Long-baseline Neutrino Facility (LBNF) and Deep Underground Neutrino Experiment (DUNE) Update

Chris Mossey, LBNF/DUNE-US Project Director
Fermilab Community Advisory Board
26 Jan 2023

LBNF Project partners:
US/DOE
Brazil/FAPESP-UNICAMP
CERN
India/DAE
Poland/WUST
Switzerland/SERI, and
UK/UKRI-STFC

plus the DUNE international Collaboration and consortia
What are Neutrinos?

• Ever present
  - One of Mother Nature’s handful of fundamental matter particles
  - More neutrinos in the Universe than any other matter particle
  - ~65 billion pass through every cm$^2$ every second

• Mysterious and surprising
  - Almost massless
  - Almost always pass straight through matter without interacting

• Important
  - Pivotal role in the evolution of the Universe
  - May hold the key to why there is so little anti-matter (i.e. why the matter that makes up stars, planets, and everything else in the universe, including us, exists)

• Experimentally Challenging
  - Need different approach than CERN’s circular Large Hadron Collider
  - Observable interactions very rare
    • Need very powerful beams (many, many neutrinos)
    • Need very large detectors
LBNF will support DUNE Science Objectives:

Neutrinos – the most ubiquitous matter particle in the universe, yet the least understood → Opportunities for game changing physics discoveries:

• **Origin of matter**
  Discover what happened after the big bang: Are neutrinos the reason the universe is made of matter?

• **Neutron Star and Black hole formation**
  Use neutrinos to look into the cosmos and watch the formation of neutron stars and black holes in real time

• **Unification of forces**
  Move closer to realizing Einstein’s dream of a unified theory of matter and energy by looking for proton decay

LBNF will drive neutrino discovery science forward the way CERN’s Large Hadron Collider drove the Nobel Prize-winning Higgs discovery
LBNF: From Illinois to a mile underground in South Dakota

Illinois:
- World’s most powerful and advanced neutrino beamline
- DUNE “near” detector

South Dakota:
- Surface and underground facilities
- Cryostats - Massive membrane cryostats to hold liquid argon
- Cryogenic systems
- DUNE “far” detectors – up to four liquid argon detector modules
Project Scope - Delivered at Two Sites through Five Subprojects

Far Site – SURF in Lead, SD
Facility/Infrastructure and Far Detectors

- FSCF-EXC – Far Site Excavation
- FSCF-BSI – Far Site Building & Site Infrastructure
- FDC – Far Detectors and Cryogenic Infrastructure

Near Site – FNAL in Batavia, IL
Facility/Infrastructure, Neutrino Beamline, and Near Detectors

- NSCF+B – Near Site Conventional Facilities + Beamline
- ND – Near Detectors
The “Far Site” in Lead, South Dakota – Former Homestake Gold Mine
Far Site Underground Facilities

- Generator Room
- 1,200’ Raise Bore Vent Shaft
- Spray Chamber
- Expanded Drift
- Maintenance Shop
- Ross Brow
- #6 Winze Dump
- Concrete Supply Chamber

- North Detector Cavern
- Central Utility Cavern
- South Detector Cavern

**2 x Detector Caverns:**
- 475’L x 65’W x 92’H
- 145m L x 20m x 28m

**1 x Central Utility Cavern (CUC):**
- 624’L x 64’W x 37’H
- 180m L x 20m W x 11m H

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LBNF/DUNE Update to FNAL CAB
Excavation Progress –Reached 50% on 9 January 2023

At 51.5% as of 16 Jan
Main Excavation Focus now on “Benching” down in each cavern

North Cavern

CUC Cavern

South Cavern

At 51.5% of in-situ rock volume removed as of 16 Jan 2023
## Benching in North Cavern

<table>
<thead>
<tr>
<th>Cut 3 100%</th>
<th>Cut 1 100%</th>
<th>Cut 2 100%</th>
</tr>
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<tbody>
<tr>
<td>C1 48%</td>
<td>C2 48%</td>
<td>C4 48%</td>
</tr>
<tr>
<td>D1</td>
<td>D2</td>
<td>D4</td>
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<tr>
<td>E1</td>
<td>E2</td>
<td>E4</td>
</tr>
<tr>
<td>F1</td>
<td>F2</td>
<td>F4</td>
</tr>
<tr>
<td>G1</td>
<td>G2</td>
<td>G4</td>
</tr>
</tbody>
</table>

North Cavern
North Detector Cavern – West End

Drilling holes for blast charges for bench C (left) and removing muck (right) in North Detector Cavern (4850-33)
Central Utility Cavern

Drilling holes for blast charges in Central Utility Cavern (4850-36)

Installing CT Rock Bolts in Central Utility Cavern (4850-36)
Extending monorails that will support material handling cranes in South Detector Cavern (4850-37)
Photos taken in Spray Chamber (facility to reject heat from cryogenics systems and transfer up the raise bore)
DUNE Far Detectors Status

- 1st far detector module to be based on Anode Plane Assembly (APA) technology with horizontal drift
- 2nd far detector module to be based on Charge Readout Plane (CRP) technology with vertical drift
- CERN Neutrino Platform has operated two 8m x 8m x 8m prototypes to mature and prove technology
  - Both detectors have performed extremely well and in excess of specification/requirement
- Approximately 50% of each detector is being provided by DUNE international partners

APAs for Module 0 ProtoDUNE being tested at Daresbury Laboratory, UK. One 2.3m x 6.3m APA is shown; UK to provide 130 APAs.

NP-02 and NP-04 ProtoDUNE 8m x 8m x 8m detector prototypes at CERN.

NP-02 ProtoDUNE 8m x 8m x 8m cryostat at CERN has demonstrated 300 kV across field cage for CRP detector technology
Far Site – Logistics Planning for Far Detectors

• Anode Plane Assembly (APA) test lift successfully completed at SURF between in early November – proves the largest detector components can be successfully moved to 4850L.
  - Test included handling and lowering of the APA shipping container (holding 2 APAs) to the 4850L.
  - “Slung load” movement in the shaft was smooth and stable. Traveled at 100 ft/min to the 4850 level, which takes ~45 minutes.
  - The APAs are now at Fermilab for wire fidelity and tension testing – critical validation test.
  - Lessons learned include some minor redesign to shipping frame and better sealing against moisture in the shaft.

26 Jan 2023

One 2.3m x 6.3m APA is shown
Signature Ceremony - Agreement for CERN to Provide Second Cryostat

Ceremony at CERN on 16 September 2022; Agreement signed by Fabiola Gianotti (CERN DG) and Dr. Asmeret Berhe (DOE Director of Office of Science)
Photo by Jacques Fichet, CERN
FDC - Cryostat Fabrication Progress

Thank you to CERN Neutrino Platform!
Near Site Conventional Facilities + Beamline Subproject (NSCFB)

- Beamline design is at >69% final design status and on track.
- Conventional facilities design remains at 100% final design status. Preparing construction documents.
- Schedule for this subproject is funding limited, plan contract awards in 2025.

Note: ND Hall facilities is part of NSCF+B Subproject
DUNE Near Detector

• The Near Detector is a critical element to make neutrino measurements in DUNE

fully instrumented 20% scale ND-LAr prototype has been successfully operated at LHEP/University of Bern
### LBNF/DUNE-US Safety Performance through December 2022

<table>
<thead>
<tr>
<th>Organization</th>
<th>Labor hours</th>
<th>DART Cases</th>
<th>DART Rate</th>
<th>TRC Cases</th>
<th>TRC Rate</th>
<th>ORPS Cases</th>
<th>DART Cases</th>
<th>DART Rate $^1$</th>
<th>TRC Cases</th>
<th>TRC Rate $^2$</th>
<th>ORPS Cases</th>
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<td>1,439,535</td>
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<td>0.4</td>
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<td>TMI</td>
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<td>0.6</td>
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<td>1</td>
<td>7.5</td>
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<td><strong>8</strong></td>
<td><strong>0.5</strong></td>
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Comparison with:

<table>
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<tr>
<th>Industry</th>
<th>DART Rate $^1$</th>
<th>TRC Rate $^2$</th>
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<tbody>
<tr>
<td>Heavy and Civil Engrg Construction (237)</td>
<td>1.5</td>
<td>2.4</td>
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<td>Metal Ore Mining (2122)</td>
<td>1.4</td>
<td>1.9</td>
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</table>


$^1$DART = Days Away, Restricted, or Transferred

$^2$TRC = Total Case Rate

Numbers represent rates; lower rate of occurrence is better

- LBNF/DUNE subcontractors continuing strong overall safety performance
Thank you. Questions?

Videos:
- PIP-II/LBNF/DUNE
- Science of DUNE
- Far Detectors
Summary Schedule with Critical Paths through Start of Science (FD1) and Beam-on

Notes:
- Fiscal Year display
- Sep 2022 reporting cycle
- Based on “CD-1RR ESAAB” funding profile
Summary
Schedule with Subproject Links

Notes:
- Fiscal Year display
- Sep 2022 reporting cycle
- Based on “CD-1RR ESAAB” funding profile
Summary Schedule with Critical Paths through the Far Site

Notes:
- Fiscal Year display
- Sep 2022 reporting cycle
- Based on "CD-1RR ESAAB" profile

Legend:
- **Red**: Critical Path
- **Blue**: Subproject Links
- **Purple**: Critical Path and Subproject Links
## Capabilities Planned in Phases

**Phase I:** (what the project will deliver)
- Accomplished with PIP-II, LBNF/DUNE-US, and DUNE International Partners
- Meets P5 minimum requirements to proceed by 2035 timeframe
- Same project scope as proposed at CD-1R in July 2015

**Phase II** (future, not part of project)
- Increased mass at Far Detector
- More Capable Near Detector (MCND)
- Increased beam power by Booster replacement

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### Capability Description

<table>
<thead>
<tr>
<th>Capability Description</th>
<th>Phase I</th>
<th>Phase II</th>
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<tbody>
<tr>
<td><strong>Beamline</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.2MW (includes 2.4MW infrastructure)</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>2.4MW</td>
<td></td>
<td>X(^1)</td>
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<tr>
<td><strong>Far Detectors</strong></td>
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<td></td>
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<tr>
<td>FD1 – 17 kton</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>FD2 – 17 kton</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>FD3</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>FD4</td>
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<td>X</td>
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<td><strong>Near Detectors(^2)</strong></td>
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<tr>
<td>ND LAr</td>
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<td>X</td>
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<tr>
<td>TMS</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>SAND</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>MCND (ND GAr)</td>
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<td>X</td>
</tr>
</tbody>
</table>

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**Note 1:** requires upgrades to LBNF neutrino target and upgrades to Fermilab accelerator complex. The LBNF facility is built to support 2.4MW in Phase I.

**Note 2:** Near Detector Subproject threshold scope provides “day 1” requirements to start the DUNE experiment.