LANSCE Modernization Project (LAMP): Overview and Update

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Talk Outline

• LANSCE Overview
  - Review of the accelerator system that provides beam to users
  - Facility configuration impacts potential upgrade paths

• Failure Modes and Motivation
  - Trends and risk analysis

• LAMP Work Scope and Impact
  - Process to date and anticipated timeline
  - Pre-conceptual proposal and progress
Accelerator facility consists of integrated sub-systems that sequentially condition and accelerate proton beams

- 750-keV proton (H+) and H- Sources and Injectors
- 201.25 MHz, 100-MeV Drift Tube Linac (DTL)
- 805 MHz, 800-MeV Side-Coupled Cavity Linac (SCCL)
- 800-MeV Proton Storage Ring (PSR)
- Beam Switchyard, Line-D (south side), Line-X (north side), Line-A (straight ahead, inactive), … beam transport lines
Bird’s eye view of LANSCE Facility

- Ultra Cold Neutron (UCN) Area
- Proton Radiography (pRad)
- Cooling Towers
- Side-coupled-cavity accelerator and equipment building (100-800 MeV)
- Isotope Production Facility
- Drift tube accelerator and equipment building (0.75-100 MeV)
- Area A (inactive)
- Lujan Center 1L Target
- WNR Target 4 Target 2
- PSR & REB
- Central Control Room
- Injector (0-0.75 MeV)

Beam propagates west to east on mesa
Beam originates in Sector J from H+ and H- ion sources

• H+ Duoplasmatron
  - Operational parameters
    ▪ 10% duty factor
    ▪ 10 mA_p (more available)
    ▪ $\epsilon_{\text{rms,n}} \approx 0.002 \, \pi \text{cm.mr}$
    ▪ Lifetime $\approx$ very robust, years

• H- Multicusp field, cesiated, surface converter
  - Operational parameters
    ▪ 10% duty factor
    ▪ 14-16 mA_p typical
    ▪ $\epsilon_{\text{rms,n}} \approx 0.02 \, \pi \text{cm.mr}$
    ▪ Lifetime $\approx$ 4 weeks
First-stage acceleration occurs in Cockcroft-Walton (CW) injectors

• Components
  – H- ion source, 80-keV LEBT & 670-kV Cockcroft-Walton (CW)
  – Proton ion source & 750-kV CW
  – Separate and combined 750-keV LEBTs

• Functions
  – Provide proper intensity beam that is correctly chopped, bunched and transversely matched beams to DTL
  – Initial acceleration, delivery, and control of beams into DTL
Beam chopper produces requisite formats for H- beams

- **Lujan(-)**
  - Macropulse: 20 Hz x 625 µs
  - Minipulse: 290 ns / 358 ns
  - Micropulse spacing: 5 ns (201 MHz)

- **WNR(-)**
  - Macropulse: 100 Hz x 625 µs
  - Minipulse: NA
  - Micropulse: every 1.8 µs

- **pRad(-)**
  - Macropulse: 1 Hz/SS x 625 µs
  - Minipulse: 10’s of 60 ns wide every ~us
  - Micropulse spacing: 5 ns

- **UCN(-)**
  - Macropulse: burst of 20 at 1 Hz x 625 µs
  - Minipulse: NA
  - Micropulse spacing: 5 ns
**Acceleration to 100-MeV via 201.25-MHz Drift Tube Linac**

- **Makeup**
  - Four separate accelerating tanks (modules 1-4): 5, 41, 72 and 100 MeV
  - Total Length = 61.7 m
  - Separate HPRF and LLRF systems for each tank/module
  - FODO lattice: EMQ’s insides DT’s for transverse focusing
  - $E_0$: 1.6-2.3 MV/m (T1), 2.4 MV/m (T2-4); $\varphi_s = -26^\circ$
  - Duty Factor: ~10%

- **Concerns**
  - Beyond expected end-of-life, exhibiting failures
100 MeV Beam Transport (Transition Region - TR)

- **Function**
  - Independently match, steer and phase $H^+$ and $H^-$ beams into CCL
  - Extraction point for 100 MeV IPF($H^+$) beam
  - Independent phasing necessary for dual species operation with frequency jump from 201 to 805 MHz
Acceleration to 800 MeV via Coupled Cavity Linac (CCL)

- Design
  - Side coupled structure developed at LANL
  - 44 Modules (5 to 48) – \( L_{\text{tot}} \): 727 m
    - M5-12: 4 tanks per module
    - M13-48: 2 tanks per module
  - 100 – 800 MeV
  - Frequency: 805 MHz
  - \( E_{\text{0T}} \): \( \sim 1.4 – 1.2 \text{ MV/m, 10\% Duty Factor} \)
  - Design phase: -36° to -30°
  - FDO Quad lattice
    - M5-12 FDO, 4 doublets per module
      (gradient profile: ramped)
    - M13-48: FDO, 2 doublets per module
      (gradient profile: constant)
LANSCE Linac Delivers Beam to Five Experimental Facilities

Accelerator pulses of 625 μs come at a nominal rate 120 per second

IPF (100 Hz) and WNR (100 Hz) or pRad/UCN pulses
Lujan pulses (20 Hz)

H+ Beam
H- Beam
Proton Storage Ring (PSR)

• Design & Operational parameters
  - Layout:
    - **FODO** lattice – 10 cell
    - Circumference: 90.23 m
    - Rev freq/period: 2.795 MHz / 357.8 ns
    - Direct H- injection, 400 µg/cm² C/B foil
    - **Buncher cavity** (2.8 MHz, 0-18 kV)
    - Inductive inserts (s.c. compensation)
    - Stripline extraction kickers
  - Input beam: 799 MeV; macropulse width: 625µs pulse; minipulse width: 290 ns, 70 ns extraction gap
  - Output beam: 799 MeV; 150 ns FWHM
  - Beam current/charge:
    - 100 uA average @ 20 Hz, 5 µC/pulse, \(6.2 \times 10^{12}\) ppp
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• LAMP Work Scope and Impact
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The LANSCE Modernization Project (LAMP) is a critical upgrade required to ensure LANSCE readiness and reliability.

The timeline for LAMP is driven by four factors:

- Data from LANSCE will be required to support assessment and certification at least through 2050.
- We have already started to experience end-of-life failures that have reduced beam availability.
- We have developed a high-TRL pre-conceptual upgrade design which would take ~7 years to complete. It would replace everything from the ion sources through the drift-tube linacs.
- We are investigating alternatives involving multiple projects, potentially with a raised GPP limit, to allow more options for completion of this work.
LANSCE beam availability significantly lags behind its peers.

Beam reliability only 60-85%; LAMP (plus other investments) will bring this to 90% or better.

Long maintenance period determined by work required and obsolete designs.

Startup ~6 weeks; other accelerators ≤ 2 weeks.

Low availability is particularly problematic in light of LANSCE’s chronic oversubscription.
**Rationale for front end upgrade comes from its risk analysis and commonality to all present and future beam availability**

<table>
<thead>
<tr>
<th><strong>Cockcroft-Walton (C-W) injector System</strong></th>
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<tr>
<td>H+ CW Accelerator</td>
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<td>49</td>
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<tr>
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<td>LAMP Project</td>
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<tr>
<td>LEBT Lines</td>
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<table>
<thead>
<tr>
<th><strong>201.25 MHz Drift Tube Linac System</strong></th>
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<tr>
<td>Accelerator Tanks</td>
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<td>Drift tubes</td>
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<td>RF Power system</td>
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<td>Continuous</td>
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<tr>
<td>Diagnostics</td>
<td>10s</td>
<td>Marginal</td>
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<td>Moderate</td>
<td>Replace/repair as needed</td>
</tr>
<tr>
<td>Magnets</td>
<td>10s</td>
<td>Significant</td>
<td>49</td>
<td>Moderate</td>
<td>Refurbishment in progress</td>
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<td>49</td>
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<tr>
<td>Diagnostics</td>
<td>10s</td>
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<tr>
<td>Vacuum system</td>
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<table>
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<tr>
<th><strong>Proton Storage Ring</strong></th>
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<tr>
<td>RF Power systems</td>
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<td>Significant</td>
<td>30</td>
<td>Moderate</td>
<td>None</td>
</tr>
<tr>
<td>Diagnostics</td>
<td>10s</td>
<td>Marginal</td>
<td>30</td>
<td>Moderate</td>
<td>Replace/repair as needed</td>
</tr>
<tr>
<td>Pulsed Magnets</td>
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<tr>
<td>Stripper foil system</td>
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<td>Replace/repair as needed</td>
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<table>
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<td>12</td>
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<td>Replace every ~10 years</td>
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<tr>
<td>Target 4</td>
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<td>Significant</td>
<td>1</td>
<td>Low</td>
<td>Replace target every year</td>
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<table>
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<th><strong>Control System</strong></th>
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<td>Refurbishment in progress</td>
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<tr>
<td>Timing system</td>
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<td>Critical</td>
<td>40</td>
<td>Moderate</td>
<td>Refurbishment in progress</td>
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<th><strong>Protective Systems</strong></th>
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<td>Radiation Security System (RS)</td>
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<td>Significant</td>
<td>25</td>
<td>Low</td>
<td>Replace/repair as needed</td>
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<tr>
<td>Machine Line-up System (RP)</td>
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<td>Significant</td>
<td>15</td>
<td>Low</td>
<td>Replace/repair as needed</td>
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<tr>
<td>Machine protection system (FP)</td>
<td>1</td>
<td>Significant</td>
<td>4</td>
<td>Low</td>
<td>Replace/repair as needed</td>
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<thead>
<tr>
<th><strong>Facility Interface</strong></th>
<th></th>
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<tbody>
<tr>
<td>Power distribution</td>
<td>1</td>
<td>Critical</td>
<td>49</td>
<td>Moderate</td>
<td>Replace/repair as needed</td>
</tr>
<tr>
<td>Water systems</td>
<td>10s</td>
<td>Significant</td>
<td>49</td>
<td>Moderate</td>
<td>Replace/repair as needed</td>
</tr>
</tbody>
</table>
The LAMP project will modernize obsolete equipment at the front end of the accelerator

- Upgrade of sources to end of Drift Tube Linac (DTL) at 100 MeV
  - Utilizes latest advances in accelerator design (e.g., not just like-for-like replacement of components)
- System integration and testing to 20 MeV (sources to end of first DTL)
- System integration and testing up to 100 MeV (sources to end of last DTL)
- Development of controls and new operating procedures
- Operator training on new systems before deployment in LANSCE tunnel
Thanks to FY21 investment, preconceptual efforts in Mod/Sim show LANL RFQ with simultaneous p & H⁻ beams

Two beams near RFQ exit: all particles (left), p or H⁻ only (right)

$t = 404$ ns; 190,285 particles total

Snapshot at $t = 404$ ns; color shows energy

The use of the same RFQ for accelerating multiple beams (with different species and different current densities), though is novel approach, but looks practical, and allows us both, increase the availability of the whole system (due to simplification, and reduction of number of =the required components), and simplify maintenance, required for supporting of those system.
The upgrade concept will minimize impacts to existing user facilities and off-line testing (possibly in LEDA tunnel) will minimize future outages.

The scale of this upgrade will likely cause an interruption of one operational cycle, depending on the project planning and other constraints.

Front End of LANSCE

<table>
<thead>
<tr>
<th>Facility</th>
<th>Species</th>
<th>Pulses / sec</th>
<th>Pulse length (µs)</th>
<th>Chopper fraction</th>
<th>Current /µbunch</th>
<th>Current, 10-sec (mA)</th>
<th>Power, 10-sec (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lujan/PSR</td>
<td>H⁺</td>
<td>20</td>
<td>625</td>
<td>0.8</td>
<td>10</td>
<td>8</td>
<td>100</td>
</tr>
<tr>
<td>IPF</td>
<td>H⁺</td>
<td>100</td>
<td>625</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>250</td>
</tr>
<tr>
<td>WNR</td>
<td>H⁺</td>
<td>100</td>
<td>625</td>
<td>2.8×10⁻³</td>
<td>25(³)</td>
<td>0.07</td>
<td>4.5</td>
</tr>
<tr>
<td>pHad</td>
<td>H⁺</td>
<td>On demand</td>
<td>&lt;625</td>
<td>-</td>
<td>10</td>
<td>~1(⁴)</td>
<td>&lt;1</td>
</tr>
<tr>
<td>UCN</td>
<td>H⁻</td>
<td>10, at 0.2 Hz</td>
<td>625</td>
<td>0.8</td>
<td>10</td>
<td>8</td>
<td>10</td>
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</table>
A notional schedule is being prepared that reflects our initial assumptions factoring in possible funding constraints at a cost range of $200-$500M.
Summary: Next Steps

- LANL to submit LAMP Proposal for consideration by NNSA.
  - Need to agree on planning assumptions that will underpin the project planning and document submittals
  - Need to understand the process and timeline for key HQ briefings / decisions prior to a CD-0 ESAAB and finalizing documents
  - *Note of thanks to contributing members (past and present) to the modeling and simulation efforts*
- Received $2M investment in FY21 and would like to maintain momentum to enable more robust pre-conceptual project planning (modeling / simulation of beam physics, experimental workshops, and CD-0 project documentation)
- ALDPS prepared to formally establish LAMP Project (within ASO) to secure a funding profile beginning in FY23.

To ensure that we can meet the need for LANSCE for decades to come, we need to invest in the facility and its experiments