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STATUS OF THE LANSCE REFURBISHMENT PROJECT*

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ABSTRACT

The Los Alamos Neutron Science Center (LANSCE) accelerator is an 800-MeV proton linac that drives user facilities for isotope production, proton radiography, ultra-cold neutrons, weapons neutron research and various sciences using neutron scattering. The LANSCE Refurbishment Project (LANSCE-R) is an ambitious project to refurbish key elements of the LANSCE accelerator that are becoming obsolete or nearing end-of-life. The preliminary design phase for the project is funded and underway. The 6 year, \$150M (US) project will enable future decades of reliable, high-performance operation. It will replace a substantial fraction of the radio-frequency power systems (gridded tubes and klystrons) with modern systems, completely refurbish the original accelerator control and timing systems, replace obsolete diagnostic devices, and modernize other ancillary systems. An overview of the LANSCE-R project will be presented. The project requirements will be discussed, the preliminary technical solutions presented, and the plan for successful project execution while meeting annual customer expectations for beam delivery will be reviewed.

1. Introduction

The LANSCE User Facility accelerator is capable of simultaneously accelerating protons or negative hydrogen ions to beam powers of up to 800 kW. A beam switchyard allows tailored time-structured beams to be delivered to the five distinct experimental areas.

1.1 Vision and Goals

LANSCE produces one of the highest beam currents in the world of medium energy protons to irradiate experimental targets directly or to produce intense pulses of spallation neutrons. Our goal is to perform state-of-the-art experiments in proton radiography, nuclear science, and materials science with safe, secure, environmentally-compliant, cost-effective performance in beam delivery that meets or exceeds the expectations of our customers.

The LANSCE Refurbishment Project (LANSCE-R) ensures that the LANSCE User Facility will continue to be the premier neutron science facility at Los Alamos National Laboratory, providing NNSA with critical data in support of its Defense Programs mission. A schematic of the project scope is shown in Figure 1.

1.2 Assumptions

Operation of the scientific program will continue during the refurbishment project in a tailored way to meet customer expectations to the extent possible while

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simultaneously implementing the refurbishment project during scheduled operational outages. Refurbishment elements will be pre-assembled, staged, and tested to the greatest extent possible prior to possible multi-shift installation evolutions.

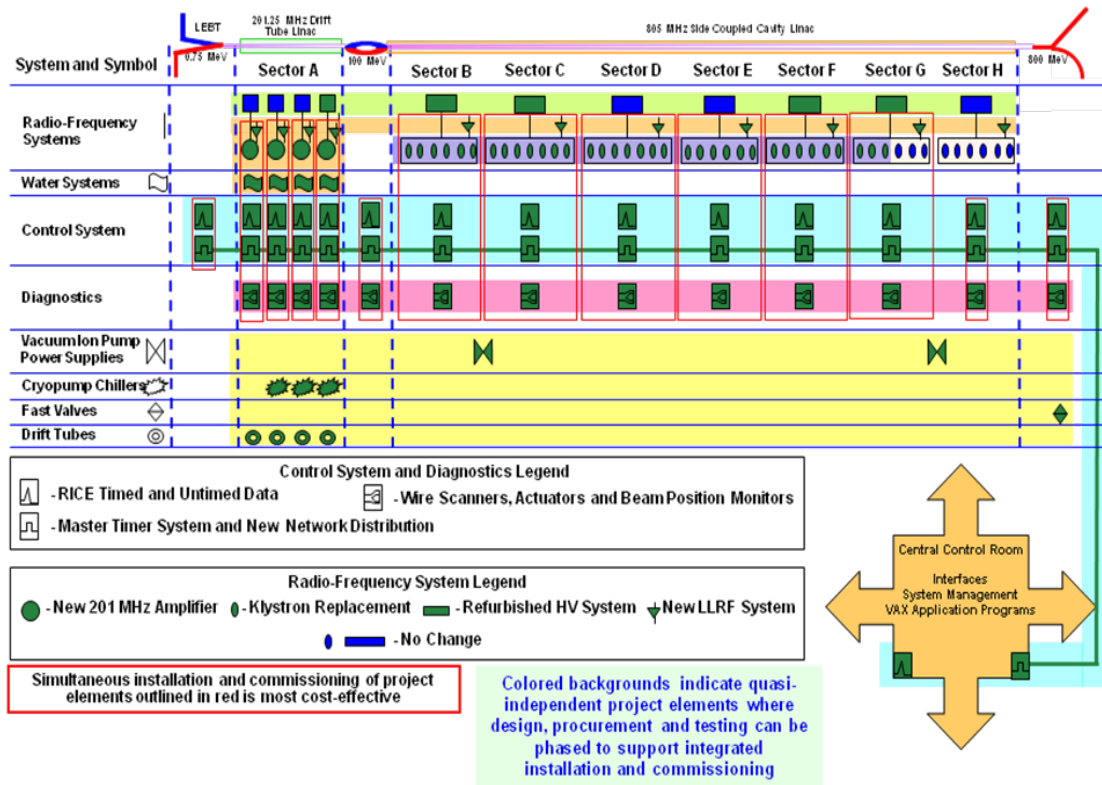


Figure 1: A summary diagram showing the scope of LANSCE-R.

2. Strategies and Projects

2.1 Implementation Strategies

The overall implementation strategy is to integrate ongoing LANSCE User Facility operation with the execution of the LANSCE-R project. The operations organization for LANSCE is both well established and strong. Capital projects have a successful history of integration with the operating facility. The experience of integrating the construction of the Isotope Production Facility is an example of strong cooperation between a project and the operating facility.

The overall success of both LANSCE Operations and the LANSCE-R Project rests on the ability of the responsible organizations to retain and, where appropriate, develop the skilled technical staff needed to support ongoing operations, maintenance and related improvements as well as the remaining preliminary and final designs of LANSCE-R sub-systems, oversight of component procurement, acceptance testing, pre-installation assembly and testing, and final installation and commissioning.

The following key operational elements are essential for the integrated model to be successful:

- A commitment to schedule at least 3,000 hours of beam operation for users each fiscal year from FY2010 through FY2016 and beyond, with appropriate allocation of sole-use and beam development time.
- No more than one cold-start facility turn-on in each fiscal year.

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- An appropriate distribution of annual outages of several months duration to accommodate both a modular approach to LANSCE-R sub-system installation and other operations-funded system improvements as well as appropriate cool-down times for routine maintenance on activated equipment in areas such as the Proton Storage Ring and the 1L Target for the Lujan Center.
- Disciplined configuration management for accelerator and beam delivery systems to minimize time for return to service after short and extended outages.
- Continuous certification of the Radiation Security System to minimize the time required for resumption of production beam operation.
- No changes to the facility proper or to the Authorization Basis.

2.2 LANSCE-R Scope

The scope that is included to support the Mission Need for the LANSCE-R Project will enhance cost effectiveness by system refurbishments or improvements that reduce operating costs and will improve decreasing facility reliability by replacing systems that have a significant impact on reliability.

The LANSCE-R project will also eliminate the following sources of operational inefficiencies that should improve operational effectiveness:

- Equipment that is beyond its predicted end-of-life,
- Technologies that the modern workforce is not capable of supporting
- Obsolete equipment for which no spare parts are available.

The baseline refurbishment project consists of replacing the 201 MHz RF systems, updating about 75% of the 805 MHz RF systems, modernizing the control system, and replacing or refurbishing a variety of diagnostics and accelerator subsystems.

The project scope maintains reliability and addresses single point failures in the LANSCE facility that serves all the user community with a focus on the NNSA Defense Programs mission. It specifically requires that the current facility capability will be maintained. LANSCE-R includes scope to support mission research at 120 Hz and 625 micro-s beam gate. It specifically includes beam delivery elements common to pRad, WNR and Lujan Center that all have NNSA mission deliverables. As a result, it does not include refurbishment of equipment/systems from the end of the accelerator to WNR and the Lujan Center, including Line D and the PSR.

3. RF Systems Scope

The RF-system and power supply scope consists of refurbishing four systems:

- 201 MHz RF for the Drift Tube Linac (DTL) – All new except for High Voltage
- Low Level RF Controls – All new LLRF in the 201 MHz and 805 MHz sections
- 805 MHz Klystrons – 5.5 sectors of new old style klystrons (leaving 1.5 sectors of klystrons not replaced)
- High Voltage Power Systems – 5 sectors of refurbished high voltage systems.
- Magnet power-supply systems (refurbished as project funding allows.)

The 201-MHz RF system provides power for the accelerating gradient in the 4 DTL tanks. The scope consists of replacing a majority of the components of these four amplifier systems. However, the coaxial transmission lines, anode power supplies, capacitor banks, and several amplifier subsystems will be reused. The refurbished 201-MHz RF system (Fig. 2) will restore the historical 120-Hz high-duty-factor operation, increase reliability, reduce system complexity, improve electrical efficiency, and improve

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control of RF fields in the accelerating structures. The refurbished system will also reduce the number of gridded tubes in the 201-MHz RF power plant from 24 to 8.



Fig. 2. The existing 201 MHz 7835 triode on the left and the proposed TH628 Diacrode® on the right.

The 805-MHz RF system refurbishment scope consists of replacing 35 of the 44 klystrons in use. The 35 replaced klystrons will be kept as spares. The baseline approach replaces the 35 klystrons with new klystrons that are identical in design to the original klystrons.

The HV-system scope matches the klystron replacement option. The baseline approach refurbishes, by replacing or rebuilding the interior components, 5 of the transformer rectifiers and 5 of the inductrol voltage regulators.

All of the LLRF control systems will be replaced throughout the accelerator. The LLRF control systems maintain very precise control over the amplitude and phase of the RF field within the accelerating structure, which is required to accelerate the proton beam down the LINAC. At each of the RF stations all of the field control modules (4 buncher modules, 4 DTL modules, and 44 CCL modules) will be replaced. The master reference system, the system that synchronizes all the RF stations on the LINAC, including oscillators and transport, will be replaced. Additionally, based on obsolescence and reliability concerns, the system that controls the resonance of the DTL, including water controls, slug tuner actuators, and electronics will be replaced.

As project funding allows, based on obsolescence and reliability concerns, up to 20% of the magnet power-supply and shunt systems will be replaced.

4. Instrumentation Controls and Diagnostic Systems Scope

The overall Control and Instrumentation scope includes the following:

- Replace RICE systems (Remote Indication and Control Equipment systems)
- Replace Master Timer System.
- Replace Linac Beam Position Monitors and incorporate phase measurements
- Replace the Delta T system

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- Replace 53 Wire scanners in the linac
- Replace VAXs and VAX applications.

4.1 Controls Replacement Overview

The controls replacement scope includes the control and instrumentation functions implemented by the RICE system, satellite Digital Equipment Corporation (DEC) MicroVAX computer systems, DEC workstation computer systems, Sun Solaris Sparc-platform computers, and application software that comprise the current LANSCE control system (LCS) (Fig. 3). LCS provides control and data monitoring for most devices in the LINAC and for some of its associated experimental-area beam lines. The LCS allows the operation of the LANSCE user facility (LUF) from the Central Control Room.

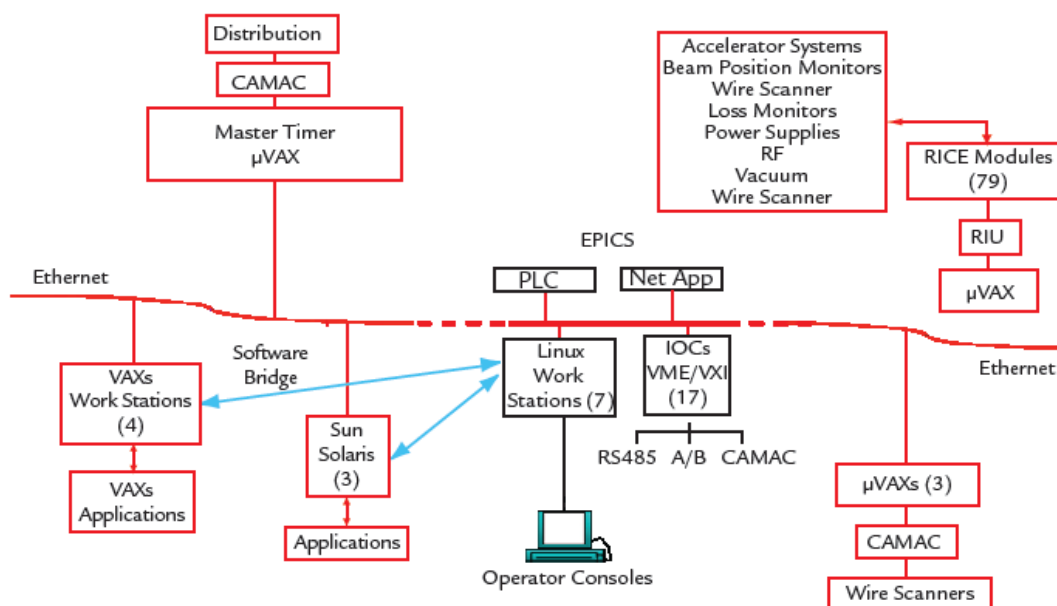


Figure 3. A block diagram of the present LANSCE Control System.

At a high level, RICE functions can be divided into industrial controls and timed data. Industrial controls consist of command and read-back of two-state devices, along with set-point generation and analog read-back of devices, such as magnet power supplies and vacuum equipment, which have little or no time correlation with accelerator operations. RICE provides no closed-loop control. The timed data will address both the time into beam pulse and beam flavor requirements, which permits data to be taken with a specific relationship to the beam-type (flavor) and timing. Typically, this function is used to read information from beam-parameter measurement devices, such as profile- and current-monitors.

Replacement of the vital RICE functions will be accomplished by installing commercial industrial-type programmable automation controllers (PAC). Network-addressable devices (NADs) will function as stand-alone instruments for measuring beam parameters. Standard bus systems will form the hardware platforms for the new EPICS system's input-output controllers (IOCs). These changes, in addition to the network and timing-system replacements described below, will be integrated with EPICS systems to complete the control system replacement.

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4.2 Timing-System Replacement Overview

The timing system provides the overall synchronization of all accelerator subsystems, including injection from the ion sources, front-end chopping, gating the RF energy into the accelerating cavities, kicking the beam to the appropriate experimental areas, and triggering beam line data acquisition, diagnostic devices, and experimental detectors. In addition to replacing obsolete and hard to maintain hardware, better timing resolution, better jitter, some new features to accommodate the refurbishments being implemented for the LLRF, diagnostics, and timed-and flavored front-end data-acquisition equipment will be realized.

4.3 Controls Infrastructure Overview

To simplify system management and training of personnel, and to ensure the availability of hardware, all the functions presently provided by VMS and Solaris computers will be moved to current or new Linux computers. The new systems and the transferred functions will be built, configured, and managed during the refurbishment project.

The current control system network connects satellite computer systems to computers in the CCR that run higher-level applications and display system status to accelerator operators. The network consists of 10 base-TX, 100 base-TX, and fiber-optic IEEE 802.4-compliant equipment; however, no network connections for maintenance and troubleshooting are available along the one kilometer length of the LINAC. The project will replace the communication paths and provide connection points for the equipment that replaces RICE.

4.4 Diagnostics - Wire Scanner Profile and Beam Phase & Position Measurements

Wire scanners are interceptive measurements whose primary purpose is to provide transverse (horizontal and vertical) projected-beam distribution measurements. The wire scanner actuators precisely move a wire or fiber through the beam and then measure the amount of secondary electrons leaving the wire or fiber as beam impinges on the wire. The RICE system controls the actuators' movement and acquires the wire scanner data. To accomplish the required synchronized movement and data acquisition, the time and flavored functions of the RICE system are employed, which leads to slow responses during tune-up periods when the accelerator repetition rate is low. The present wire scanner mechanical actuators, cables, and electronics will be replaced. Decoupling the wire scanner measurement from the control system by implementing a stand-alone NAD that reports only the resulting measurement information will improve efficiency.

Beam Phase & Position Measurements (BPPM) systems that will be provided by LANSCE-R do not intercept the beam but provide beam centroid information in all three Cartesian coordinates (that is, the transverse and longitudinal planes of the beam bunch), and provide additional relative peak or bunched beam-current information. Currently only the LINAC has a beam position measurement system deployed, which will be replaced in LANSCE-R. Facility operators and beam physicists do not use the existing system to measure and verify that the beam is properly positioned because it does not provide useful data for beam position measurements. However, the system is used to make longitudinal energy measurement referred to as Delta-T.

5. Accelerator Subsystems

Three major accelerator subsystems will be part of the LINAC refurbishment:

- 1) Accelerator Water-Cooling Systems

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- 2) Accelerator Vacuum System
- 3) Accelerator Drift Tubes.

The accelerator water-cooling system scope addresses the in-tunnel water control and distributions system, which services the drift tubes, post couplers, tank heads, and tank-to-tank beam-line diagnostics. The LINAC's water distribution system, shown in Fig. 4, is at end-of-life and can no longer control the water temperature to the required fidelity for stable 201-MHz resonance. The refurbishment effort will benefit from experience gained in designing the SNS DTL systems.



Fig. 4. Photograph of (a) the LANSCE-DTL water-cooling systems and (b) similar SNS-DTL systems.

The accelerator drift-tube scope addresses the need to manufacture 2 spare-drift-tubes necessary to complete a full complement of 12 spares. 164 uniquely-sized drift tubes have been grouped into 12 basic drift-tube sizes. One spare is fabricated to the largest size possible in that group to be machined down to replace any failed drift tube in that group. In addition to manufacturing 2 spare drift tubes, 12 full quadruple-magnet assemblies will be fabricated to facilitate the rapid manufacture of additional drift tubes, if needed. LANSCE-R will reestablish the capability to manufacture replacement drift tubes.

As project funding allows, and based on obsolescence and reliability concerns, the accelerator vacuum-system scope will address the replacement of a subset of the ion-pump power-supplies for the DTL and CCL. Three new self-contained water-chillers may be installed to eliminate long down times associated with recovery of cyro-cooled vacuum-systems, which are currently cooled by one of the main tunnel water systems. Fast valves may be added to Line X and Line D in the facility beam switchyard to protect the LINAC from errant loss of vacuum events.

6. Implementation Of A Seven-Year Plan For FY10-FY16

6.1 Operations Objectives for Project:

- Operate for approximately 3,000 hours exclusive of development, documentation, and sole use operation consistent with operations in FY2009.
- Retain key staff required to perform both operations and LANSCE-R implementation at the same time.
- Train the next generation of engineers and physicists required to replace attrition and support future operations.

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6.2 LANSCE-R Current Year – FY2010

Conduct the agreed-upon scope of work for preliminary design and place the procurements for klystrons and the network.

6.3 LANSCE-R Future Years – FY2011-16

Given the funding profile that is ultimately determined for the \$150M(US) project, we will manage the work to be accomplished in each annual outage (each an identified subproject) to achieve the highest priority items first within budget and funding profile constraints, while making progress on all sub-projects. Acquisition and installation of new klystrons remains a critical long-lead procurement along with the network.

Integration of new hardware will occur during the extended outages that occur each calendar year. These will be approximately 6 months in duration and will be integrated into the operating schedule well in advance. Installation, checkout and commissioning of the first DTL module water systems and resonance control will take place in the FY2012 outage. Installation, checkout and commissioning of the first module of upgraded 201 MHz RF systems will take place in the 2014 outage with the rest of the modules to be completed in 2015 and 2016.

Each outage will constitute a sub-project in itself that can be integrated with planned routine plant maintenance and scheduled FIRP projects. Each annual outage will include required activities with checkout and verification of interlock systems, operations manual updates, and commissioning time commensurate with extent of changes. For example, LLRF system testing requires cooling water, RF power, and control system interfaces.

Ancillary system upgrades will be planned to minimize disruption, and will begin with systems that have the least impact to gain experience and improve project estimation for more complex installations. For example, network infrastructure will be put in place and commissioned before final upgrades are made to the Master Timing system. Refurbishment of high voltage systems for the 805 MHz systems will be accomplished as one TR/IVR set per annual outage.

The three primary high-level objectives of the LANSCE-R project are to preserve reliable operations by procuring new klystrons, to convert the control system from a RICE-based system to EPICS-based, and to restore capability for 120Hz operations. The project is designed to complete these objectives by the end of 2016.

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