LA-UR- 10-01216

Approved for public release; distribution is unlimited.

Title:	Operational Status of the Los Alamos Neutron Science Center (LANSCE)
Author(s):	Kevin W. Jones John L. Erickson Kurt F. Schoenberg
Intended for:	To be presented at the ICANS-XIX Meeting, March 8-12, 2010, Grindelwald, Switzerland

Los Alamos
NATIONAL LABORATORY
EST. 1943

ICANS XIX,
19th meeting on Collaboration of Advanced Neutron Sources
March 8 – 12, 2010
Grindelwald, Switzerland

Operational Status of the Los Alamos Neutron Science Center (LANSCE)

Kevin W. Jones, John L. Erickson and Kurt F. Schoenberg

Los Alamos National Laboratory, Los Alamos, NM 87544 USA

Abstract

The Los Alamos Neutron Science Center (LANSCE) accelerator and beam delivery complex generates the proton beams that serve three neutron production sources; the thermal and cold source for the Manuel Lujan Jr. Neutron Scattering Center, the Weapons Neutron Research (WNR) high-energy neutron source, and a pulsed Ultra-Cold Neutron Source. These three sources are the foundation of strong and productive multi-disciplinary research programs that serve a diverse and robust user community. The facility also provides multiplexed beams for the production of medical radioisotopes and proton radiography of dynamic events. The recent operating history of these sources will be reviewed and plans for performance improvement will be discussed, together with the underlying drivers for the proposed LANSCE Refurbishment project. The details of this latter project are presented in a separate contribution.

LA-UR-09-05568

Please tack your preference

- ■ **Facility reports**
- ☐ **Accelerator system developments**
- ☐ **Target station design and engineering**
- ☐ **Instruments**
- ☐ **Fundamental physics with neutrons**

Please tack your preference

■ **Oral** ☐ **Poster**

Final decision will be made by the programme committee.

ICANS XIX,
19th meeting on Collaboration of Advanced Neutron Sources
March 8 – 12, 2010
Grindelwald, Switzerland

OPERATIONAL STATUS OF THE LOS ALAMOS NEUTRON SCIENCE CENTER (LANSCE)*

Kevin W. Jones
Accelerator Operations and Technology Division, Los Alamos National Laboratory, Los Alamos, NM 87544 USA

and

John L. Erickson and Kurt F. Schoenberg
Accelerator Operations and Technology Division and LANSCE Division, Los Alamos National Laboratory, Los Alamos, NM 87544 USA

ABSTRACT

The Los Alamos Neutron Science Center (LANSCE) accelerator and beam delivery complex generates the proton beams that serve three neutron production sources; the thermal and cold source for the Manuel Lujan Jr. Neutron Scattering Center, the Weapons Neutron Research (WNR) high-energy neutron source, and a pulsed Ultra-Cold Neutron Source. These three sources are the foundation of strong and productive multi-disciplinary research programs that serve a diverse and robust user community. The facility also provides multiplexed beams for the production of medical radioisotopes and proton radiography of dynamic events. The recent operating history of these sources will be reviewed and plans for performance improvement will be discussed, together with the underlying drivers for the proposed LANSCE Refurbishment project. The details of this latter project are presented in a separate contribution.

1. Introduction

The Los Alamos Neutron Science Center (LANSCE) is a unique multidisciplinary facility for science and technology. The core of the facility is an 800-MeV linear accelerator system with demonstrated 1MW capability that presently accelerates up to 100kW of negative hydrogen ions with unique and highly variable timing patterns suitable for a wide variety of experimental programs. The core of the user facility comprises five experimental facilities. Three areas utilize the 800-MeV negative hydrogen ion beams directed by appropriate pulsed kicker systems to drive neutron sources: at the Manuel Lujan Jr. Neutron Scattering Center (Lujan Center) fourteen operational flight paths utilize pulsed thermal and epithermal neutrons produced at 20Hz by intense 0.29μs bursts of protons incident on a tungsten spallation target and moderated by water or liquid hydrogen; the Weapons Neutron Research Facility (WNR) provides the most intense source of high-energy neutrons in the world for neutron nuclear science and is an accepted world standard for irradiation of semiconductor electronics; and the Ultra-Cold Neutron (UCN) facility uses a moderated solid deuterium target to generate intense pulses of ultra-cold neutrons for fundamental science research.

The Isotope Production Facility (IPF) at 100 MeV utilizes a proton beam of up to 275μA to produce proton-induced isotopes for medical imaging diagnostics and fundamental research. The Proton Radiography Facility (pRAD) provides a unique facility for the study of shock-induced dynamic processes by directly imaging the scattering of the primary proton beam from materials subject to shocks that are driven by high explosives or projectiles. The scattering and imaging process permits quantitative reconstruction of material densities during the evolution of the shock, and other diagnostic tools can enhance the data set by measuring parameters such as surface velocity.

LANSCE continues a disciplined approach to both operations and maintenance that maintains operational performance and user satisfaction in a constrained funding environment.

2. The LANSCE User Facility

The Lujan Center provides 11 neutron scattering instruments capable of studying materials structures of diverse items such as proteins, machinery components, powders, and single crystals using both elastic and inelastic techniques. Nuclear science is supported by three flight paths, one of which is equipped with a 4π detector used to measure thermal neutron capture cross sections on unstable nuclei. This suite of instruments applies and advances neutron scattering for both defense and academic research. Beam current to the Lujan target is nominally $100\mu A$ but can be as high as $125\mu A$ depending on ion source and accelerator optimization.

The WNR facility can receive beam at 40-100Hz with a variable micro-pulse spacing (typically $1.8\mu s$) to address the needs of LANSCE Users in the areas of basic and applied nuclear science. The beam capability for this facility is presently limited to 40Hz because of reliability challenges with the 201.25MHz final power amplifier tubes that generate the RF power for the Drift Tube Linear Accelerator part of the LANSCE accelerator complex. The pulse spacing permits resolution of frame overlap in the neutron spectra. This white neutron source (Target 4) is the most intense source of high-energy (<700 MeV) neutrons worldwide and is equipped with six flight paths that determine neutron energy using time-of-flight techniques. A key flight path used principally by industry users provides a neutron spectrum essentially identical to that of cosmic-ray neutrons to permit accelerated studies of single-event-upset sensitivity for the electronics and avionics industries. A related facility (Target 2) provides direct access to proton beams with energies up to 800 MeV for studies of proton-induced reactions and target irradiations for materials testing. This target station is also equipped with five neutron flight paths.

The pRAD facility provides a unique experimental technique for studies of dynamic processes. Up to 45 pulses of protons, each with approximately 10^9 particles per pulse, temporally spaced at appropriate intervals, are directed at a dynamic object. The scattering characteristics of each pulse are imaged by a collimator and magnetic lens system and recorded by a camera. This technique permits multi-frame radiographs of dynamic events driven by gas guns or high explosives. These radiographs permit the study of material dynamics and failure mechanisms under shock conditions.

The UCN facility accepts several full charge ($\sim 5\mu C$) accelerator pulses separated by a period suitable for the moderation and bottling of the neutrons and compatible with average current limits, typically about 5-7 seconds. The ultra-cold neutrons are then directed through a guide to a decay volume where beta-decay parameters are measured.

The IPF irradiates source materials to produce proton-induced isotopes for applications in medical diagnostic imaging and research. Most notable is the production of ^{82}Sr used for cardiac imaging, and other isotopes for the calibration of PET scanners. The operation of this facility is interleaved with others around the world to assure a constant supply of the necessary isotopes.

A schematic representation of the facility and its operating characteristics is given in Figure 1.

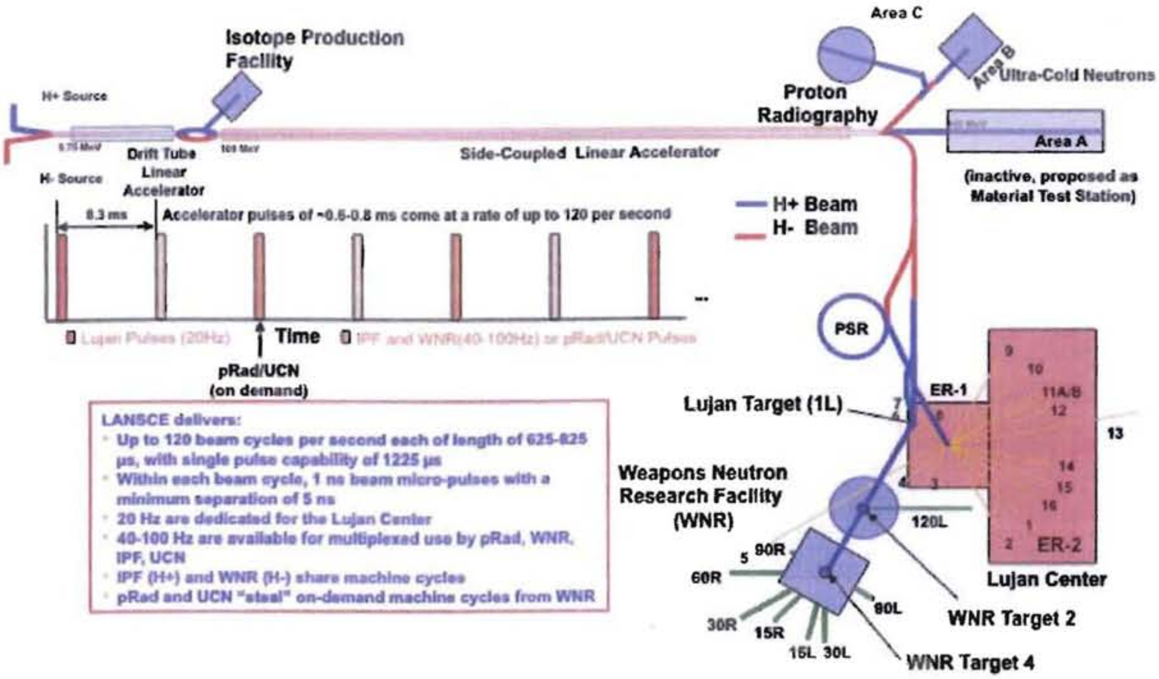

Figure 1: Schematic layout of the LANSCE User Facility with defined operating modes

3. Operations Performance

Integrated performance for the LANSCE User Facility has been remarkably consistent since the year 2000. This is best illustrated by reliability data for the Lujan Center from 1991 to 2009 as shown in Figure 2 and for the WNR facility from 2000 to 2009 as shown in Figure 3. These areas represent the most complex beam delivery system including the injectors and linac, the proton storage ring, and beam transport lines.

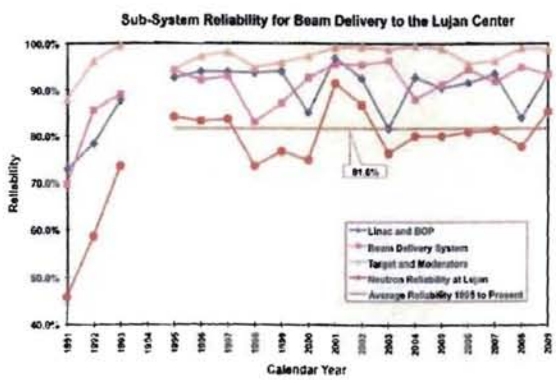

Figure 2: Reliability data for the Lujan Center from 1991-2009

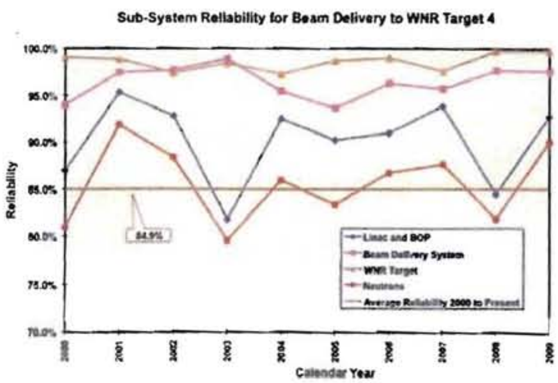

Figure 3: Reliability data for the WNR Facility from 2000-2009

Facility performance data for calendar year 2009 are summarized in Table I. All beams met or exceeded the reliability standard of 85% in 2009. This is a remarkable achievement for a facility that is now 37 years old with much of the original equipment still in service.

Table I: CY2009 Reliability performance for the five LANSCE User Facility Experimental Areas

CY2009			
Target	**Hours Scheduled**	**Hours Delivered**	**Reliability**
Lujan Center	3329.8	2838.8	85.3%
WNR Target 4	3219.8	2895.8	89.9%
pRad	1240.9	1138.3	91.7%
IPF	3420.6	3255.1	95.2%
UCN	1038.7	880.7	84.8%
WNR Target 2	194.7	178.2	91.5%

Strong efforts have recently been made to increase the number of operating hours for the facility, but budget constraints coupled with increasing power costs dictate that future operating schedules be limited to ~3,000 hours per calendar year. This operating scenario is consistent with that planned for the LANSCE Refurbishment Project discussed elsewhere at this conference [1].

Sub-system down time is recorded throughout each scheduled operating period with 1-minute resolution. Historical data allow for careful trending and allocation of scarce maintenance resources. These data have proved valuable in the definition of the scope of the LANSCE Refurbishment Project [1], and are shown in Figure 4.

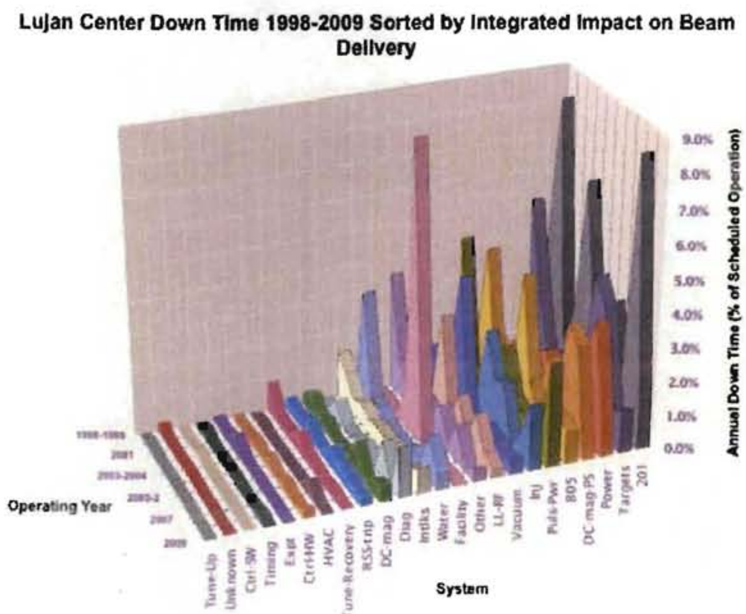

Figure 4: Historical Down Time by Sub-System for the Lujan Center beam from 1998 to 2009

4. Experimental Facility Status Updates

4.1. The Manuel Lujan Jr. Neutron Scattering Center

The Maunel Lujan Jr. Neutron Scattering Center is a National User Facility that uses cold and thermal neutrons for basic and applied research by the international community of scientists from universities, national laboratories, and industry. Research tools are provided for cross-disciplinary work in materials science, biology, condensed matter physics, polymers and other soft matter, magnetism and nuclear physics [2]. Moderators include high intensity thermal water, high-resolution thermal water, partially-coupled thermal water and hydrogen.

The IPNS single-crystal diffractometer was installed and is operational on Flight Path 6, and other IPNS equipment was used to enhance several instruments, sample environments, detectors, electronics and data acquisition hardware. A number of other investments have been made in sample environments, including a 20mK dilution refrigerator, collimators, and a vacuum thin film sputtering system. The ventilation system in ER-1 has been upgraded to provide adequate cooling for experimental hardware, and initial work has begun on a substantial (~US$4.5M) upgrade to the air conditioning and power distribution for ER-2.

The Lujan Center User program continues to attract about 250 unique users each year, and the facility has a healthy over-subscription rate.

The Mark III Target, Moderator and Reflector assembly is under construction and will be installed prior to scheduled operation in June 2010 [3,4].

4.2. The Weapons Neutron Research Facility (WNR)

The WNR facility continues to support a strong and growing program of high-energy neutron research (Target 4) bolstered by a number of world-class detector systems. Of particular interest is the heavily over-subscribed single-event upset facility used by most of industrial electronic chip manufacturers to assess device performance in cosmic ray neutron fields. The accelerated testing rates are of great signficance as device scales shrink and junction spatial densities increase [5]. This capability is considered sufficiently important that an investment of ~US$2M is expected in 2009 to design and construct a new building to convert the one under-utilized flight path at WNR to a second irradiation station for this purpose.

The Target 2 facility allows access to the primary micro-pulse or extracted Proton Storage Ring beams, and these capabilites are used every year. The micro-pulse beam, in conjunction with the Lead Slowing Down Spectrometer, permits neutron cross section measurements on very small and highly activated samples. The extracted PSR beam can be used for shock damage testing of materials such as the SNS target system, or to generate intense short pulses of radiation to assess vulnerabilities in electronic systems.

The nuclear science program at both WNR and the Lujan Center continues to attract over 200 unique users each year.

4.3. The Ultra-Cold Neutron Facility (UCN)

The UCN facility is the only operating source in the United States at this time and provides a density of 35 UCN/cm^3 at the experiment location. This density is comparable to that of the established reactor-based turbine source at the ILL facility in France. The source is based on thermalizing neutrons produced by 25μC of protons striking a tungsten target in 200ms in cold graphite, beryllium and polyethylene, and using quantummechanical scattering of the resulting cold neutrons in a solid deuterium moderator. The source feeds an experimental station dedicated to long-term experimental measurements. Another unique feature is a test port that allows development of new experimental capabilities while operating the principal facility for data acquisition. Initial results (4% uncertainty) from the UCNA experiment have been reported in the literature [6]. Recent production data runs have significantly enhanced the accuracy of this measurement to better than 1%; analysis of recent data is underway with publication expected in mid-2010.

4.4. Facility Safety Basis

The neutron production targets at LANSCE were governed in the past (beginning in 1998) by US Department of Energy rules applicable to nuclear facilities. This increased the complexity of operations and drove significant investment in and ongoing operational and administrative cost associated with protective systems to mitigate the consequences of highly unlikely design basis accidents. In late 2006 it was decided that the facility should be operated under the rules applicable to accelerator facilities, consistent with other such installations in the United States.

This decision precipitated a substantial effort to revise and streamline the safety basis documentation. A key element of this effort was a more pragmatic and defensible definition of the design basis beam loss accident for the facility, a task undertaken by and reported on by Kelsey [7]. This important work allowed the development of a modular approach to the safety basis documentation and clearer definition of allowable shielding and active instrumentation configurations for the protection of workers and the public. The documents were approved early in 2009, and fully implemented by May 2009 to support the operating period for that year.

4.5. Beam Performance Development Efforts

The LANSCE User Facility Accelerator Operations staff continues to devote significant effort to improving the performance of the LANSCE User Facility for all users. Improvement in the peak current output of the H- ion source, coupled with an extension of the source lifetime in a predictable and reproducible way, can have significant impact on facility performance. A careful study of operational protocols indicates that careful conditioning of the source discharge filaments in the first few days of operation can significantly improve source lifetime. Additional investigations that involve control of source body temperature and improved cooling of the molybdenum converter indicate the strong possibility of measurably increasing source output while maintaining both beam emittance quality and source lifetime. Some of these advances may be implemented in the 2010 operating period [8].

Accelerator development activities focus on improving the coincident performance of the low-current H- ion beam delivered to WNR that must be accelerated simultaneously with the high-current H+ beam delivered to the Isotope Production Facility. Additional studies have focused on the alignment of magnetic elements in the accelerator and the contributions of misalignments to beam losses. Several problems have been identified and corrected.

There continues to be substantial emphasis on ongoing studies of beam dynamics in the Proton Storage Ring, including the development of predictive modelling tools for first-turn and stored beam orbits, studies of electron clouds in quadrupole and dipole magnets as well as drifts, and active damping of beam instabilities. The PSR can now routinely operate with acceptable losses at pulse charges of up to 6.5μC.

Performance of the UCN target can be enhanced, possibly by a factor of two, if beam loss and beam focusing challenges in the high energy beam transport can be solved. There is an active effort underway to correct these problems.

5. Future Plans

5.1. Material Test Station

A Material Test Station (MTS) is under consideration for installation in the decommissioned high-power beam end-station, Area A, which in the past housed the pion and muon production targets and experimental stations for the original LAMPF nuclear physics program. Site preparation in Area A is largely complete; the shielding doors surrounding the production targets were successfully opened, the majority of the shielding monolith and activated targets, magnets, and other materials have been removed. Materials not selected for re-use have been disposed of. The MTS will provide a target facility capable of accepting at least 800kW of proton beam power to irradiate fast-fission spectrum fuel elements for material science studies, and will be designed to accept beam powers of up to 3.6MW [9].

5.2. LANSCE Refurbishment (LANSCE-R)

Substantial effort has been invested in the LANSCE Refurbishment Project (LANSCE-R) that is discussed elsewhere at this conference [1]. The project has successfully passed the DOE Critical Decision 1 milestone and and about 28% of the planned project budget is in hand. Preliminary design is nearing completion, as are procurement specifications for long-lead items such as klystrons and control system fiber-optic networks. The investment in LANSCE-R is planned to be US$149M.

Another core element of facility refurbishment is replacement of electrical, water, and HVAC utilities in the linac service building. This has been done for one of the eight sectors of the accelerator, Sector B. Efforts to secure funding for the remaining 7 sectors, budgeted at US$22M, are ongoing.

Two partner organizations also plan significant investment in the facility. The DOE Office of Science/Basic Energy Sciences plans to enhance the materials science instrument suite at the Lujan Center to emphasize utilization of cold neutrons and improve compatibility with the Spallation Neutron Source at Oak Ridge National Laboratory. This will also involve a new design of the moderator suite for the target-moderator-reflector system that serves the Lujan Center. This work is underway.

5.3. Pulse Stacking in the Proton Storage Ring

The Proton Storage Ring (PSR) beam may be utilized in different ways. Recent successful development activities have focused on modifications to the PSR to allow accumulation of stacked micro-pulses rather than the 290ns pulse intended for the Lujan Center. Modifications are required to the timing system, the ring RF buncher, and the extraction kicker system. These stacked micropulses can be delivered to WNR Target 4 to enhance the low-energy component of the neutron spectrum from the white source; a region of significant interest to the neutron science program. These development activities permitted the acquisition of initial data that will form the foundation for a formal proposal for this upgrade.

A second concept under consideration would extract high-charge ($\sim 10\mu C$) pulses from the PSR and deliver them to a new low-enriched sub-critical assembly where the proton burst would drive the assembly to generate a substantial neutron burst, essentially emulating a short-pulse critical assembly. This facility could replace the Short Pulse Reactor facility at Sandia National Laboratory that had been used to study neutron-induced radiation effects on materials and electronics.

5.4. Matter and Radiation in Extremes (MaRIE)

The Los Alamos National Laboratory is developing conceptual plans for a new signature experimental facility, MaRIE. The existing LANSCE User Facility will form the foundation for this new facility. Plans include an increase in power capacity for the present linac from 1MW to 1.8-3.6MW for enhanced operation of the MTS. Plans also include a 35GeV high-gradient electron linac and XFEL facility that will produce radiation of ~50-100keV for enhanced material science capabilities and real-time interrogation of samples in extreme radiation environments [10]. MaRIE build on the existing investment in LANSCE with the addition of an XFEL, a Fission-Fusion Materials Facility based on MTS, a Multi-probe Diagnostic Hall, and a facility for Making, Measuring, and Modeling Materials.

The LANSCE User Facility is the subject of resurgent interest in the spectrum of science accessible at the facility, and the future is bright.

6. References

1. J. Erickson, P. Prince and K. Jones, *The Los Alamos Neutron Science Center (LANSCE) Refurbishment Project,* ICANS-XIX, Grindelwald, CH, AO018 (2010).
2. J. Rhyne, *Present Status and Plans for Upgrading the Lujan Neutron Scattering Center,* ICANS-XIX, Grindelwald, CH, FO011 (2010).
3. M. Mocko, *Neutron Beam Characteristics Measurements at the Manuel Lujan Jr. Neutron Scattering Center,* ICANS-XIX, Grindelwald, CH, TO054 (2010).
4. M. Mocko, *Experimental Investigation of New Neutron Moderator Materials,* ICANS-XIX, Grindelwald, CH, TO052 (2010).
5. S. Wender and A. Hurd, *Accelerated Testing for Neutron-Induced Failures in Semiconductor Devices,* ICANS-XIX, Grindelwald, CH, IP108 (2010).
6. R. W. Pattie et al., UCNA Collaborators, *First Measurement of the Neutron β Asymmetry with Ultracold Neutrons,* Phys. Rev. Lett. 102, 012301 (2009).
7. C. Kelsey, *LANSCE Design Basis Beam Spill Accident,* ICANS-XIX, Grindelwald, CH, AO019 (2010).
8. G. Rouleau, *Recent Development Efforts with the LANSCE H- Source,* ICANS-XIX, Grindelwald, CH, AO022 (2010).
9. E. Pitcher, *Nuclear Fuel Irradiation Conditions in the Proposed Material Test Station,* ICANS-XIX, Grindelwald, CH, TO186 (2010).
10. K. Schoenberg, *Future Plans for Nuclear and Extreme Matter Research at Los Alamos: The LANSCE and MaRIE Facilities,* ICANS-XIX, Grindelwald, CH, FO012 (2010).

*Work supported by the U. S. Department of Energy, National Nuclear Security Administration, Contract No. DE-AC52-06NA25396 – Publication Release LA-UR-10-NNNN.