Report from the NEAC Facilities Subcommittee: 12/11/2013

Subcommittee Objectives

The objective of our subcommittee deliberations has been to develop a means to identify, prioritize and make available those facilities important to Nuclear Energy Research and Development. While our most recent emphasis has been on university facilities, all facilities are considered, including those existing at DOE laboratories, universities, industry and international. Also considered are new facilities that would enhance the U.S. position as a player in international development of nuclear energy.

Background

There have been many studies conducted to identify facilities that exist within the DOE and university complex. The list of facilities is long. It is difficult to independently assess capability and readiness of many of these facilities, not only because there are so many, but also because their use and availability changes as program priorities and needs change. The lack of a consistent long-term plan for nuclear R&D has hindered their maintenance and use. This is especially troubling since facilities important to nuclear R&D are expensive and without consistent funding, will be lost. The U.S. at one time was the world leader in nuclear R&D but is no longer. It is important, therefore, that the work of the subcommittee address the issue of facility availability in new ways. We have attempted to do that.

The important documents from prior assessments include:

"Facilities for the Future of Nuclear Energy Research: A Twenty-year Outlook", DOE-NE, Feb/ 2009

"2012 Annual Report for the Research Reactor Infrastructure Program", Idaho National Laboratory

"Research and Test Facilities Required in Nuclear Science and Technology", NEA, Organization for Economic Co-operation and Development, ISBN 978-92-64-99070-8, NEQA No. 6293, OECD 2009

"Nuclear Energy for the Future, Executive Recommendations for R&D Capabilities", Battelle, July 2008

"A Strategy for Nuclear Energy Research and Development" EPRI and INL, INL/EXT-08-15158, December 2008

"Required Assets for a Nuclear Energy Applied R&D Program" INL, 2008

"Assuring a Future in U.S.-Based Nuclear and Radiochemistry Expertise", National Academy of Sciences, ID=13308, 2012

The information contained in these reports provides an extensive catalogue of capabilities, needs and priorities from several points of view. A consistent theme is the need to maintain U.S. expertise at a high level by conducting relevant research. The question is how to accomplish that goal with seemingly ever-changing priorities for research that requires facility support.

Another important question is how to capture those facilities not directly related to materials studies, which has been the emphasis in previous studies. For example, there are significant facility needs in radiochemistry (as the NAS report details), criticality safety, thermal-hydraulics, cyber-security and modeling and simulation of nuclear systems. To this juncture, there has not been a consistent means for identifying, coordinating and providing access to those facilities.

Approach

We may have found a way. DOE and the INL have been conducting a pilot program for the creation of a "virtual laboratory" user-facility since 2007. At its heart it provides a means for researchers at national laboratories, universities and industry to access facility capability that would otherwise be unknown or unavailable. Partners in this virtual laboratory ***self-select***, offering their facilities for use to the broader community. Currently, there are 3 national laboratories, 8 universities and 1 industry partner participating. The benefit of this self-selection is that it draws capabilities that are both current and relevant, with demonstrated support from their parent institutions. Support from parent institutions includes training and assistance to researchers who are interested in use of an individual facility.

Facilities include everything from reactors (ATR, HFIR, MIT reactor, NCSU PULSTAR etc.), hot cells (HFEF, ORNL, etc.), beam-lines (Michigan Ion Beam, Advanced Photon Source, Wisconsin Tandem Ion Accelerator Ion Beam) to special diagnostic instrumentation (CAES, etc.) and experts to aid researchers using them. While the emphasis has been on fuels-and-materials testing, the user facility model can be expanded to other facility-supported research such as thermal-hydraulic modeling. Availability of a broad range of relevant facilities is necessary for the simulation-and-modeling community and this provides a means for bridging a gap between experimentalists and modelers.

The pilot program has been successful, in spite of limited funding. Important features include

1) Team visits at offered facilities to verify advertised capabilities and expertise,

2) Reviews by independent experts to confirm capability and need,

3) Training for researchers in use of facilities and equipment,

4) Assessment of research proposals to recommend the best facilities considering capability, availability and cost, and

5) Subsidies for researchers based upon priorities and need.

To date, the program has been limited, not including major DOE research programs, the Nuclear Energy University Program (NEUP) and others. In effect, it has been its own program, providing partial funding for university-centered research that includes partners from industry and national laboratories. However, even with limited scope, there have been 76 projects awarded, university and laboratory researchers have produced 114 research papers, and an average of ~90 people participate in users week each year . Selection of projects is made through a peer review system, not unlike that for other university programs funded by DOE-NE and DOE-SC. Industry funded research is also accepted; (there is a range of ways to access facility capability). Research is reviewed for the most appropriate facilities to be used based on capability, availability and cost. An example would be scoping irradiation in the MIT reactor followed by full scale irradiation at the ATR. PIE could be conducted at ORNL, INL or one of the university partners.

The virtual user-facility is the “ATR National Scientific User Facility (NSUF)”. (The name reflects how it began and should not be judged to be specific only to ATR).

Recommendations

It is time, in our opinion, to ***use this model to integrate use of facilities for all DOE-NE programs that require them***. Doing so will improve the efficiency of facility utilization across the board. Competition for facility space, particularly at DOE hot cells, has always been a problem and this represents an effective way of ensuring that priorities are fairly established and that capability, heretofore not considered, will be a part of the discussion. For DOE researchers, it opens access to university and industry capability and for university researchers it opens access to DOE national laboratory capability in ways previously not available. Consolidation of the other university research programs, notably NEUP, would fit well into the “ATR”-NSUF framework, potentially expanding the number of partner organizations and enhancing opportunities for use of unique facility capability

Specifically**, the *“ATR”-NSUF should be front and center in any update of the DOE-NE roadmap for nuclear R&D***. It should be identified as the means by which facility utilization is prioritized and selected. Doing so will encourage others to offer their facilities as partners and clarify what capability exists in the broader community. It is also consistent with DOE’s announced initiative in ‘Hub and Spoke” utilization of resources. Considering the many DOE-NE programs that utilize facilities, including industry, funding for experimenters can continue to be tied directly to their sources. However, funding for administrative and facility support should be its own, dedicated budget.

As mentioned earlier, the scope of DOE interests in nuclear technology is much broader than materials development. Consideration should be given to including facilities that support other areas. Criticality safety, which is highly cross-disciplinary (conducted within NNSA, not DOE/NE), is an excellent example. Others of interest include thermal-hydraulic testing (both integral and special effects), ion-beam irradiation capabilities, and severe accident testing facilities. Some of these might also include detector-testing composed of many sites/facilities, sources, and capabilities, e.g. a nuclear cyber-security user facility composed of simulators connected to real components and other facilities. (Note that a cyber-security user facility has already been established at the INL based upon the ATR-NSUF model, so the precedent has been established). With the expanded scope, a name change is in order; Perhaps the National Nuclear Scientific User Facility (NNSUF).

Information about the "ATR"-NSUF may be found at their website: https://atrnsuf.inl.gov/ .

Previous Studies and Conclusions

It is important that previous work in identification of facility needs and priorities be summarized since such work has been extensive in considering fuels and materials development and provides a context for understanding the above recommendation. As noted earlier, the list of available facilities is long and comprehensive. What has been lacking is a means to address facility status in today's ever-changing environment.

Perhaps the most relevant document is *"Facilities for the Future of Nuclear Energy Research: A Twenty-year Outlook", DOE-NE, Feb/ 2009.* It is important not only because it represents an official DOE-NE position but also because it is based upon many previous evaluations. To quote:

"Facilities for the Future of Nuclear Energy Research follows the recommendations of the National Academy of Sciences and is informed by several studies conducted in 2008, including those of DOE's national laboratory directors, DOE's Nuclear Energy Advisory Committee, and studies by the Battelle Memorial Institute that provide the foundation for the identification of core facilities.

These studies reflect the insight of the Nation's leading nuclear education programs, Nobel laureates, industry experts, users of DOE research capabilities, Federal executives, the international research community, and other stakeholders. *Facilities for the Future of Nuclear Energy Research* describes a capabilities baseline that addresses the most essential and complex nuclear R&D facilities. This plan is intended for use by other DOE programs and laboratory directors to make sound business decisions on the need to maintain individual high-cost nuclear facilities by clarifying the needs and planning assumptions of nuclear energy R&D. Multi-year program plans and associated budget requests will be developed for these larger facilities. Smaller scale facilities will be described and justified in specific program budgets as they are required. Human capabilities will remain in limited supply for the foreseeable future; however, these essential resources can be drawn upon regardless of where they currently exist to support the baseline facilities. The details of the plan may change as new technical challenges arise, as research matures, and as the nuclear science and engineering infrastructure evolves. Nevertheless, the plan represents the best estimate of critical facility needs at this time".

The report addressed facility needs according to the following criteria:

"Considerations for Core Capabilities and Facilities:

- Focus on core set of materials test reactors, hot cells, and specialized facilities needed to support nuclear energy R&D for 20 years
- Evaluate DOE's existing research facilities against needed capabilities, considering functionality, capacity and demand, operating status, adequacy of supporting infrastructure, and economy achieved through co-location with other needed facilities
- Use same criteria to assess university, industry, and international facilities
- Consider facilities in standby when no suitable operating facilities exist
- Building new facilities to satisfy capability requirements will be considered if no other reasonable alternative exists in the U.S. or internationally, and will be necessarily justified and funded by the sponsoring program

• New facilities may best be located at remote sites, where existing infrastructure can support new capabilities
• Facilities need not be co-located with research expertise, provided experts have access to the facilities".

The following conclusions were reached regarding important facilities:

Table 6.1

Core Nuclear Energy Research and Development Capabilities and Facilities

Core Capabilities		Existing Core and Supplementary Facilities			
Research Priority		Tier 1 Base Case	Tier 2 Secondary	Tier 3 Tertiary	Tier 4 Other
Materials Test Reactors					
I – IV	Thermal irradiation	INL ATR	ORNL HFIR	MIT, MURR	France JHR, Japan JMTR, Norway Halden, Holland Petten
V	Np-237 target irradiation	INL ATR	ORNL HFIR		
IV	Fast irradiation – small samples/surrogates	INL ATR	ORNL HFIR		
I – IV	Transient testing	INL TREAT		Japan NSRR	
Hot Cells					
I – IV	Hot cells capable of handling and examining full-length rods or fuel assemblies	INL HFEF[1]	ORNL IFEL[2]		
I – IV	Hot cells capable of supporting high-level mechanical testing	INL HFEF	ORNL !MET		
IV	Aqueous separations – lab scale	ORNL 7920 and/or INL RAL3			
IV	Aqueous separations – lab scale integrated testing	SRNL shielded hot cells or INL RAL	PNNL RPL		
IV	Aqueous waste form development – lab scale	SRNL shielded hot cells, PNNL RPL, INL RAL or ORNL 7920			
IV	Electrochemical separations – lab scale	INL HFEF			
IV	Electrochemical separations – engineering scale	INL FCF			
IV	Electrochemical waste form development – engineering scale	INL HFEF			
IV	Hot fuel fabrication – test pins	INL FMF and FCF	ORNL 7920		
V	RPS final assembly and testing	INL SSPSF			

Research Priority Key

I. Sustain existing LWRs as long as possible
II. Build new LWRs as fast as possible

[1] *Includes associated radiochemical laboratories and glove-box lines.*

The following recommendations were drafted by the NEAC Facilities Subcommittee earlier this year after reviewing the various reports and considering changes in program priorities. While this list is not exhaustive, it includes those facilities which are most prominent in availability and use for irradiation services. Yet to be added, for example, are facilities related to thermal-hydraulic testing.

Facilities to support Research and Development in nuclear technology

Irradiation Facilities

- Thermal Spectrum Reactors
  - **ATR** INL – Primary facility for thermal irradiation services
  - **HFIR** ORNL – Secondary facility for thermal irradiation services
  - **MIT** – Primary facility for thermal irradiation services from the university community
  - **MURR** UM – Secondary facility for thermal irradiation services from the university community
  - **TREAT** INL – Primary facility for transient safety testing of fuel
  - **NSRR** Japan – Secondary facility for transient testing.

In addition to these reactors, which represent no fast spectrum capability of significance, the following are identified:

- Fast Spectrum Reactors
  - **JOYO** Japan – Primary facility for fast spectrum irradiation
  - **BOR-60** Russia – Secondary facility for fast spectrum irradiation

In addition, there are many smaller thermal reactors in operation at a number of universities that are useful for scoping irradiations followed by subsequent experiments in the aforementioned reactors. They include:

- University reactors
  - **McClellan Nuclear Research Center** (**MNRC**) at UC – Davis. This facility includes a 2 MW TRIGA research reactor. Is relatively new, build in 1990 by the Air Force for neutron radiography and now used for general research. Capabilities include tomography, neutron activation analysis, radiation effects testing, research scale isotope production and silicon doping capabilities. It is one of the three largest university research reactors in the nation.
  - **Rhode Island Nuclear Science Center** – University of Rhode Island. This facility includes a 2 MW reactor to be used as a tool for education, research and service work related to the nuclear industry and technology. The long term vision is for it to become an integral part of the national infrastructure. Plans are to upgrade the reactor to 5 MW.
  - **Oregon State University TRIGA reactor (OSTR)** is a 1 MW facility with the capability of power "pulses" that can reach several thousand MW. It is used for a wide variety of applications including chemistry, physics, geology, archaeology, nuclear engineering and radiation health physics.
  - **University of Texas at Austin – TRIGA II at the Nuclear Engineering Teaching Laboratory (NETL)**, a reactor licensed for 1.1 MW operation and power pulses. Includes a cold source, 6-meter neutron guide tube, and a capillary focusing device. It is the newest U.S. University reactor, licensed in 1993.
  - **North Carolina State University PULSTAR,** a 2 MW pool type research reactor. Because of its fuel and core design, the reactor has dynamic characteristics similar to commercial LWR power reactors. Allows for teaching experiments to measure reactivity coefficients, for example. Has significant irradiation and neutron diffraction capability. It also includes capabilities for an intense positron source and an ultra-cold neutron source.
  - **Penn State University Breazeale Reactor (PSBR),** a 1 MW TRIGA reactor with pulsing capabilities. It is the nations' longest continuously operating university research reactor with extensive in-core irradiation capability as well as neutron radiography. New facilities and

capabilities are routinely added, including a cold neutron source and cold neutron prompt gamma activation analysis.

- **Texas A&M University Nuclear Science Center (NSC),** includes a 1 MW TRIGA reactor. It is used to produce radioisotopes for commercial use, neutron activation analysis and support for the nuclear engineering department.
- **University of Massachusetts at Lowell Research Reactor (UMLRR)** is a 1 MW pool type reactor. Its design power capability is 5 MW which could be achieved with a licensing upgrade. It provides multidisciplinary capabilities for use in nuclear related education and research. Includes significant in-core and out-of –core irradiation capability, including fast neutrons for radiation effects research.
- **University of Wisconsin TRIGA Reactor,** a 1 MW facility. Is an integral part of the nuclear engineering program and supports work-force development for the nuclear industry. Provides capabilities in neutron activation analysis as well as neutron radiography and radiolysis.
- **Washington State University Nuclear Radiation Center (WSUNRC)** includes a 1 MW TRIGA reactor. It provides irradiation services, radioisotope production and analytical services for researchers at PNNL as well as for the radiochemistry program at WSU. Produces radioisotopes for national laboratory and business clients. Includes a power pulsing capability (to 1000MW) which has been frequently used in cooperation with PNNL). It has been used extensively for research in boron neutron capture therapy.
- **Ohio State University Research Reactor (OSURR)** operates a .5 MW pool-type reactor. It is fueled with MTR-type LEU fuel. It includes significant in-core and out-of-core irradiation capability serving a wide range of researchers.
- **Kansas State University TRIGA,** a pulsing research reactor licensed for operation up to 1.25 MW. Its primary roles are research support, education, training and outreach. It includes significant in-core and out-of –core irradiation capabilities.
- **Reed College Research Reactor**, a .25 MW TRIGA reactor used for instruction, research and analysis by faculty and students at Reed College. It provides in-core irradiation capability.
- **University of California at Irvine Nuclear Reactor** is a .25 MW TRIGA with pulsing capabilities to 1000 MW. The facility specializes in neutron activation analysis. It provides tracer radionuclides and activation analysis for a wide range of applications, including solvent extraction separations of actinides and lanthanides in spent fuel reprocessing.
- **University of Maryland Training Reactor** is a .25 MW TRIGA. It operates as need to support the educational and experimental programs of the university.
- **University of Missouri S&T Research Reactor (UMRR)** is a .20 MW pool type reactor. It has gamma and alpha spectroscopy capabilities and state-of-the art data acquisitions and spectrum analysis software. They provide research opportunities for faculty and students from non-reactor owning universities.
- **University of Florida Training Reactor (UFTR)** is a .10 MW loop-type LWR. It is used to train students to operate reactors, and to support courses in physics, chemistry, geology, and mechanical engineering anthropology and environmental sciences. It is a radiation source for various research programs such as trace element analysis of ocean sediments, river sediments foods, plants and many other materials.
- **University of Utah TRIGA Reactor (UUTR)** is a .10 MW reactor used for research, training and education. Supports a new nuclear engineering curriculum. Includes radiation services.
- **Purdue University School of Nuclear Engineering PUR-1 reactor** is a 1 KW pool type reactor utilizing flat plate MTR type fuel. It is operated primarily for education.

    - **Idaho State University AGN-201 reactor** is a 5 watt reactor used for training.
    - **University of New Mexico AGN-201M reactor** is a low power reactor used for training.
    - **Rensselaer Polytechnic Institute Reactor Critical Facility (RCF)** is a zero power critical facility used for training.

Hot Cells and supporting facilities

- Multipurpose Hot Cells
    - **HFEF** INL – Primary Facility for multipurpose PIE
    - **IFEL** ORNL – Secondary Facility for PIE
- Reprocessing R&D Facilities
    - **7920** ORNL – Primary Facility for aqueous separations R&D
    - **RAL** INL – Secondary Facility for aqueous separations R&D
    - **FCF** INL – Primary Facility for electrochemical separations R&D
    - **HFEF** INL – Secondary Facility for electrochemical separations R&D
- **Significant University-Based Capabilities**
    - **The University of Missouri Research Reactor (MURR)** is a multi-disciplinary research, development and education center. The reactor is rated at 10MW and is supported by facilities that address development of radiopharmaceuticals in cooperation with the School of Medicine, College of Veterinary Medicine and College of Agriculture, Food and Natural Resources. Other programs included nanotechnologies, materials analysis, nuclear battery development, semiconductors, bio-membranes, environmental analyses, epidemiology, boron neutron capture therapy and international databases with applications in archaeology, anthropology and geology.
    - **The MIT Nuclear Reactor Laboratory (NRL)** is an interdepartmental center that operates a 5 MW research reactor. The reactor is supported by an extensive infrastructure at the university. The reactor and associated facilities are used to address radiation effects in biology and medicine, material studies, neutron physics, geochemistry and environmental studies. A major objective is to provide researchers with a service-based infrastructure that supports the US initiative for designing and building the next generation of nuclear reactors, by supporting research in the area of advanced materials and fuel research.
    - **The McClellan Nuclear research Center (MNRC)** hosts four bays to perform neutron imaging. Two bays are large enclosures that can accommodate large samples using robotic manipulators. The Center has the largest radiography capability in the US. The highly collimated and thermalized neutron beams provide high spatial resolution and quality. Dynamic radiography can be taken at 30 frames/second. Collaborates with other facilities to keep its imaging facilities at the state of the art. (Probably worth a visit).
    - **Rhode Island Nuclear Science Center (RINSC)** has two rabbit systems, four in-core facilities, a central irradiation facility, six beam ports, a through port, a thermal column, dry tubes, and an irradiation room. (No information on hot cell or other facility support but this is a large multi-purpose facility).
    - **Oregon State University (OSTR)** operates a suite of experimental facilities in support of teaching and research. Facilities include a rabbit tube, rotating rack, thermal column, neutron radiography facility, prompt gamma neutron activation analysis, several in-core irradiation tubes to tailor flux. (Need information about other support facilities).
    - **North Carolina State University PULSTAR** provides a significant number of exposure and beam ports, neutron powder diffraction and imaging facilities, and an intense positron source

as well as a cold neutron source facility. Includes for user facilities harnessing the intense radiation fields from the reactor. (This appears to be a major facility with significant capability, worth a visit?)

- **Penn State University Breazeale Reactor (PSBR)** includes capability in radiochemistry and nuclear security research. It includes significant in-core and out-of-core irradiation capability for neutron imaging, a cold neutron source and cold neutron prompt gamma activation analysis.

From these lists, it is apparent that there is considerable capability in the complex when the university facilities and expertise are included. However, the real question is access to the facilities, enabled by detailed knowledge of capability and support. This is where the “ATR”-NSUF provides an important service. Namely, as noted earlier, partners “self-select”, offering their facilities. Capabilities are independently reviewed and if accepted, made available through both training and on-site support to experimenters. Proposed experiments which require facility support are reviewed for recommended “best fit” based on facility capability, availability and cost. It is a formula that will help ensure that the most important capability is maintained and that the system functions efficiently.