Established 2007 as DOE Office of Nuclear Energy first and only user facility

- Energy Policy Act of 2005
  - Secretary of Energy should consider establishing user facility at INL
  - First founded as Advanced Test Reactor National Scientific User Facility (ATR-NSUF)
  - Expansion to facilities outside INL initiated in 2008
  - Name changed to Nuclear Science User Facilities in 2014
- Idaho National Laboratory is lead and primary institution
- Irradiation effects in nuclear fuels and materials
- Provide access to capabilities and expertise at no cost to user
- Support design, fabrication, transport, irradiation, PIE, disposition
- Link intellectual capital with nuclear research infrastructure to fulfill mission of DOE-NE
Recognized early that needs of community exceed capacity at INL
- Partner Facilities program started in 2008
- Name changed to Nuclear Science User Facilities in 2014
- 11 Universities + 4 Universities in CAES, 7 National Laboratories, 1 industry

|--------|------|------|------|------|------|------|------|------|

NSUF – A consortium
A group formed to undertake an enterprise beyond the resources of any one member

![NSUF Partner Logos]
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)
  - PIE only (~$500K, up to 3 years)
  - Irradiation only ($500K - $3.5M)
  - Beamlines at other user facilities

- Rapid Turnaround Experiments (RTE, 3 calls/year, limited $$, executed within 9 months)

- Proposals welcome from University, National Laboratory, Industry, Small Business, International (RTE only)
  - International PI applicants need US collaborator

- All projects fully forward funded
- Requires accurate cost estimate and schedule
- Requires project scope to be reasonable
- Requires early contact and negotiations with facilities

- Letters of Intent – initiate the process
- Pre-proposals
  - Evaluated for feasibility
  - Evaluated for relevancy to NE mission
  - Evaluated for technical and scientific merit

- Invited full proposals
  - Evaluated for feasibility (final cost estimate and schedule required)
  - Evaluated for relevancy to NE mission
  - Evaluated for technical and scientific merit
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<th>Neutron Irradiations</th>
<th>Ion Irradiations</th>
<th>Gamma Irradiations</th>
<th>Hot Cells &amp; Shielded Cells</th>
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Visit nsuf.inl.gov for details at individual facilities
NSUF Capabilities

High radiation level measurements/instrumentation

- Neutron Radiography
- Elemental & Isotopic Analyses
- Gas Sampling and Analyses
- Profilometry
- Gamma Scanning
- Mechanical Testing (tensile, charpy)
- Micro-focus X-ray Diffraction
- Thermal Analyses
- Eddy Current
- IASCC
- 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
**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, 109 pre-proposals, 50 full proposals, 15 awards

Graphics created by Brenden Heidrich
Beginning to see results from early irradiation tests
Increase in RTE awards.
Journal of Nuclear Materials is by far the most published in journal.
Project portfolio spans a variety of research objectives that are ultimately focused on both near and long-term technology development goals

- Understanding atomic level phenomena in fuels that affect thermal transport, elemental migration/diffusion, interface interaction, etc. as complex microstructures develop under irradiation
  - ceramic, metallic, TRISO, Accident Tolerant Fuel (ATF)
    - High dose Xe irradiation in UO$_2$
    - U-Zr metal fuel fcci diffusion couple short term irradiation
    - Pd and Ag fission product transport in TRISO fuels
    - U$_3$Si$_2$ irradiations (material and PWR coolant interactions
Impactful Nuclear R&D

- Understanding fundamental defect evolution in irradiated structural materials across multiple length scales as they affect mechanical properties.
  - RPV, austenitic, F/M, Zr alloys, ATF
    - Hardening and embrittlement precipitate and defect cluster formation mechanism in RPV
    - Bor-60 irradiated 304, 316, and cast CF-3 (neutron – ion correlation)
    - Nanostructured ferritic
    - Fuel channel Zry-2 and Zry-4 materials irradiation
    - Fe-Cr-Al and SiC cladding materials and joining

- Development of innovative radiation resistant materials for advanced reactor systems
  - Fe-Cr alloys
  - Oxide dispersion strengthened (ODS) steels
  - MAX phases (Ti2SiC2, Ti3AlC2)
Development of radiation resistant sensors for collecting high fidelity on-line irradiation test data
  • Piezoelectric and magnetostrictive transducer materials irradiation
    - AlN, ZnO, BiTiO$_2$

Development of materials from advanced manufacturing techniques
  • Irradiation of materials
    - Direct Metal Laser Melting
    - Powder Bed Fusion

Providing fundamental actinide nuclear data that can help inform advanced reactor and fuel cycle modeling and simulation campaign.
SCK-CEN BR-2 Reactor (Belgium)
- DOE – SCK/CEN MOU and Belgium Nuclear Research Centre – INL CRADA signed in early FY 2017
- 4 projects with in-kind contributions
- SCK-CEN continues to pursue EU-NSUF organization

UK National Nuclear User Facility (NNUF)
- Ongoing for ~4 years
- Continued strong interest in linked NFML. UK received authorization to “save” some specimens from decommissioning.
- US invited to Nuclear Academics Discussion Meeting (NADM) and Executive Committee Meeting of National Nuclear User Facility (NNUF)
- Access to NSUF facilities provided to UK researchers
  - Access to NNUF facilities not (yet) provided to US researchers (no proposal process)
  - NSUF would like affiliation agreement with NNUF but US-UK agreement stalled
2016
- Ion Beam Investment Options Workshop

2017
- Ion Beam Irradiation Roadmap
- NSUF/GAIN Nuclear Thermal Hydraulics Workshop

2018
- Nuclear Materials Technical Readiness Level (TRL) Definitions Workshop
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 is located at nsuf-infrastructure.inl.gov (public launch Nov 2015)

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.

Infrastructure information collected can be combined with information on R&D needs as part of infrastructure gap analysis.
US Domestic and International Infrastructure / Capabilities
• 80% Domestic, 20% International

Over 140 institutions operating over 450 facilities housing over 960 instruments

- Test and research reactors
- Hot cells
- Ion beams
- Support infrastructure (shipping casks, test fabrication, etc.)
- State-of-the-Art instrumentation & Expertise
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 by year end.
- 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.
- Interest in collaboration on international efforts.

Materials Include:

- Steels
- Other alloys
- Ceramics
- Pure materials
- Actinides
- Fission products