

**Office of High Energy Physics  
Office of Science**

**Critical Decision 3a (CD-3a)  
Approve Initial Far Site Construction for the  
Long-Baseline Neutrino Facility/Deep Underground Neutrino Experiment  
at  
Fermi National Accelerator Laboratory and  
Sanford Underground Research Facility**

**A. Purpose**

The purpose of this paper is to document the review by the Office of Science Energy Systems Acquisition Advisory Board-equivalent for Critical Decision 3a (CD-3a) “Approve Initial Far Site Construction” for the Long-Baseline Neutrino Facility/Deep Underground Neutrino Experiment (LBNF/DUNE) Project at the Fermi National Accelerator Laboratory (Fermilab) and Sanford Underground Research Facility (SURF).

**B. Project & Scope Description**

The U.S. Department of Energy (DOE) Office of High Energy Physics (HEP) mission is to understand how our universe works at its most fundamental level. HEP supports elementary particle physics research, which explores the fundamental constituents of matter and energy, revealing the profound connections underlying everything we see, including the smallest and the largest structures in the universe. Neutrinos are elementary particles that may hold the key to explaining the existence of matter in the universe and could unveil new, exotic physical processes currently beyond reach. On January 8, 2010, the Department of Energy Deputy Secretary approved CD-0, Mission Need, for a new long-baseline neutrino experiment that would enable a world-class program in neutrino science. A facility to carry out this science requires a specialized detector of very large size with sensitivity surpassing that of current experiments, and located 1000-1500 km from a neutrino beam source.

The purpose of the LBNF/DUNE Project is the construction of facilities at two separate geographical locations, Fermilab in Batavia, IL and SURF in Lead, SD, in order to achieve the physics goals established in the mission need and supported by recommendations of the Particle Physics Project Prioritization Panel (P5).

P5 recommended that a new international collaboration be formed to design and execute a highly capable Long-Baseline Neutrino Facility (LBNF) hosted by the U.S, to meet minimum specified requirements in beam power, detector mass and exposure. These requirements are intended to achieve desired sensitivity to Charge-Parity (CP) violation through study of neutrino oscillations, along with capability to study supernova burst neutrinos and proton decay. A large detector located underground and shielded from cosmic backgrounds can provide the required sensitivity and capability. The international Deep Underground Neutrino Experiment (DUNE) brings together a global neutrino collaboration to pursue an accelerator based long-baseline neutrino experiment, as well as neutrino astrophysics and nucleon decay. DUNE proposes to build a large

liquid-argon neutrino detector located deep underground at SURF (called the “far site”) and a high-resolution near neutrino detector located at Fermilab (called the “near site”).

LBNF/DUNE is the project developed to support this program, with CD-1 approval achieved on November 5, 2015, establishing a cost range of \$1.3 billion to \$1.9 billion and a Total project Cost (TPC) estimate of \$1.5 billion. LBNF is the part of the project building the facilities needed for the DUNE experiment, and includes facility contributions from international partners. The DUNE detectors and experiment will be built by the international DUNE collaboration, to include a detector contribution from DOE.

In particular the LBNF project scope at SURF, the far site, includes conventional construction, which is all DOE funded, as well as cryogenic infrastructure, which includes both DOE and non-DOE partner contributions. The LBNF far site conventional construction includes underground excavation, surface building, utilities and site infrastructure above and below ground. The LBNF far site conventional construction provides the space and infrastructure needed for subsequent underground installation of LBNF cryostat and cryogenic systems, and then DUNE far detector installation within the LBNF cryostats. The LBNF/DUNE design configuration includes four excavated underground chambers (at the 4850’ level underground), each to house an individual cryostat that will contain a 10 kiloton mass DUNE far detector module, for up to 40 kiloton detector capacity.

The LBNF/DUNE critical path at the far site is defined by underground excavation, then cryostat construction, then DUNE detector installation followed by liquid argon filling and detector commissioning. Along this critical path is the installation and readiness of the first cryostat to support installation of the first 10 kiloton DUNE detector module, which the international community plans to start in 2022 to meet early science goals. To ready the first cryostat to start detector installation in 2022 requires initiating LBNF conventional construction five years before that, to provide the needed facility space and infrastructure for the cryostat and detector. The requested CD-3a approval would authorize initial far site conventional construction to start, prior to the planned CD-2 date to baseline the overall LBNF/DUNE Project in 2020.

### **C. Definition of CD-3a**

During the CD-1 phase, the project identified long lead approvals for critical far and near site activities prior to CD-2, to reduce cost and schedule risk and ensure optimum use of resources while awaiting CD-2 and CD-3 authority. CD-3a, Approve Initial Far Site Construction, authorizes initiation of critical path far site conventional facilities construction. Completing this long lead work enables installation of the first two DUNE 10 kiloton detector modules to start by 2022, to meet the needs of the global neutrino community. This action reduces project cost due to extended management and escalation and advances completion of the overall project and availability of the DUNE detector for science. In addition, it is expected that start of the underground cavern excavation will spur significant additional international involvement and investment in LBNF/DUNE.

The CD-3a scope covers the initial far site conventional facilities construction required, prior to baselining the full LBNF/DUNE Project, to support installation of cryostats and cryogenic systems needed to start DUNE detector installation. This includes portions of the total

conventional facilities to be constructed on the surface, in the shafts, and underground, i.e. that which is necessary and sufficient to enable installation of cryostats, cryogenic infrastructure, support systems and detector for the first 20 kilotons needed for early science. The CD-3a scope includes construction management, pre-excavation, cavern and drift excavation (for two detector chambers and a central utility cavern for cryogenic systems), and supporting buildings and site infrastructure. Table 1 shows a scope and cost breakdown of the CD-3a request. The cost is \$308 million including 33% contingency.

**Table 1  
CD-3a Scope and Cost**

<b>WBS</b>	<b>Cost (\$M)</b>
2.4.1 Far Site Conventional Facilities Construction Management	28
2.4.2 Pre-Excavation	45
2.4.3 Cavern & Drift excavation	109
2.4.4 Building & Site Infrastructure	49
	Base Cost 231
	Contingency 77
<b>Total</b>	<b>308</b>

The far site conventional facilities design is well matched to the requirements of the DUNE detector and technical support facilities (cryogenics, utilities, ventilation, safety and other). The interface definitions between conventional facilities, the cryogenics/cryostat and the detector are well defined and managed. The logistics to support underground construction and installation are sufficiently developed and will be managed in a credible way. A thorough project-wide risk assessment has been completed, and risks are mitigated, tracked, updated and managed effectively, with adequate contingency available.

A DOE Independent Project Review (IPR) was conducted December 2-4, 2015 to assess readiness for approval of CD-3a. IPR recommendations have been addressed, and the committee supported LBNF/DUNE proceeding to CD-3a. The Office of Project Management Oversight and Assessments (PM) conducted an Independent Cost Estimate (ICE) of CD-3a scope in December 2015. The ICE team concluded that the project team produced a comprehensive, reasonable and credible cost estimate, that used appropriate estimating methodologies and was fully supported and properly documented. PM concluded that their review supports the CD-3a approval request. A DOE IPR status review was conducted August 11-12, 2016 which confirmed readiness for CD-3a approval.

**D. Preliminary Cost and Schedule**

The CD-1 cost range for the LBNF/DUNE Project DOE contributions is \$1.3 billion to \$1.9 billion, with a Total Project Cost (TPC) estimate of \$1.5 billion. The proposed funding profile for this project is shown in Table 1.

**Table 2- Proposed DOE Funding Profile for the LBNF/DUNE Project (\$M)**

Fiscal Year	Prior Yrs	FY 16	FY 17	FY 18	FY 19	FY 20	FY 21	FY 22	FY 23	FY 24	FY 25	FY 26	Total
OPC	85							2			3	3	93
TEC	36	26	45	95	145.1	170	183	202	200	180	147	13.9	1443
<b>LBNF/DUNE TOTAL</b>	<b>121</b>	<b>26</b>	<b>45</b>	<b>95</b>	<b>145.1</b>	<b>170</b>	<b>183</b>	<b>204</b>	<b>200</b>	<b>180</b>	<b>150</b>	<b>16.9</b>	<b>1536</b>

The preliminary schedule is shown in Table 3. CD dates shown are the early completion dates, and the final DOE completion dates, which have twelve months of float. Relative to the early Project Completion date, the DOE CD-4 milestone has 40 months of float (or 31% of remaining duration).

**Table 3  
Preliminary Schedule**

Critical Decision Milestone	Early Schedule	DOE Completion (with float)
CD-0 , Approve Mission Need	1/8/2010 (Actual)	
CD-1, Approve Alternative Selection and Cost Range	12/10/2012 (Actual)	
CD-1, Approve Alternative Selection and Cost Range (Update)	11/5/15 (Actual)	
CD-3a <sup>(1)</sup> , Approve Initial Far Site Construction	2 <sup>nd</sup> Quarter, FY2016	2 <sup>nd</sup> Quarter, FY2017
CD-2 , Approve Performance Baseline	1 <sup>st</sup> Quarter, FY2020	1 <sup>st</sup> Quarter, FY2021
CD-3b <sup>(2)</sup> , Approve Start of Construction, Far Site	1 <sup>st</sup> Quarter, FY2020	1 <sup>st</sup> Quarter, FY2021
CD-3 <sup>(3)</sup> , Approve Start of Construction, Near Site	1 <sup>st</sup> Quarter, FY2021	1 <sup>st</sup> Quarter, FY2022
CD-4, Approve Project Completion	3rd Quarter FY2027	4 <sup>th</sup> Quarter FY2030

<sup>(1)</sup>CD-3a is for the critical path LBNF Far Site Conventional Facilities to mitigate risks and minimize delay in providing a facility ready to accept detectors for installation.

<sup>(2)</sup> CD-2/3b is to baseline LBNF/DUNE and construction approval for balance of LBNF far site conventional facilities, cryogenics and detectors

<sup>(3)</sup>CD-3 is to approve start of construction of near site conventional facilities and beamline

## **E. Acquisition Strategy**

Acquisition of the LBNF/DUNE will be conducted through Fermi Research Alliance (FRA), the Fermilab M&O contractor, which will have the ultimate responsibility to successfully execute the LBNF/DUNE project for DOE. Fermilab is the site of the only existing neutrino beam facility in the U.S. and has extensive experience managing complex construction, fabrication and installation projects involving multiple national and international partners at on-site and off-site locations.

FRA/Fermilab, in coordination with DOE-HEP and the DUNE collaboration has established a set of structures to provide coordination among participating funding agencies, oversight of LBNF/DUNE project, and coordination between LBNF and DUNE parts of the project. DOE is adopting the successful model for international cooperation that was used by CERN to construct the Large Hadron Collider (LHC), i.e. a host lab to construct a facility, with international contributions, and detector construction managed by an international collaboration with contributions from many institutions. DOE will cooperate and coordinate with interested international and domestic partners to plan and execute the overall LBNF/DUNE project. International contributions to the design and construction of LBNF/DUNE will be defined in the context of agreements between the U.S. and other participating countries. Mechanisms are in place to facilitate joint consultation between the partner funding agencies, such that coordinated oversight and actions will be taken to ensure the success of the overall program. These mechanisms include an International Neutrino Council, and Resources Review Boards with representatives of funding agencies that meet regularly to facilitate global coordination and monitoring across the entire LBNF/DUNE enterprise, analogous to the mechanisms used by CERN for the LHC.

DOE will be responsible for providing LBNF scope (e.g. conventional facilities, cryogenic support systems and beamline), and for incorporating in-kind technical or material contributions from CERN and other international partners. For DUNE, DOE will be providing in-kind contributions for detector systems, as agreed upon with the international DUNE collaboration. At the far site, all project work will be planned and coordinated with the South Dakota Science & Technology Authority (SDSTA), owner and operator of SURF and partner on the LBNF/DUNE Project.

An Acquisition Plan and a Request for Proposals (RFP) for LBNF Construction Manager/General Contractor (CM/GC) for Far Site Facilities outline the acquisition approach for LBNF Far Site construction, and have been approved by the DOE Office of Science Head Contracting Authority. This Acquisition Plan and RFP cover the procurement action needed to complete the CD-3a scope, with the RFP currently in the solicitation and proposal response phase. DOE has entered into a lease for land and space at SURF to support the DOE-funded construction by Fermilab of LBNF facilities to house and support the DUNE detector. Fermilab will execute the LBNF far site construction utilizing CM/GC services. This strategy is chosen to provide reduced risks, increased quality and safety performance; provide a more collaborative approach to construction, and offer the opportunity for reduced cost and shortened construction schedules. FRA/Fermilab will establish a performance measurement baseline for the CD-3a scope, and will implement earned value management of this scope following FRA's certified EVMS to monitor and help manage work progress and performance. EVMS information will be reported into PARS-II as required and agreed upon between OPA, PM and the Project.

## **F. Environment Safety & Health**

An Integrated Safety Management Program is in place for LBNF/DUNE Project to provide consistent ES&H program guidance and implementation for work activities at FNAL and SURF sites. A Preliminary Hazards Analysis Report (PHAR) has been developed and updated for LBNF/DUNE to support CD-3a, to ensure hazards are identified and mitigations integrated into the design. A Construction ES&H Plan has been developed and approved for CD-3a to cover

LBNF far site conventional construction at SURF. This plan identifies responsibilities, requirements and hazard identification and control processes that will be implemented by Fermilab and contractors for construction work at SURF, which are in accordance with DOE and Fermilab ES&H policies and requirements. The PHAR and Construction ES&H Plan serve as the basis for planning and providing the physical and administrative controls to protect the health and safety of workers, contractors and the environment. All NEPA requirements have been met. An Environmental Assessment (EA) was developed to cover all LBNF/DUNE activities at the near and far sites and the EA has been approved, with a Finding of No Significant Impact issued.

A sustainability strategy for LBNF/DUNE is in place based on DOE's Strategic Sustainability Performance Plan, that includes the requirement for new construction to meet the federal Guiding Principles (GP) for Federal Leadership in High Performance and Sustainable Buildings. A wide range of sustainable strategies and objectives are incorporated throughout the design and construction process, while meeting the requirements of an advanced technology and experimental research facility and creating a workplace that is environmentally friendly, energy-efficient, and both healthy and functional to be in.

A Preliminary Security Vulnerability Assessment has been completed and no unique safeguard and security issues are presented. For LBNF/DUNE Project work at SURF, appropriate site access and safeguards and security considerations will be included in contracts or leases as appropriate. During project execution, these security requirements and procedures will be followed by all project contractors accessing the site. Security considerations will continue to be evaluated and documented as the project moves forward.

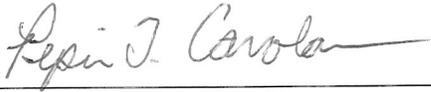
## **G. Risk Management**

LBNF/DUNE Project follows a detailed risk management process in accordance with the Fermilab Risk Management Procedure for Projects (RMPP). The RMPP defines the process used to identify and manage project related risks throughout the project's life cycle and ensure minimal impact on the project's cost and schedule. Project risk is mitigated through a structured and integrated process for identifying, evaluating, tracking, abating and managing risks in terms of three risk categories: cost, schedule and technical performance. A Project-managed Risk Register is developed and maintained, to include the risks that represent significant threat or opportunity, and to which cost and/or schedule contingency is assigned for DOE-funded LBNF/DUNE project work .

The RMPP establishes the guidelines for risk management and analysis, defining and describing the Risk Registry, describing roles and responsibilities of project personnel in performing risk management functions, and defining the reporting and tracking requirements for risk related information and Risk Registry updates. The Risk Register captures and monitors the status of risks associated with each WBS. Monthly reports that determine the status of current risks, near term risks, and risks that can be retired are generated and distributed at Risk Management Board meetings for statusing and action. When the status of risks is determined, the Risk Register is updated and maintained current.

**Critical Decision 3a, Approve Initial Far Site Construction  
for the LBNF/DUNE Project**

**Submitted by:**



\_\_\_\_\_  
Pepin T. Carolan  
Federal Project Director  
Fermi Site Office

8/23/2016

\_\_\_\_\_  
Date



\_\_\_\_\_  
Michael J. Weis  
Site Manager  
Fermi Site Office

8/23/2016

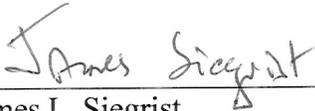
\_\_\_\_\_  
Date



\_\_\_\_\_  
Michael Procaro  
Program Manager  
Office of High Energy Physics

8/23/2016

\_\_\_\_\_  
Date



\_\_\_\_\_  
James L. Siegrist  
Associate Director for High Energy Physics  
Office of Science

8/25/16

\_\_\_\_\_  
Date

