

TECHNOLOGY MATURATION FOR THE LANSCE ACCELERATOR MODERNIZATION PROJECT (LAMP)*

J. Lewellen[†], M. Holloway, A. Alexander, K. Bishofberger, G. Dale, D. Dimitrov, R. Garnett, H. Gaus, J. Medina, S. Swickley, R. Thornton, Los Alamos National Laboratory, Los Alamos, United States

Abstract

The LANSCE accelerator is extraordinarily flexible in its ability to simultaneously accelerate both H⁺ and H⁻ beams, and provide concurrent beam delivery to five independent user stations. LANSCE has been in operation for more than 50 years, and many of the accelerator structures, such as the Cockcroft-Walton injectors and drift-tube linac tanks, are original. To address end-of-life concerns and position the facility for extended operation into the future, the LANSCE Accelerator Modernization Project (LAMP) encompasses replacement of the upstream portions of the LANSCE accelerator, from the H⁺ and H⁻ ion sources through the end of the drift-tube linac. In order to meet beam delivery requirements with modern equivalent systems, elements of the LAMP design require technical maturation. This paper describes the Critical Technology Elements (CTEs) in the LAMP conceptual design, presents the design elements requiring additional development, and discusses the maturation plan and schedule.

INTRODUCTION

The LANSCE Accelerator Modernization Project (LAMP) [1] will modernize the upstream portion of the LANSCE accelerator, replacing aging 750-keV Cockcroft-Walton injector with modern, 65-keV H⁺ and H⁻ ion sources feeding into a single 201.25-MHz Radio Frequency Quadrupole (RFQ), and replacing the DTL [2].

LAMP's design approach maintains LANSCE's unique dual-beam capability while reducing facility footprint and operational complexity. However, this configuration incorporates design elements requiring technology maturation.

Four Critical Technology Elements (CTEs) have been identified that must achieve Technology Readiness Level (TRL) 7 prior to CD-2 approval: (1) beam choppers; (2) a dual-species RFQ structure; (3) a dual-species MEBT; and (4) dual-current gated H⁻ ion source. The technology maturation strategy employs two test facilities: the RFQ Test Stand (RFQTS) for initial component validation and the LAMP in ADEF Tunnel (LAT) for integrated system demonstration in a relevant environment.

This paper describes the technical challenges of each CTE, the maturation approach, and progress toward achieving TRL-7 for all critical technologies.

CRITICAL TECHNOLOGY ELEMENTS

The LAMP project has identified three CTEs requiring technology maturation to TRL-7 prior to CD-2 approval.

Each addresses unique technical challenges arising from the dual-species capability and modernization requirements.

CTE A: Beam Choppers

The LAMP front-end requires beam choppers at two locations: downstream of the 65-keV ion source in the Low Energy Beam Transport (LEBT) and in the 2.1-MeV MEBT section. These choppers must provide fast rise/fall times (~10 ns in LEBT, ~2-3 ns in MEBT) to generate the disparate LANSCE bunch train patterns, and to provide single high-charge microbunch delivery to the Weapons Neutron Research (WNR) facility [3].

The 65-keV LEBT chopper faces the challenge of operating in a space-charge dominated environment where beam dynamics are highly sensitive to electric field perturbations. The 2.1-MeV MEBT chopper must maintain "clean" chopping performance to minimize activation of downstream accelerator components. Both choppers must achieve >99.9% extinction efficiency to meet stringent "dark current" requirements for WNR.

CTE B: Dual-Species RFQ Structure

Operating at 201.25 MHz, the LAMP RFQ must accelerate both H⁺ and H⁻ beams in the same macropulse from 65 keV to 2.1 MeV while maintaining good beam quality and high transmission for both species.

The RFQ design must also accommodate significant differences in beam current requirements: high peak bunch charge but low average current for the H⁻ beams to WNR; modest beam current for the concurrently accelerated H⁺ beams to the Isotope Production Facility (IPF); and moderate beam current to the remaining LANSCE user facilities [4,5]. Additionally, RF power coupling and thermal management become more complex when optimizing for two distinct beam loading conditions.

CTE C: Dual-Species MEBT

The MEBT transport line between the RFQ and DTL must transport both H⁺ and H⁻ beams using a single set of steering correctors and focusing elements. This seemingly straightforward beamline presents subtle but significant challenges for dual-species operation.

Magnetic focusing and steering elements affect both species, but in opposite directions (steering correctors) or planes (quadrupoles). The LAMP MEBT includes re-buncher cavities to longitudinally match beams into the DTL; these cavities must provide appropriate RF phasing and amplitude for both species despite their different bunch charges exiting the RFQ.

* Work was performed under the auspices of the US Department of Energy by Triad National Security under contract 89233218CNA000001.

[†] jwlewellen@lanl.gov

LA-UR-26-23710

An additional complexity arises from the integration of the 2.1-MeV choppers and diagnostics within the MEBT. The choppers must not adversely affect beam quality for either species, while diagnostic instrumentation must characterize both beams independently to verify proper transport and matching conditions. Demonstration of dual-species steering algorithms, verification of minimal cross-species coupling effects, and demonstrating proper matching of all beams into the first DTL tank are critical validation objectives for this CTE.

CTE D: Fast-pulsed focusing electrostatic lenses

LANSCE requires two different H⁻ beam currents that must be interwoven for delivery to the appropriate user facility: 55 mA for the WNR facility, and 15 mA for the remaining LANSCE facilities that require H⁻ beam. This suggests using either multiple sources, which increases the technical complexity of the LEBT, or a single source that can modulate the beam current on a macropulse-to-macropulse basis.

The current LAMP design utilizes a single SNS-type H⁻ source, with macropulse current variation effected by varying the RF drive power to the ion source; this technique has been demonstrated at SNS. The different beam currents require different focusing strength from the source's electrodes to match into the H⁻ LEBT line and RFQ, requiring simultaneous pulsing of multiple electrodes to achieve the required Twiss parameters.

This approach is an extension/modification of existing technology that has not yet been demonstrated. Therefore, the pulsed focusing electrodes of a single H⁻ source poses a new technical risk to the project and therefore is considered a CTE.

MATURATION APPROACH

The LAMP technology maturation strategy employs a phased approach utilizing two dedicated test facilities to progress CTEs from their current state (assessed at TRL-5 for all CTEs) to TRL-7. This approach balances technical risk reduction with schedule efficiency by validating technologies incrementally before full-scale integration.

Overall Strategy

Technology maturation follows a three-stage progression: (1) component-level validation at TRL-5/6 using single-beam test stands or existing facilities, (2) integrated subsystem demonstration at TRL-6 using the RFQ Test Stand (RFQTS), and (3) full-scale system validation at TRL-7 via LAT. This staged approach allows early identification and mitigation of technical issues while providing multiple decision points for project management.

CTE A (choppers) follows a streamlined path, leveraging existing single-beam facilities such as the Spallation Neutron Source (SNS) Beam Test Facility for initial validation before integration into LAT for final dual-beam environment testing. CTEs B and C require the complete maturation path through both RFQTS and LAT, as their dual-species operation cannot be validated at existing single-beam

facilities. CTE D will utilize both the RFQTS and single beam facilities (such as SNS) if available but will also utilize LAT for final TRL-7 demonstration.

RFQ Test Stand (RFQTS)

The RFQTS provides an intermediate validation environment between component testing and full-scale demonstration. This facility will eventually incorporate 35-keV H⁺ and H⁻ ion sources, a short (~1 meter) 4-rod RFQ operating at 201.25 MHz, and sufficient diagnostic instrumentation to characterize beam quality for both species independently. The H⁺ source is currently operational, the RFQ has been high-power conditioned, and the H⁻ source is under construction. The post-RFQ diagnostics beamline is being designed.

RFQTS objectives include demonstration of simultaneous acceleration of both beam types with acceptable quality, and initial tests of dual-species transport and diagnostics. Beam diagnostics at RFQTS include time-resolved current measurements, emittance scanners, energy analyzers, and beam loss monitors. The short RFQ section accelerates beams to approximately 750 keV, sufficient to validate key design features while not requiring shielding.

LAMP in ADEF Tunnel (LAT)

LAT represents a full-scale, integrated demonstration of the LAMP front-end (sources through the first DTL tank) operating in an environment representative of the final LANSCE installation. This facility when completed will include the complete system: 65-keV ion sources with LEBT choppers, full-length 2.1-MeV dual-species RFQ, MEBT with choppers and rebuncher cavities, and the first DTL tank accelerating to approximately 8.6 MeV.

LAT will operate at LANSCE duty factor and macropulse formatting requirements, enabling validation of thermal management, RF power systems, and long-term operational reliability, and providing early confidence in beam quality and other key metrics.

Critical validation objectives at LAT include: demonstration of >95% transmission for both species through the complete front-end, validation of LEBT and MEBT chopper performance, demonstration of dual-species steering and matching algorithms in the MEBT, demonstration of single-source current modulation and matching, and integration of all subsystems under realistic operational conditions including simultaneous dual-species operation.

The DTL tank included in LAT enables validation of proper matching for injection for all beam species and formats, and assessment of beam quality delivered to downstream accelerator sections. Successful operation of LAT with performance meeting LANSCE requirements constitutes achievement of TRL-7 for all CTEs, as well as early operational experience at nominal LANSCE operating conditions.

MATURATION PATHWAYS

- CTE A pathway: Component testing at SNS BTF (TRL-5/6) → Integration into LAT for dual-environment validation (TRL-7). Timeline: CY27-CY30.

- CTEs B & C pathway: Physics validation at RFQTS (TRL-6) → Full-scale integrated demonstration at LAT (TRL-7). Timeline: CY27 (RFQTS), CY28-CY30 (LAT).
- CTE D pathway: Scaled testing on the 35keV RFQTS H⁻ source (TRL-6) → Testing at the SNS Beam Test Facility CY26-CY27. Full-scale integrated demonstration at LAT (TRL-7).

This approach provides multiple validation milestones enabling risk-informed decision making while maintaining schedule efficiency; independent pathways, where possible, allow for schedule optimization.

CURRENT STATUS AND PROGRESS

The LAMP technology maturation program is active, with multiple parallel efforts advancing toward the TRL-7 demonstrations planned for CY27-30.

CTE A: Beam Choppers

In-house pulser development work has initially focused on the MEBT chopper power supplies, which have demonstrated fast-switching capabilities approaching the required <3 ns rise/fall times at the ~650 V level; board stacking to achieve the required 1.5 kV is in progress.

The project is also exploring engaging with a commercial vendor to pursue parallel development efforts as a risk-reduction measure.

CTE B: Dual-Species RFQ Structure

Construction of the RFQTS is ongoing, with mechanical fabrication advancing and beam-tests ongoing with the operating H⁺ source and LEBT line. Following installation of the RFQ and H⁻ ion source, key dual-species physics phenomena including simultaneous bunching, acceleration, and transport of both beam types through a single RF structure will be demonstratable, as will initial tests of dual-species steering and focusing predictions.

CTE C: Dual-Species MEBT

The LAMP MEBT lattice is being integrated into the LAT design. A reduced capability MEBT will be designed for the RFQTS to test key aspects of dual-beam transport.

CTE D: Fast-pulsed focusing electrostatic lenses

An initial analysis of the requirements for the pulsed-electrode system for the H⁻ LEBT suggests several options for implementation; options are being evaluated.

RFQ Test Stand Status

RFQTS facility infrastructure is substantially complete, with high-voltage power supplies, vacuum systems, and utilities installed. The 35-keV H⁺ ion source is operational; the SNS-type H⁻ ion source is being fabricated. First beam through the RFQ is scheduled for Q3 CY26, with dual-species operation demonstration planned for CY27.

LAT Planning

Preliminary design of the LAT facility has commenced. Facility infrastructure requirements including RF power (up to 1 MW peak), cooling systems, and radiation shielding have been assessed and are being integrated into facility design.

Long-lead procurement items for LAT have been identified, including the RFQ, high-power RF systems, and specialized vacuum components. Procurement planning is coordinated with RFQTS results to incorporate lessons learned while maintaining LAT schedule commitments. First beam at LAT is targeted for Q3 CY27, with TRL-7 validation for all CTEs scheduled for completion by Q2 CY30.

CONCLUSION

The LAMP project addresses critical mission requirements for the NNSA while modernizing aging infrastructure with contemporary, supportable technology.

The LAMP technology maturation program has identified four CTEs requiring advancement to TRL-7 prior to CD-2 approval.

A phased maturation approach, utilizing the RFQTS and LAT, provides systematic risk reduction through incremental validation. The RFQTS enables early validation of dual-species physics design at reduced scale and duty factor, while LAT provides full-scale integrated demonstration of all CTEs under conditions representative of LANSCE operations. This approach balances technical risk mitigation with schedule efficiency, providing multiple decision points while maintaining aggressive timelines toward CD-2 readiness.

REFERENCES

- [1] J.W. Lewellen et al., *et al.*, "LANSCE Accelerator Modernization Project Conceptual Design Report," Office of Scientific and Technical Information (OSTI), Nov. 2025. doi:10.2172/3005578
- [2] T. Caldwell, "Program Requirements Document for LANSCE Modernization Project (LAMP)," U.S. Department of Energy / National Nuclear Security Administration, Washington, DC, 2023.
- [3] J.W. Lewellen *et al.*, "Performance requirements for the LANSCE Accelerator Modernization Project", in *Proc. NAPAC'25*, Sacramento, California, USA, Aug. 2025, pp. 1078-1081. doi:10.18429/JACoW-NAPAC2025-THP060
- [4] S. Mosby *et al.*, "The LANSCE experimental program: accelerator requirements," Office of Scientific and Technical Information (OSTI), Feb. 2023. doi:10.2172/1960151
- [5] S. Sosa Guitron *et al.*, "The LANSCE Accelerator Modernization Project front-end physics design and model," presented at IPAC'26, Deauville, France, May 2026, paper WEP4332, this conference.