Laboratory	Oak Ridge National Laboratory	CAES Center for Advanced Energy Studies	Brookhaven National Laboratory	
Massachusetts Institute of Technology	Argonne National Laboratory	Sandia National Laboratories	PNNL	Oak Ridge National Laboratory	NC State University	
NC State University	Sandia National Laboratories		Los Alamos National Laboratory Est. 1943	Cal	Los Alamos National Laboratory Est. 1943	
Ohio State	Texas A&M University		Westinghouse	PNNL		
Sandia National Laboratories	Lawrence Livermore National Laboratory		University of Michigan	Los Alamos National Laboratory Est. 1943		
SCK•CEN Studiecentrum voor Kernenergie Centre d'Etude de l'Energie Nucleaire			SCK•CEN Studiecentrum voor Kernenergie Centre d'Etude de l'Energie Nucleaire	NC State University		
				University of Michigan		
				Purdue University		
				UNLV University of Nevada Las Vegas		
				University of Florida		
				SCK•CEN Studiecentrum voor Kernenergie Centre d'Etude de l'Energie Nucleaire		
				Wisconsin University of Wisconsin-Madison		

Visit nsuf.inl.gov for details at individual facilities

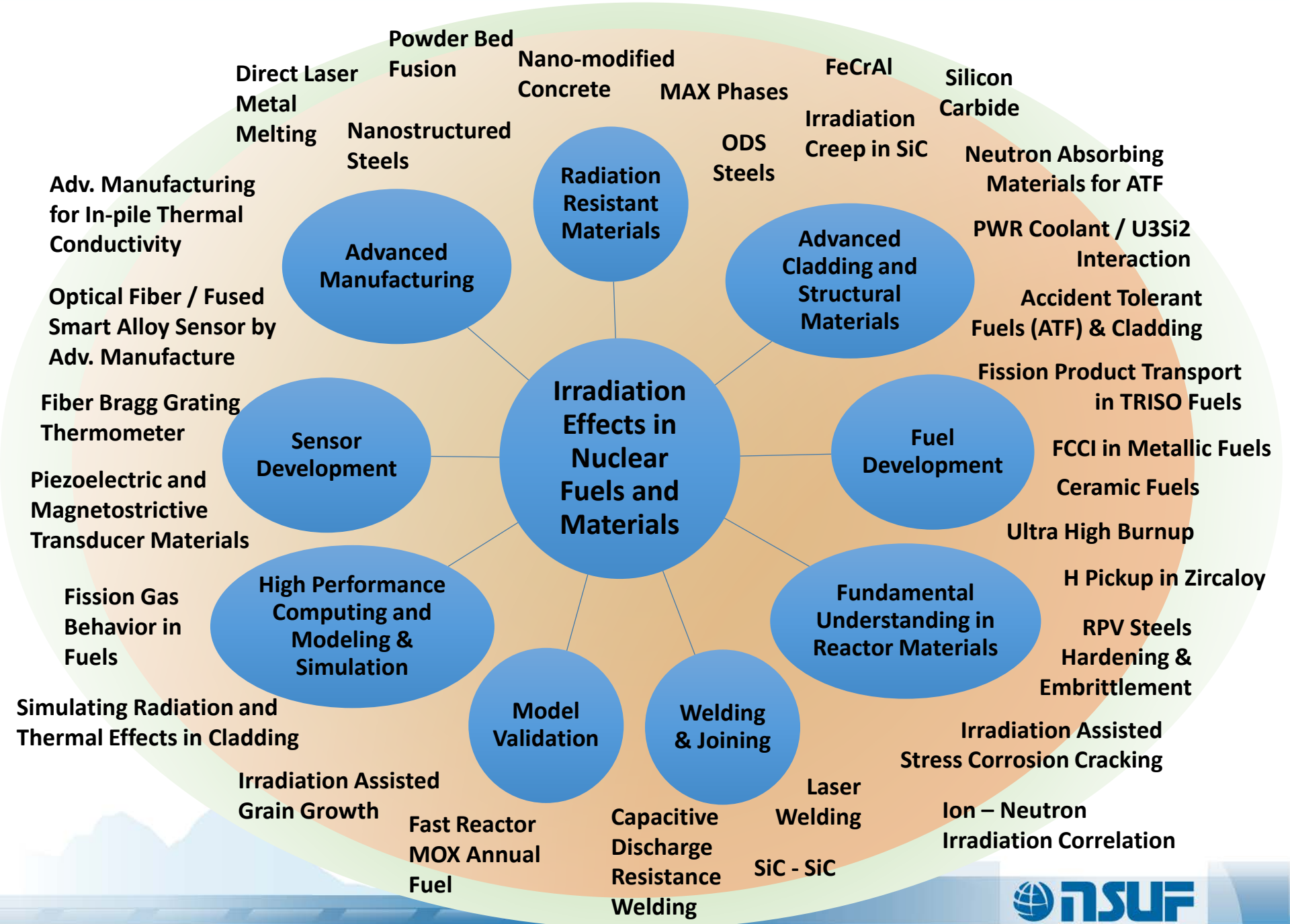
11 Universities

CAES (4 Unis)

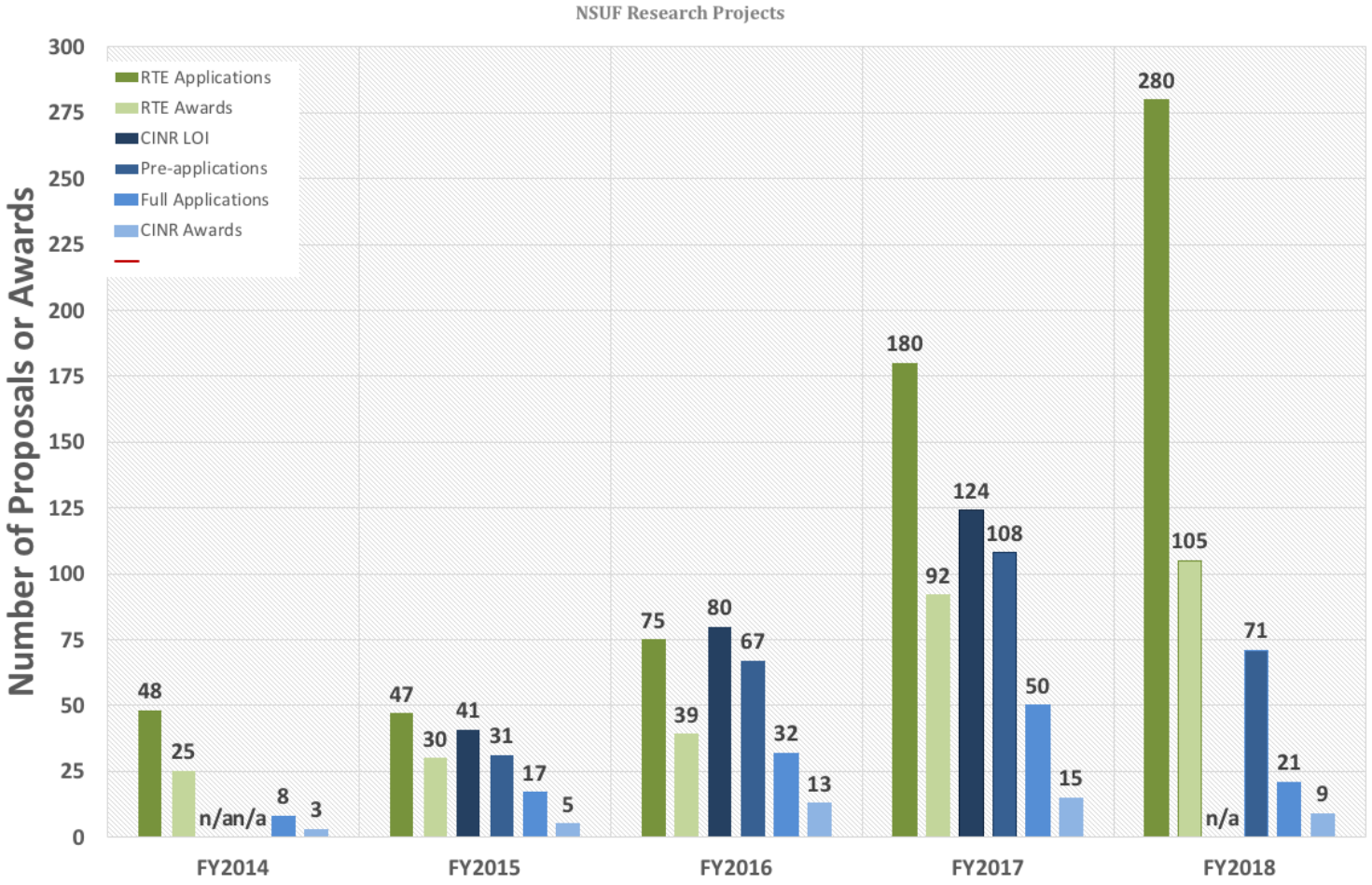
8 National Labs

1 Industry

NSUF


Irradiation Effects in Nuclear Fuels and Materials
Radiation Resistant Materials
Advanced Manufacturing
Advanced Cladding and Structural Materials
Sensor Development
Fuel Development
High Performance Computing and Modeling & Simulation
Fundamental Understanding in Reactor Materials
Model Validation
Welding & Joining
Powder Bed Fusion
Direct Laser Metal Melting
Nano-modified Concrete
MAX Phases
FeCrAl
Silicon Carbide
Nanostructured Steels
ODS Steels
Irradiation Creep in SiC
Neutron Absorbing Materials for ATF
Adv. Manufacturing for In-pile Thermal Conductivity
PWR Coolant / U3Si2 Interaction
Optical Fiber / Fused Smart Alloy Sensor by Adv. Manufacture
Accident Tolerant Fuels (ATF) & Cladding
Fiber Bragg Grating Thermometer
Fission Product Transport in TRISO Fuels
Piezoelectric and Magnetostrictive Transducer Materials
FCCI in Metallic Fuels
Ceramic Fuels
Ultra High Burnup
Fission Gas Behavior in Fuels
H Pickup in Zircaloy
RPV Steels Hardening & Embrittlement
Simulating Radiation and Thermal Effects in Cladding
Irradiation Assisted Stress Corrosion Cracking
Irradiation Assisted Grain Growth
Laser Welding
Ion – Neutron Irradiation Correlation
Fast Reactor MOX Annual Fuel
Capacitive Discharge Resistance Welding
SiC - SiC

Interest and Support Continue to Grow

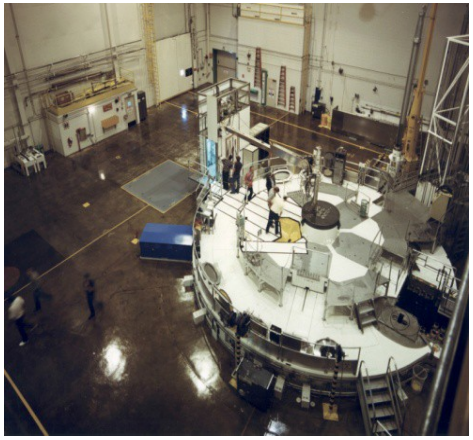


- **CINR type projects support**
  - **FY 2014 – $400K, 8 full proposals, 3 awards**
  - **FY 2015 – $4.1M, 41 LOIs, 31 pre-proposals, 17 full proposals, 5 awards**
  - **FY 2016 – $10M, 80 LOIs, 67 pre-proposals, 32 full proposals, 13 awards**
  - **FY 2017 - ~$11M, 124 LOIs, 108 pre-proposals, 50 full proposals, 15 awards**
  - **FY 2018 - ~$10M, 71 access requests, 21 full proposals, 9 awards**

Graphics created by Brenden Heidrich

NSUF Projects Summary

FY 2007 – FY2018



- Total of 39 CINR type projects executed
- Total of 30 CINR type projects currently ongoing
- Total of 222 RTEs executed
- Total of 78 RTEs ongoing
- 369 total projects awarded
  - 229 projects to 44 US universities
  - 109 projects to 6 national laboratories
  - 14 projects to industry
  - 17 projects to 8 international (Oxford U., Manchester U., Liverpool U., ANSTO, CEA Seclay, Institutio Italiano di Technologia, NNL, SCK-CEN)

FY 2018

- Total of ~$216M in DOE support (2007-2018)
- Effective FY2018 budget: ~$30M (same as FY17)
- Total effective FY 2018 budget allocated to projects: ~$14M direct (CINR + RTE) + ~$3.4M supporting (PIE coordination, experiment managers, experiment analyses, shipping, SCK-CEN pilot projects)

Recent CINR Awarded Projects

Focus on Key Technologies and Understanding

- **Additive / Advanced Manufacturing**
  - Irradiation Testing of Materials Produced by Additive Friction Stir Manufacturing ($1837K, Aeroprobe, FY18)
  - Radiation Effects on Zirconium Alloys Produced by Powder Bed Fusion Additive Manufacturing Processes ($830K, Westinghouse Electric Co., FY17)
  - Irradiation Testing of LWR Additively Manufactured Materials ($1,982K, GE-Hitachi Nuclear Energy, FY16)
  - High Dose Ion Irradiation Testing and Relevvant Post Irradiation Examination of Friction Stir Welded ODS MA956 Alloy ($182K, PNNL, FY18)
  - Nanodispersion Strengthened Metallic Composites with Enhanced Neutron Irradiation Tolerance ($2046K, MIT, FY18)
  - Enhancing Irradiation Tolerance of Steels via Nanostructuring by Innovative Manufacturing Techniques ($2,459K, ISU, FY16)
  - Irradiation Performance Testing of Specimens Produced by Commercially Available Additive Manufacturing Techniques ($2,030K, CSM, FY16)
  - Irradiation Influence on Alloys Fabricated by Powder Metallurgy and Hot Isostatic Pressing for Nuclear Applications ($1,598K, BSU, FY15)

Recent CINR Awarded Projects

Focus on Key Technologies and Understanding

- **Welding and Joining Advanced Cladding**
  - Performance of SiC-SiC Cladding and Endplug Joints Under Neutron Irradiation with a Thermal Gradient ($985K, General Atomics, FY17)
  - Capacitive Discharge Resistance Welding of 14YWT for Cladding Applications ($59K, LANL, FY17)
  - Effects of High Dose on Laser Welded, Irradiated AISI 304SS ($613K, BSU, FY16)

- **Advanced Fuel Development**
  - Irradiation, Transient Testing and Post Irradiation Examination of Ultra High Burnup Fuel ($3600K, EPRI, FY17)
  - Irradiation of Advanced Neutron Absorbing Material to Support Accident Tolerant Fuel ($630K, AREVA, FY17)
  - Fission Product Transport in TRISO Fuel ($22K, UMich, FY16)
  - Radiation Enhanced Diffusion of Ag, Ag-Pd, Eu and Sr in Neutron Irradiated PyC/SiC Diffusion Couples ($518K, ORNL, FY16)
  - Disc Irradiation for Separate Effects Testing with Control of Temperature (DISECT) ($, SCK-CEN / INL)
  - Accident Tolerant fuel Test for the Interaction of Coolant with Uranium Silicide (ATTICUS) ($, SCK-CEN / INL)

Recent CINR Awarded Projects

Focus on Key Technologies and Understanding

- **Fundamentals for Reactor Materials**
  - Improved Understanding of Zircaloy-2 Hydrogen Pickup Mechanism in BWRs ($817K, EPRI, FY17)
  - Rapid Simulation of Irradiation Damage in PWR Internals ($323K, ORNL, FY18)
  - Understanding Swelling Related Embrittlement of AISI316 Stainless Steel Irradiated in EBR-II ($1077K, INL, FY18)
  - Correlation between Microstructure and Mechanical Properties of Neutron-Irradiated Ferritic-Martensitic and Austenitic Steels ($652K, ORNL, FY17)
  - X-ray Characterization of Atomistic Defects Causing Irradiation Creep of SiC ($150K, ORNL, FY17)
  - Positron Annihilation Studies of Neutron Irradiated Ferritic Alloys ($203K, UIll-Urbana, FY17)
  - Understand the phase transformation of thermally aged and neutron irradiated duplex stainless steels used in LWRs ($579K, UFla, FY16)
  - Radial Heat Flux – Irradiation Synergism in SiC ATF Cladding ($843K, ORNL, FY16)
  - Effect of Gamma Irradiation on the Microstructure and Mechanical Properties of Nano-modified Concrete ($185K, Vanderbilt U, FY16)
  - Correlative Atom Probe and Electron Microscopy Study of Radiation Induced Segregation at Low and High Angle Grain Boundaries in Steels ($150K, ORNL, FY16)
  - Role of Minor Alloying Elements on Long Range Ordering in Ni-Cr Alloys ($90K, OrStU, FY16)
  - Feasibility of Combined Ion-Neutron Irradiation for Accessing High Dose Levels ($187K, UMich, FY16)

Recent CINR Awarded Projects

Focus on Key Technologies and Understanding

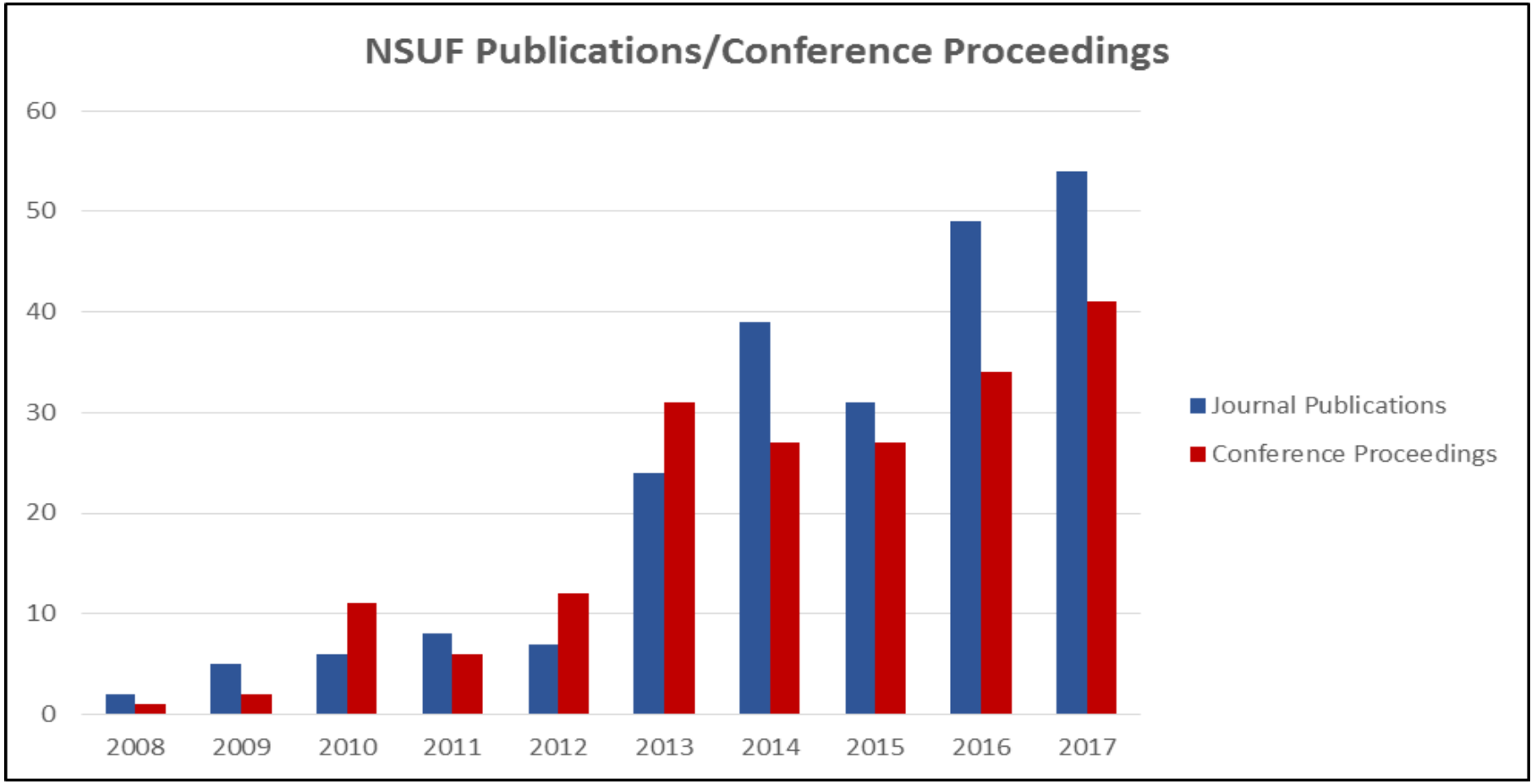
- **Sensor Development**
  - Irradiation Behavior of Piezoelectric Materials for Nuclear Reactor Sensors ($458K, OSU, FY18)
  - High Performance Nanostructured thermoelectric Materials and Generators for In-pile Power Harvesting ($655K, UND, FY18)
  - * Additive manufacturing of thermal sensors for in-pile thermal conductivity measurement ($536K, BSU, FY17)
  - Radiation Effects on Optical Fiber Sensor Fused Smart Alloy Parts with Graded Alloy Composition Manufactured by Additive Manufacturing Processes ($775K, UPitt, FY17)
  - Transducers for In-pile Ultrasonic Measurements of Fuels and Materials Evolution ($959K, INL / PSU /CEA / PNNL / ANL / MIT)
  - Ultrasound-Based Sensors for Enhanced Monitoring of Irradiation Testing ($957K, INL / UPitt / CEA / AFO Research)
  - Monitoring Of Temperature Of Reactor Experiments – MOTORE ($100K, SCK-CEN/INL, FY17)
  - Benchmarking of Ultrasonic Thermometer and Fiber Bragg Grating Thermometer ($140K, SCK-CEN / INL)

Recent CINR Awarded Projects

Focus on Key Technologies and Understanding

- **Computational Model Development and Validation**
  - Facilitating MARMOT Modeling of Radiation Phenomena in U-Pu-Zr Fuels Through Experiments (MORPH Experiment) ($801K, UFla, FY18)
  - Demonstration of a Methodology for Direct Validation of MARMOT Irradiation Induced Microstructural Evolution and Physical Property Models Using U-10Zr. ($2080K, TAMU, FY18)
  - In-Situ Ion Irradiation to Add Irradiation Assisted Grain Growth to the MARMOT Tool ($125K, PSU, FY17)
  - Simulation of Radiation and Thermal Effects in Advanced Cladding Materials ($45K, PNNL, FY17)
  - HPC Access to Advance Understanding of Fission Gas Behavior in Nuclear Fuel ($890K, UTenn, FY17)
  - Study of the Irradiation Behavior of Fast Reactor Mixed Oxide Annular Fuel with Modern Microstructural Characterization to Support Science Based Model Validation ($773K, INL, FY17)

NSUF Publications



- Continuing to see results from early irradiation tests
- Increase in RTE awards.
- H-index score of 17
- Journal of Nuclear Materials is by far the most published in journal.

Infrastructure Management Program

- NSUF created a searchable and interactive database of all pertinent infrastructure supported by, or related to, the DOE Office of Nuclear Energy (DOE-NE).
- Database known as the Nuclear Energy Infrastructure Database (NEID) and can be accessed through the NSUF website (nsuf.inl.gov).
- Used for analyses to identify needs, redundancies, efficiencies, distributions, etc., to best understand the utility of DOE-NE's available infrastructure, inform the content of infrastructure calls, and provide information to NSUF users.
- Currently 150 institutions operating ~500 facilities housing ~1000 instruments. 80% US domestic, 20% international.
- Infrastructure information collected can be combined with information on R&D needs as part of infrastructure gap analysis

Nuclear Fuels and Materials Library (NFML)

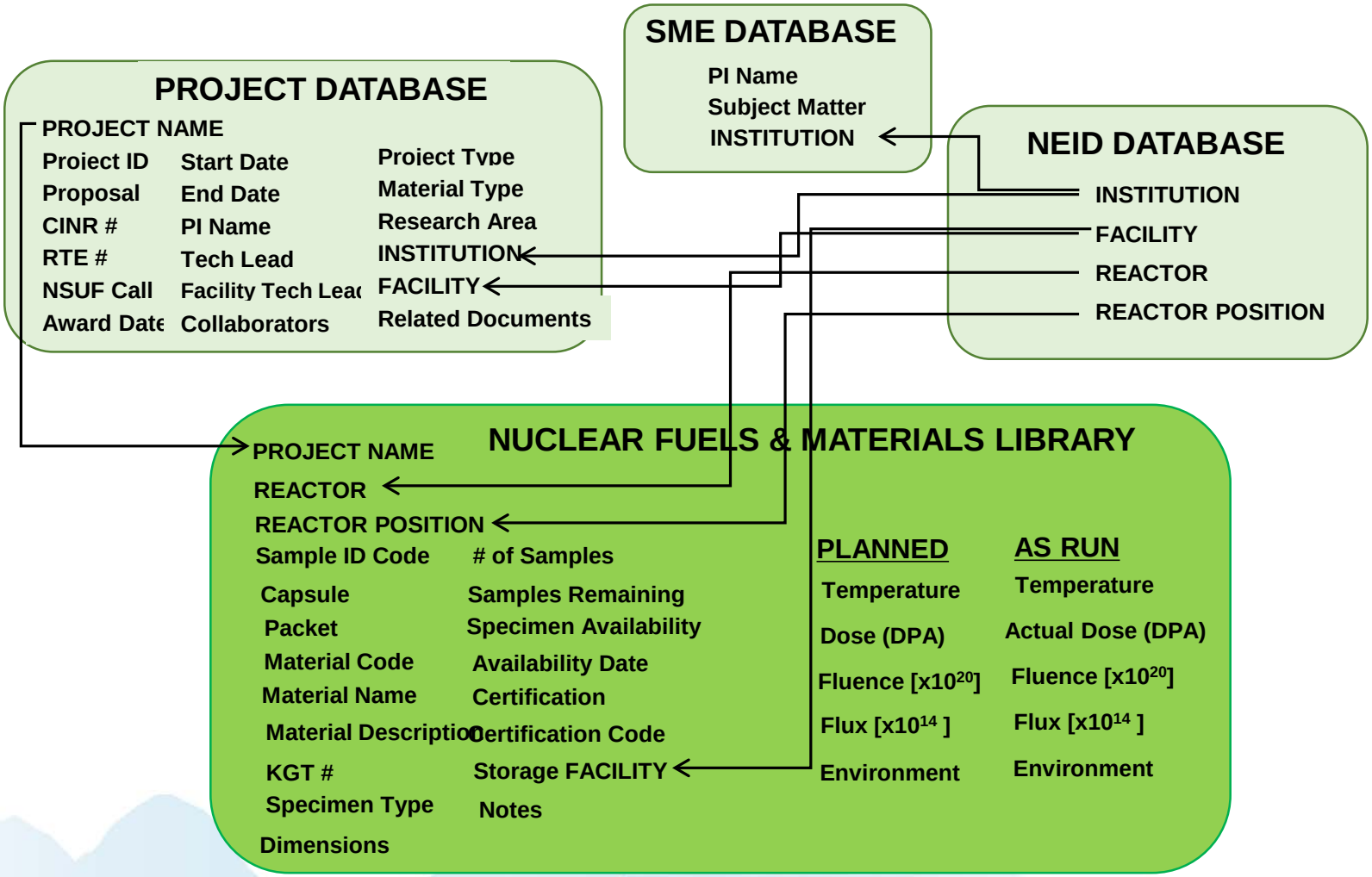
- Provides irradiated samples for users to access for experimentation through one of the competitively reviewed proposal processes.
- Critical to reducing costs and taking advantage of new ideas and future analysis techniques and equipment.
- The library includes over 3500 specimens as part of the NSUF awarded research. 6K – 7K additional specimens
- Most materials in NFML neutron irradiated with small number ion irradiated.
- SAM irradiation series to stock library moving forward
- Effort to consolidate materials into easily accessible locations to reduce costs of retrieval.
- Web-based searchable database through nsuf.inl.gov.
- Interest in collaboration on international efforts.

INL Legacy materials

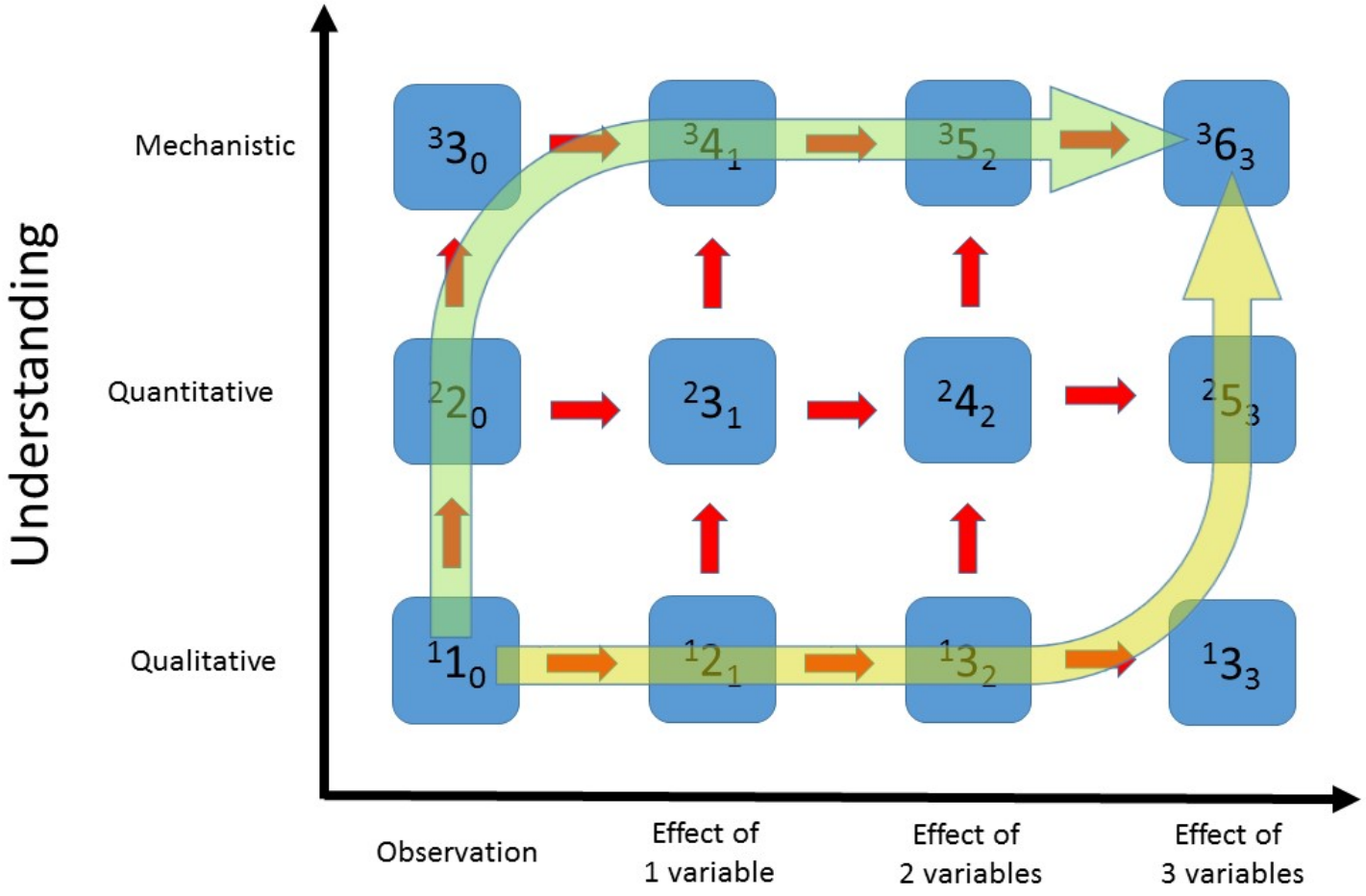
Volunteered materials from outside the INL

Supporting documentation related to samples

Database Expansion and Linkage Combined Materials Experiment Toolkit (CoMET)



Quantifying the Impact of NSUF Fuels and Materials Understanding Scale (FaMUS)

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