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NSUF Activities and Needs for In-Pile Sensors and Characterization

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Advanced Sensors and Instrumentation Program Review
October 18, 2017

NSUF Nuclear Science User Facilities

INL/CON-17-43290

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The US User Facility Model

NSUF Nuclear Science User Facilities

- **The goal is to connect intellectual capital with investigative capabilities.**
- **Typically <u>large single structure</u>, government supported facilities with unique capabilities located at a single institution.**
- **Access is typically offered at <u>no cost to the user</u> through a competitive proposal process.**
- **Principle is to offer <u>advanced, cutting edge capabilities</u> to single investigators or teams.**
- **Generally the user facility offers a <u>single type of capability</u> to a <u>broad range of technological or research areas</u>.**
- **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

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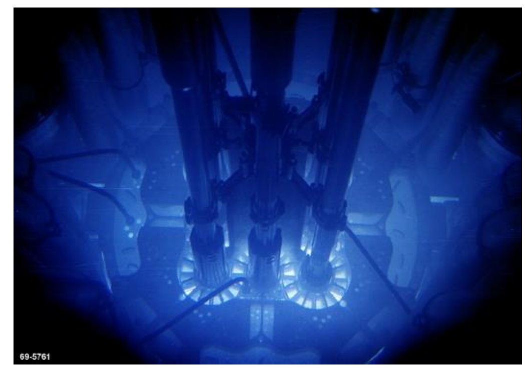
Nuclear Science User Facilities (NSUF)

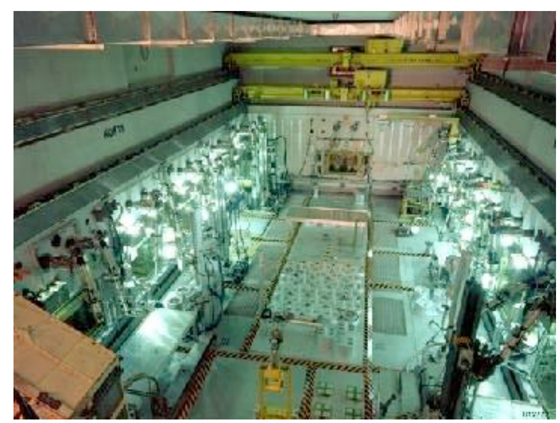
Nuclear Science User Facilities

- 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.

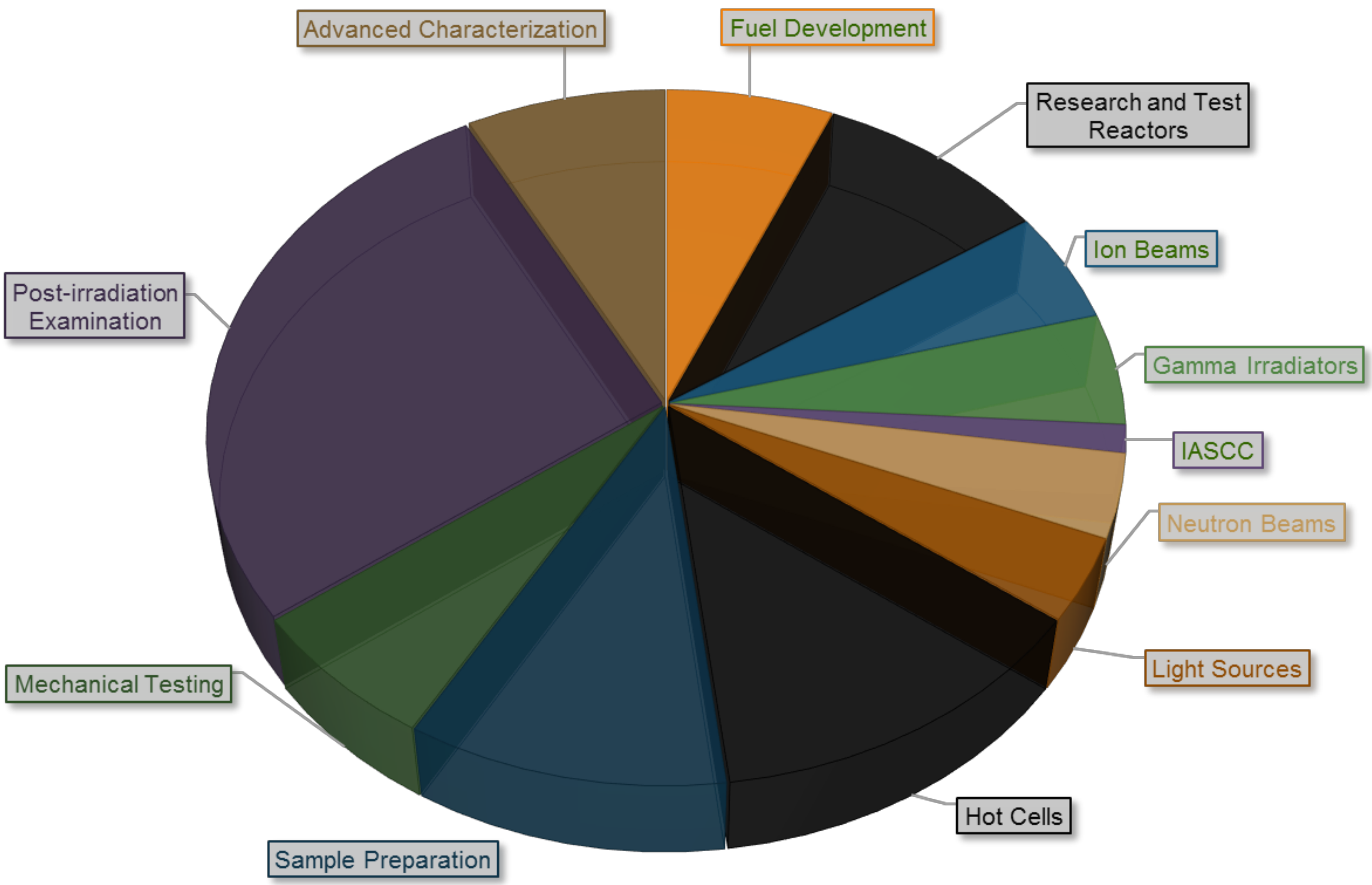
Unique aspects of NSUF

- **Consortium of facilities/capabilities, not single institution (currently 11 Universities + 4 Universities in CAES, 7 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.
  - Excess capacity is generally utilized.





NSUF Capabilities



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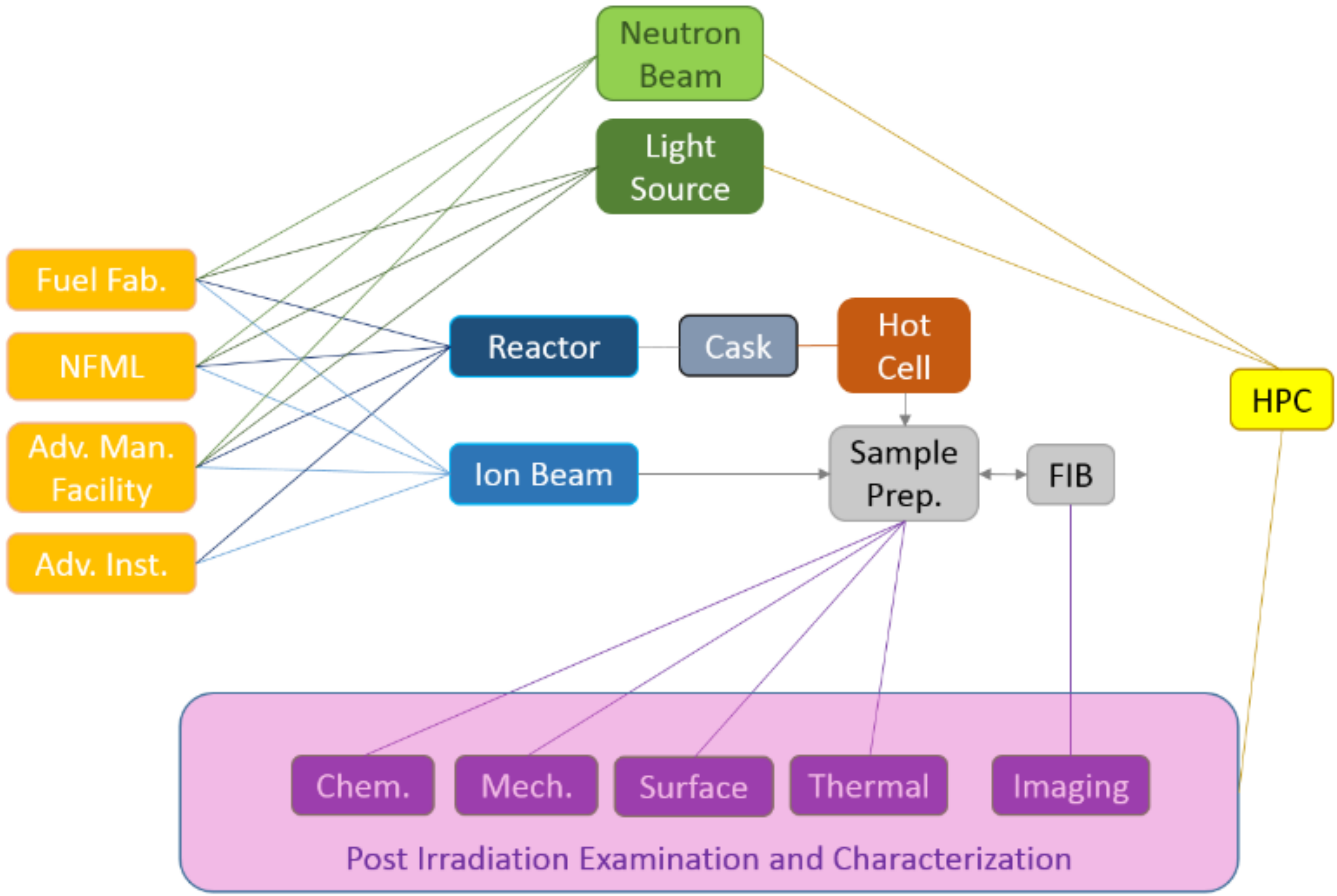
NSUF Capabilities

NSUF Nuclear Science User Facilities

Neutron Irradiations	Ion Irradiations	Gamma Irradiations	Hot Cells & Shielded Cells	Beamlines	High Performance Computing
Idaho National Laboratory	Wisconsin University of Wisconsin-Madison	Idaho National Laboratory	Idaho National Laboratory	Illinois Tech since 1890	Idaho National Laboratory
Oak Ridge National Laboratory	University of Michigan	Oak Ridge National Laboratory	Oak Ridge National Laboratory	Brookhaven National Laboratory	
Massachusetts Institute of Technology	Argonne National Laboratory	Sandia National Laboratories	PNNL	NC State University	
NC State University	Sandia National Laboratories		Los Alamos National Laboratory	Los Alamos National Laboratory	
Ohio State	Texas A&M University		Westinghouse		
Sandia National Laboratories	Lawrence Livermore National Laboratory		University of Michigan		

Visit nsuf.inl.gov for details at individual facilities

NSUF Experiment Pathways



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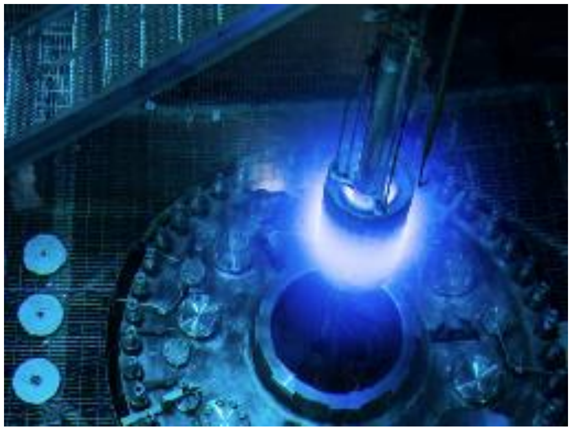
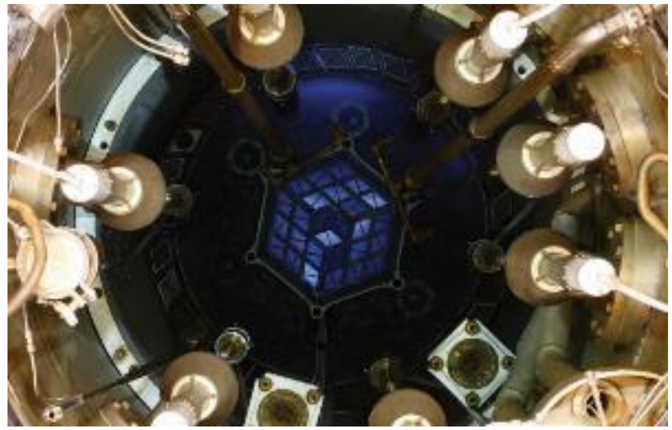
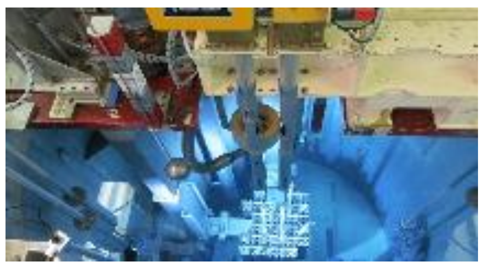
NSUF Neutron Irradiation Capabilities

NSUF Nuclear Science User Facilities





NSUF Capabilities

High radiation level measurements/instrumentation

- Neutron Radiography
- Elemental & Isotopic Analyses
- Gas Sampling and Analyses
- Profilometry
- Gamma Scanning
- Mechanical Testing (tensile, punch, Charpy)
- Micro-focus X-ray Diffraction
- Thermal Analyses
- Eddy Current
- Irradiation Assisted Stress Corrosion Cracking
- Electron Probe Micro Analysis (EPMA)
- Electron and Optical Microscopy
- Focused ion Beam (FIB)

NSUF Capabilities

Low radiation level measurements/instrumentation

- **Electron and Optical Microscopy**
  - Scanning Electron Microscopy (SEM)
  - Transmission Electron Microscopy (TEM)
- **Focused Ion Beam (FIB)**
- **Mechanical Testing**
  - Tensile
  - Hardness
  - Micro- and Nano-Indentation
- **X-ray Diffraction**
- **Photo Electron Spectroscopy**
  - X-ray Photo Electron Spectroscopy (XPS)
  - UV Photo Electron Spectroscopy (UPS)
  - Auger Spectroscopy
- **Irradiation Assisted Stress Corrosion Cracking (IASCC)**
- **Positron Annihilation Spectroscopy**
- **Atomic Force Microscopy**
- **Secondary Ion Mass Spectrometry**
- **Thermal Analysis**
  - Thermal Conductivity
  - Heat Capacity
  - Thermal Expansion
- **Nuclear Magnetic Resonance**

INL Idaho National Laboratory
CAES Center for Advanced Energy Studies
PNNL
OAK RIDGE National Laboratory
PURDUE UNIVERSITY
Cal
Los Alamos NATIONAL LABORATORY EST.1943
UNIVERSITY OF FLORIDA
NC STATE UNIVERSITY
UNIVERSITY OF MICHIGAN
UNLV

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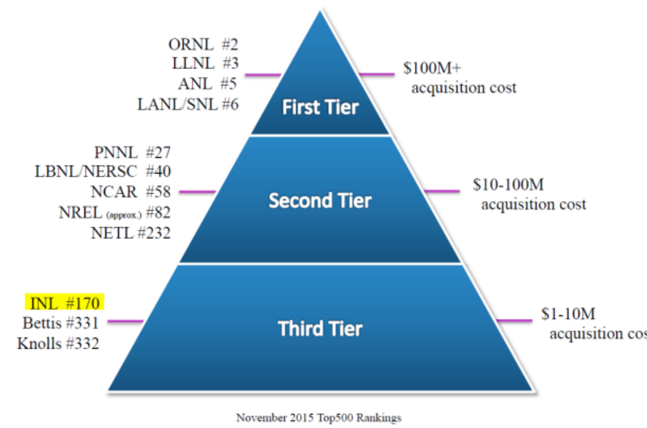
NSUF High Performance Computing Resources

NSUF Nuclear Science User Facilities

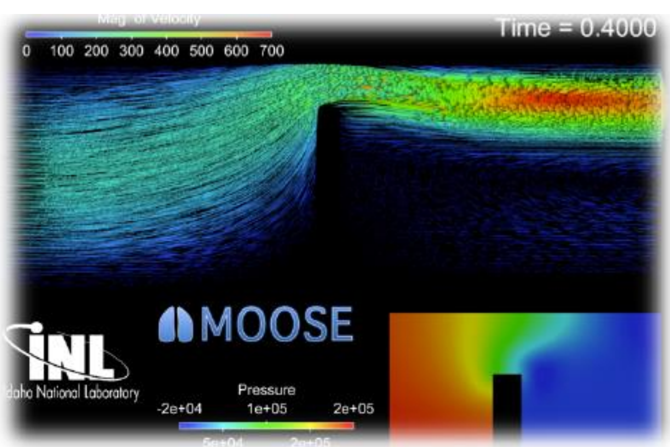
How does HPC enable DOE missions?

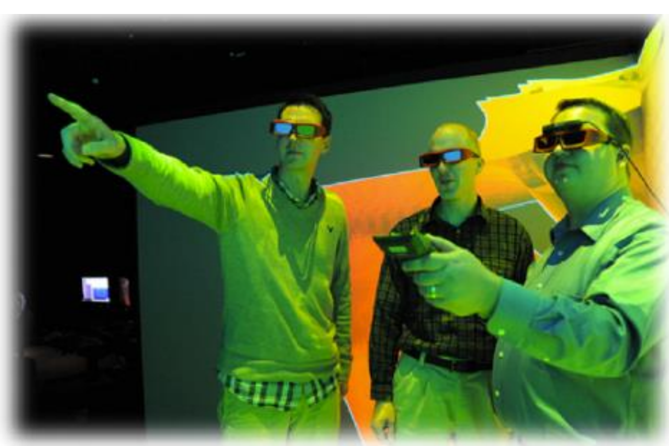
- High Performance Computing (HPC) compliments theory and informs experimental processes.
- HPC functions as a 'microscope' for researchers to better understand physics, chemistry, and engineering principles in ways not otherwise possible.
- HPC resources support NSUF, CASL, NEAMS, NEUP, and GAIN

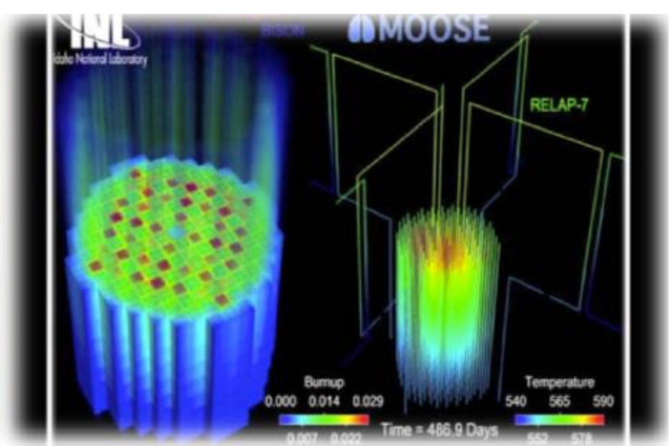


NSUF Program Support

- System already in place for quickly granting user access and prioritizing work
- Reporting and accounting systems are being modified to better capture NSUF metrics and science impact
- Implementing tools to improve and simplify user experience
- Ensuring that NSUF and related programs have needed support
  - Priority scheduling for milestones upon request
  - Supporting as-run analysis, thermal analytics, neutronics analytics
  - MOOSE support







Courtesy of Eric Whiting, Director of Scientific Computing

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Database of world-wide nuclear energy R&D resources (NEID)

NSUF Nuclear Science User Facilities

NSUF Interests

General Characteristics

* Wireless data transmission
* Spatially-resolved measurements

Neutronics

Fluence
Energy Spectrum
Transient Flux

Mechanical Properties

Swelling
Creep and Stress/Strain
Crack Initiation and Growth
Microstructural Evolution
Dimensional Changes

Thermal Properties

Temperature
Thermal Conductivity
Thermal Expansion
Thermal Diffusivity
Heat Capacity

Chemical Information

Composition and Evolution
Gas Composition and Pressure
Chemistry --> FCCI
Electrochemical Potentials

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Recent NSUF In-pile and Sensor Development Support

NSUF Nuclear Science User Facilities

- **Transducers for In-pile Ultrasonic Measurements of Fuels and Materials Evolution**
  - (FY12) Idaho National Laboratory, Penn State, CEA, PNNL, ANL, MIT, $959K
- **Ultrasound-Based Sensors for Enhanced Monitoring of Irradiation Testing**
  - (FY15) Idaho National Laboratory, Univ. of Pittsburgh, CEA, AFO Research, $957K
- **Additive manufacturing of thermal sensors for in-pile thermal conductivity measurement**
  - (FY17) Boise State University, $536K
- **Rad. Effects on Optical Fiber Sensor Fused Smart Alloy Parts with Graded Alloy Composition Manufactured by Additive Manufacturing Processes**
  - (FY17) University of Pittsburgh, $775K
- **Monitoring of Temperature of Reactor Experiments – MOTORE**
  - (FY17) Idaho National Laboratory, SCK-CEN, $80K
- **Benchmarking of Ultrasonic Thermometer and Fiber Bragg Grating Thermometer**
  - (FY18) Idaho National Laboratory, SCK-CEN, $140K

Contact Information for NSUF

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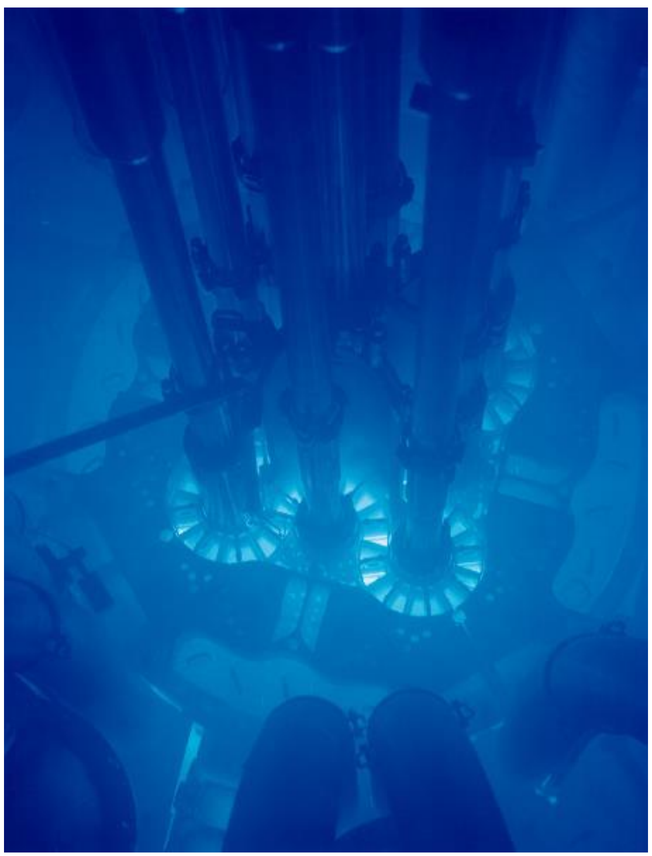

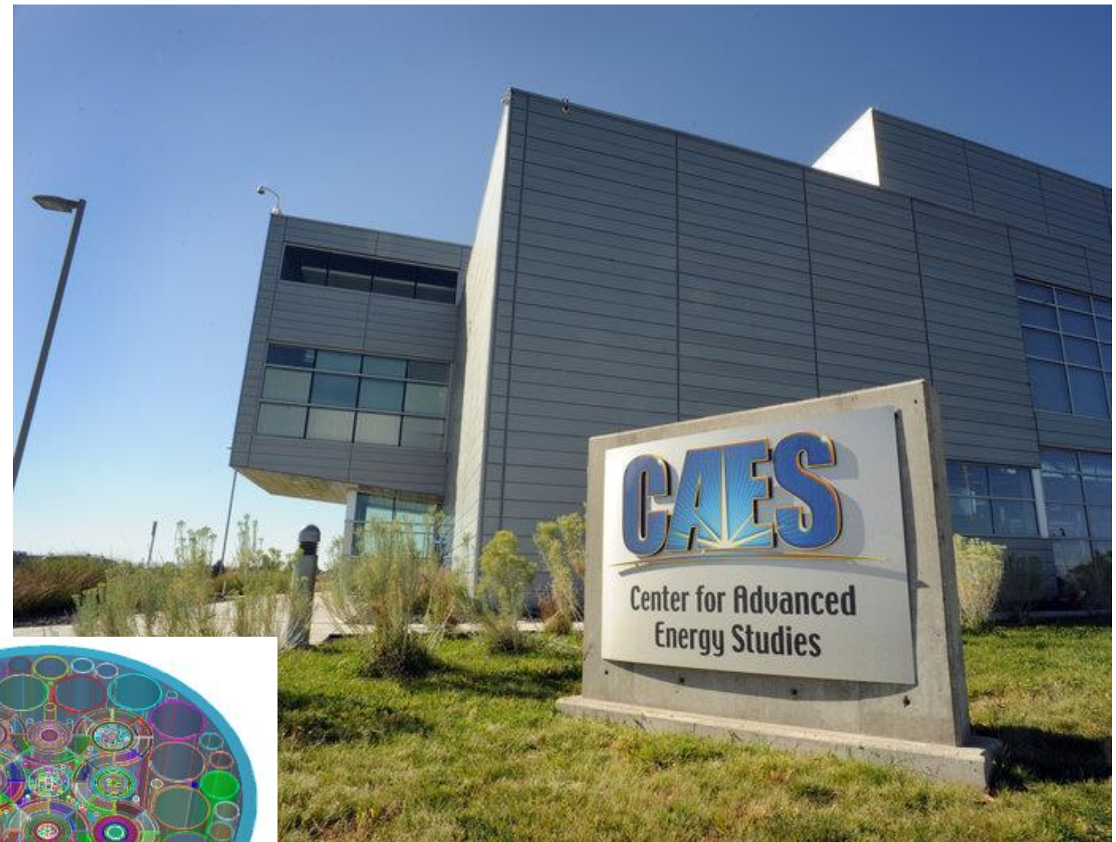

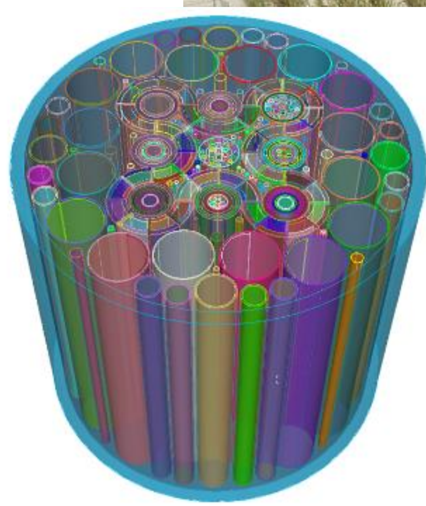

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