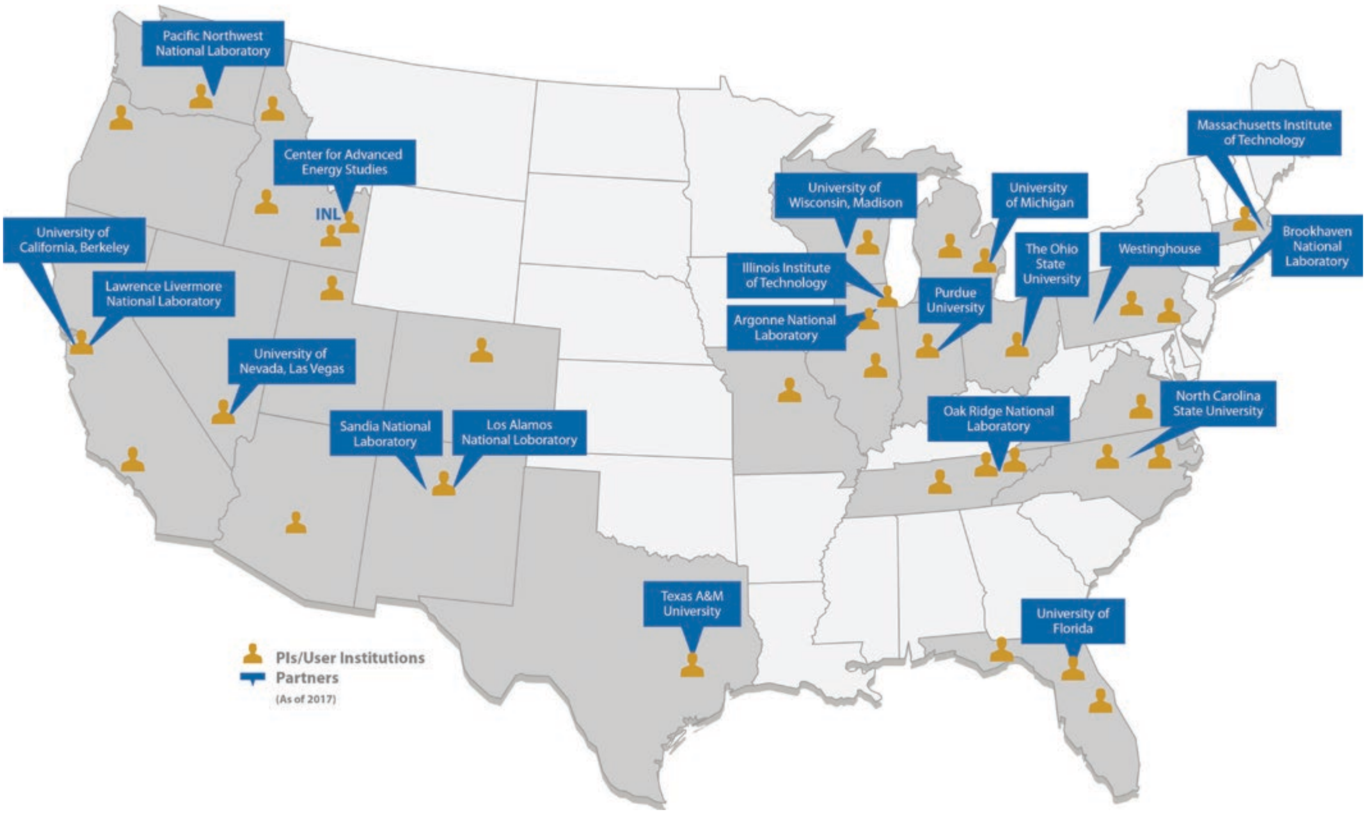

The map above shows the locations of the Nuclear Science User Facilities' principal investigators/user institutions and partner facilities in the United States.

Nuclear Science User Facilities: Driving nuclear research

Established by the Energy Policy Act of 2005, the NSUF now offers users across the country access to capabilities for the irradiation testing of nuclear fuels and materials.

By Rory Kennedy and Laura Scheele

The Nuclear Science User Facilities (NSUF) celebrated its 10th anniversary in 2017. The NSUF concept was initiated in 2005, when Idaho National Laboratory (INL) was established. Section 955 of the Energy Policy Act of 2005 states, "The Secretary [of Energy] shall develop a comprehensive plan for the facilities at the Idaho National Laboratory . . . [and shall] include a plan to develop, if feasible, the Advanced Test Reactor . . . into a user facility that is more readily accessible to academic and industrial researchers."

In response to this directive, INL management, working with the Department of Energy's Office of Nuclear Energy (DOE-NE) and Idaho Operations Office, developed and implemented a plan that created the Advanced Test Reactor–National Scientific User Facility (ATR-NSUF) (*NN*, Aug. 2011, p. 42). The user facility was to provide access, at no cost to the researcher, to the ATR and other associated INL capabilities for the irradiation testing of nuclear fuels and materials, including the design, reactor analysis, fabrication, transport, irradiation, post-irradiation examination, and final disposition of test samples. The ATR-NSUF represented DOE-NE's first and only user facility and, according to the memorandum designating the ATR a National Scientific User Facility, filled a critical need "in reestablishing the U.S. scientific and nuclear industry base that is needed for building and advancing a new generation of nuclear power plants in the United States."

In order to better accommodate the needs of the nuclear research community, the Partner Facilities program was initiated in 2008 with the inclusion of the Massachusetts Institute of Technology Reactor

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NSUF Capabilities Offer Research Opportunities

Neutron Irradiations

Idaho National Laboratory	The Ohio State University
Oak Ridge National Laboratory	Sandia National Laboratories
Massachusetts Institute of Technology	SCK-CEN
North Carolina State University	

Ion Beam Irradiations

University of Wisconsin–Madison	Sandia National Laboratories
University of Michigan	Texas A&M University
Argonne National Laboratory	Lawrence Livermore National Laboratory

Gamma Irradiations

Idaho National Laboratory	Sandia National Laboratories
Oak Ridge National Laboratory	

Hot Cells and Shielded Cells

Idaho National Laboratory	Westinghouse
Oak Ridge National Laboratory	University of Michigan
Pacific Northwest National Laboratory	SCK-CEN
Los Alamos National Laboratory	

Low Activity Laboratories

Idaho National Laboratory	North Carolina State University
Center for Advanced Energy Studies	Purdue University
Oak Ridge National Laboratory	University of Nevada, Las Vegas
University of California, Berkeley	University of Michigan
Pacific Northwest National Laboratory	University of Florida
Los Alamos National Laboratory	SCK-CEN

Beamlines

Illinois Institute of Technology	North Carolina State University
Brookhaven National Laboratory	Los Alamos National Laboratory

High Performance Computing

Idaho National Laboratory

and has grown to include 19 additional facilities at other national laboratories, universities, and one industry site, offering a variety of capabilities for test reactor neutron irradiations, ion beam irradiations, gamma irradiations, hot cell and shielded instrumentation, low activity laboratories, beamline access at other user facilities, and high-performance computing. Brief descriptions of the capabilities offered at each partner facility are provided later in this article. This expansion of capabilities over the years led to a change in the name of the user facility program to the Nuclear Science User Facilities in 2014 to better reflect the current state of the program as a consortium of facilities.

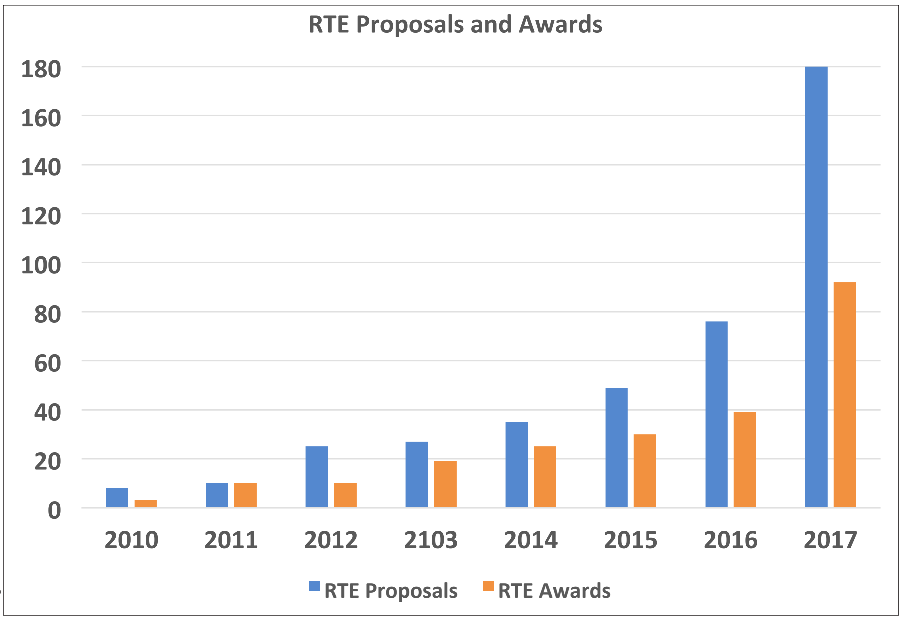
The NSUF continues to be managed and directed out of INL, and INL remains the primary facility of the NSUF. A unique aspect of the NSUF is that it does not represent a single stand-alone physical structure, but a collective of facilities, each with its own management system. The NSUF offers a range of investigative techniques and capabilities focused on advancing a single technology (nuclear energy) as opposed to the more familiar user facility model that offers a focused capability, such as synchrotron beam lines, to a broad range of technological areas. The NSUF model enables more effective use of nuclear energy research facilities and expertise and has gained international attention. The NSUF recently brought on its first international affiliate facility with the Belgian Nuclear Research Centre, SCK-CEN, which includes the Belgium Reactor 2 (BR2) and the Laboratory for High and Medium Activity.

Open, competitive access

All projects conducted by the NSUF are nonproprietary and intended for publication in the open literature. Access to NSUF capabilities is achieved through two competitive proposal processes. The first is for highly focused, short-term, limited instrument–time projects termed Rapid Turnaround Experiments (RTE) that are in line with the typical user facility model. Proposals for RTEs are evaluated three times a year.

The second proposal process—and another unique feature of the NSUF model—is the DOE-NE's once-a-year Consolidated Innovative Nuclear Research (CINR) Funding Opportunity Announcements (FOA), through which large projects can be proposed. These projects can last up to seven years for full neutron irradiation plus post-irradiation examination and can incur costs of several million dollars. It is important to note that all accepted CINR-type projects are fully forward funded, and thus are not subject to yearly funding fluctuations. In addition, there are possibilities within the CINR FOAs for researchers to obtain project research and development funds typically not offered through other user facility models in addition to the no-cost access to NSUF capabilities. Proposals are welcome from university, government laboratory, small business, and industry researchers. Details of the proposal processes can be found at <http://nsuf.inl.gov>.

Continued



Graph: Jeff Benson, NSUF

Fig. 1. Number of Rapid Turnaround Experiment (RTE) proposals received and number of RTE project awards made per fiscal year since the inception of the RTE program.

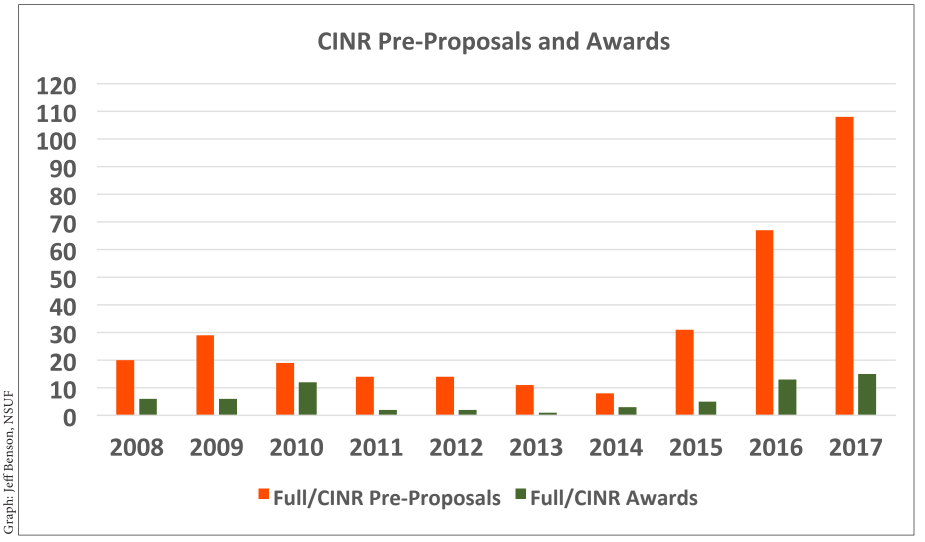


Fig. 2. Number of Consolidated Innovative Nuclear Research (CINR) pre-proposals received and number of CINR project awards made per fiscal year.

Interest in the capabilities offered through the NSUF continues to soar, as demonstrated by Figs. 1 and 2. The response to that interest from the NSUF has grown accordingly. Of particular significance is the dramatic increase in the number of applications to the NSUF over the past few years. For the RTEs, the NSUF went from 35 proposals in 2014 to 180 proposals in 2017, and the trend continues into fiscal year 2018, when the NSUF received 114 proposals in response to its first call of the year. The RTEs are a very fruitful source of significant research results, and due to the increasing quality of the proposals received, the NSUF endeavors, within its funding limitations, to support about 50 percent of the proposals received. As a side note, researchers are encouraged to take advantage of the Nuclear Fuels and Materials Library (see next section) with respect to RTE projects.

The number of CINR-type project requests has also increased significantly since a low point in 2014. Funding available to the NSUF to support these larger projects has increased from about $400,000 supporting only three projects in 2014 to about $11 million supporting 15 projects in 2017. All awarded projects are fully forward funded from that year's budget allocation. The CINR projects are of high value and therefore are highly competitive, as can be seen in Fig. 2, where less than 15 percent of the pre-proposals submitted ultimately resulted in project awards. (In 2017, 50 pre-proposals—46 percent—were selected for full proposal submission, from which 15, or 30 percent, were awarded.)

Digital tools

The NSUF created and maintains the Nuclear Fuels and Materials Library (NFML) in an effort to collect and protect legacy irradiated fuels and materials for use by the nuclear research community. The library of irradiated materials available for research will help reduce costs by avoiding redundant irradiation testing and will save materials for testing or developing new theories, as well as applying future analysis techniques and equipment. As Sir Humphry Davy stated in his 1812 publication, *Elements of Chemical Philosophy,* "Nothing tends so much to the advancement of knowledge as the application of a new instrument."

In its mission to support the DOE-NE in managing its available infrastructure for efficiency, effectiveness, and future investment decisions, the NSUF created and maintains the Nuclear Energy Infrastructure Database (NEID). The searchable and interactive database is also made available to the nuclear research community to aid in formulating research projects. Currently, the NEID contains information on 150 institutions operating nearly 500 facilities that house almost 1,000 instruments. Approximately 80 percent of these institutions are in the United States and 20 percent are in other countries. The NSUF is engaging the international community in the activities of both the NFML and the NEID to better utilize resources for the advancement of nuclear energy. (See also the article by the NSUF's chief irradiation scientist, Brenden Heidrich, page 49).

NSUF focus

The NSUF focuses on irradiation effects in nuclear fuels and materials that will advance the DOE-NE's technology development goals in both the near and long terms. The NSUF supports both fundamental and applied science projects spanning a range of technologies and degrees of development. Projects aimed at understanding the fundamental aspects of thermal and mass transport, interface interactions, and microstructure development in ceramic (e.g., UO_2), metallic (e.g., U-Pu-Zr), particle (e.g., TRISO), and advanced concept (e.g., accident-tolerant) nuclear fuels, including cladding, are part of the NSUF portfolio.

The NSUF supports projects that advance the understanding of how the evolution of defects influences the property/microstructure relationship in high technical readiness level (TRL) structural materials (e.g., Zr-alloys, austenitic and ferritic-martensitic steels, and reactor pressure vessel steels) as well as lower TRL materials (e.g., FeCrAl and 14YWT alloys and nanostructured materials). NSUF projects also include irradiation testing of new and innovative radiation-resistant materials such as oxide dispersion–strengthened steels and MAX phases (e.g., Ti_2SiC_2 and Ti_3AlC_2) for advanced reactor systems. Of great interest to the NSUF is the development of radiation-resistant sensors and detectors for high-fidelity in-pile real-time measurements and data transmittance, and the NSUF has irradiation-tested a number of materials and sensor constructs such as, for example, piezoelectric and magnetostrictive materials in transducer architectures. Of growing interest—particularly for projects generated from small business and industry researchers—are materials produced from advanced or additive manufacturing techniques. Here, the NSUF offers strong support for applied science aimed at near-term industry advances. (See also the article by the NSUF's chief post-irradiation scientist, Simon Pimblott, page 43.)

Charting the future

The DOE-NE established the NSUF to open the national nuclear research infrastructure to pair the best ideas with the needed capabilities. The results of the fundamental and applied research performed under NSUF auspices provide the foundation for light-water reactor sustainability and the development of advanced nuclear energy systems. While nuclear energy faces challenges in the United States, the research community is eagerly tackling scientific and technical questions that can ease nuclear technology licensing and commercialization moving forward.

The NSUF vision has been fostered and carried forward by previous NSUF directors (and ANS members) Mitch Meyer, Todd Allen, Frances Marshall, and Jeff Terry. NSUF partner facilities and users are grateful for their contributions to the unique partnership established by the DOE-NE. They have set a high bar that the current NSUF users, partner facilities, leadership, and team members continue to strive to meet for the betterment of nuclear professionals around the world. NN