

**Long Baseline Neutrino Committee & Neutrino Cost Group**  
DUNE Far Detector Approval Process  
January 26, 2018

**A. MOTIVATION AND SCOPE**

The Long Baseline Neutrino Facility (LBNF) / Deep Underground Neutrino Experiment (DUNE) is a groundbreaking international neutrino project, hosted by Fermilab in the United States. The international DUNE collaboration proposes to build liquid argon time projection chambers of unprecedented scale, to be located one mile underground in South Dakota. Fermilab will send the world's most powerful neutrino beam 800 miles from the LBNF facility at Fermilab in Illinois to the DUNE detectors in Lead, South Dakota.

The installation of the first of the DUNE far detector modules (17kT total liquid mass) is scheduled to begin in 2022. In preparation for this milestone, the Long Baseline Neutrino Committee (LBNC) and the Neutrino Cost Group (NCG) will work in close collaboration to ensure a timely review of the scientific and technical feasibility as well as of the cost and schedule of DUNE.

In addition, the distributed offline computing system will require substantial resources, and it will be part of a separate review process starting at a later stage, to enable the evolution of technology and technical capabilities over the period of the detector construction to be properly taken into account.

Additional guidance is detailed in Attachments to this document.

- Given the significant cost and scope of the DUNE Far Detector program, a multi-step approval and verification process is required, equivalent to internationally recognized large project management methods (e.g. ISO 21500(2012)), with phases, reviews, and decision points outlined below and detailed in the rest of the document.
- In the first step (Technical Proposal phase), the overall scope, preliminary design and cost for the DUNE Far Detector program will be defined and documented by DUNE in a Technical Proposal, with the possibility to maintain different options which may depend on technical issues and/or on funding availability. Consortia should be clearly defined in terms of the scope and organization at the time of the TP.
- In the second step (Technical Design Report phase), a detailed TDR for the DUNE Far Detector will be prepared by DUNE for review by the LBNC and NCG. Specific expectations for the content of the TDR are described in a separate document "Attachment 1 – Guidance for Technical and Costing Documents to the LBNC and NCG". The conceptual design of the Near Detector should be documented in a Conceptual Design Report, which will include a section describing and justifying the associated flux projection systematic uncertainties that will be used to characterize the physics performance of the Far Detector at this stage.

- In the third step, the final design and construction readiness of the major detector components will be prepared for review by the LBNC and NCG. It is recognized that different subsystems may be ready at different times for this third step, and will be reviewed accordingly, with the requirement that they are compatible with the overall construction and installation plan defined in the TDR.
- In the fourth step, as sub-systems are coming together in the experiment, an Operations Readiness Review (ORR) milestone should be defined and held to evaluate the capability of the completed detectors to provide the expected performance and mark the end of the DUNE Far Detector construction phase. The exact timing, scope, and procedure of the ORR will be defined at a later stage (Start of Operations or Project Completion).

The process described here is designed to enable DUNE, together with Fermilab as the host lab for the experiment and the international funding agencies contributing to the experiment, to fulfill their respective responsibilities in the approval process in a timely way. The entire process will be driven by the scientific goals of the experiment, captured with the aid of specific detector and physics performance benchmarks agreed in conjunction with the LBNC. The benchmarks can be used to gauge the cost-effectiveness of different detector options as well to provide a quantitative assessment of the degree of success of the detector construction. Technical feasibility and suitability will be also part of the LBNC review.

A global view of the DUNE Far Detector program (i.e. across the sub-systems) is needed to ensure that Funding Agencies are able to allocate resources in the optimal way. Detector construction resource requirements, which will be reviewed by the NCG, should be provided in the form of an un-indexed CORE cost (without escalation), without contingency, denominated in US dollars, and complemented by an estimate of the required staff effort expressed in FTE-years, typically separated in various work categories.

A risk analysis according to standardized categories should also be carried out at each of the four steps described above, and included in the documentation. Mitigation strategies should be devised to allow estimates of resource uncertainties and the potential scope of contingency planning.

The entire process will be monitored by the LBNF/DUNE Resources Review Board (RRB), including direct advice and recommendation from the LBNC and NCG provided in dedicated RRB sessions and through informal RRB member interactions with DUNE management and Fermilab management.

## **B. STEP 1: Approval of Technical Proposal for the DUNE Far Detector**

The process for this step will follow the methodology and requirement corresponding to a preliminary phased review process. In particular, the preliminary design documentation should include the different aspects described below:

1. The DUNE collaboration will provide an overall description of the intended construction program for the Far Detector in the form of a Technical Proposal (TP). The TP will describe the designs for both the single phase and dual phase implementations of the Far Detector modules, giving details of the status of the engineering design. It will include:
  - Physics motivation and performance, with a discussion of the optimization of cost vs. capability. In particular it is important to produce quantitative justification for any detector design requirement, for instance, in terms of channel count, data volume per channel, calibration and monitoring systems, or other critical functionality.
  - A detailed description of each subsystem, supported by R&D or prototyping results.
  - Plan and schedule for remaining R&D and prototyping needed to develop detailed designs, and to determine final cost estimates and schedule.
  - Plans for remaining R&D or other studies required to select among remaining alternative technical solutions, if any, and supporting timeline to reach resolution.
  - Current estimates of approximate total CORE construction costs, manpower, schedule and needed funding profile, in the appropriate detail to complete this step of the review.
  - A preliminary top-level project management plan setting out the project organization, key milestones (including project phases and review strategy), deliverables, and risk analysis.
  - A description of the management of the collaboration, including project management reporting structure, organization of the Consortia, leadership structure, and decision-making processes set forth in an overall plan with milestones and schedule for producing it.
2. The DUNE collaboration will provide a separate confidential document containing a preliminary funding plan, which takes account of inputs on the likely scale of funding anticipated from each of the Funding Agencies, with the “money-matrix” expected from the various funding agencies. This document will be treated in strict confidentiality between DUNE management, the LBNC and NCG Chairs, and Fermilab management, and at this stage will only represent preliminary planning figures.
3. The LBNC will be responsible for a review of the TP with respect to technical feasibility, risks, readiness, and capability to address the science, based on the documentation and on direct interactions with the DUNE management team. The NCG will specifically review the evaluation of the cost and schedule and, together with the LBNC, the project management structure and project risks including mitigation strategy. The reviews by LBNC and NCG will include consultation with Fermilab management and RRB members, if necessary, to clarify any potential issues or concerns and provide relevant information, so that these can be taken into account in formulating recommendations.
4. The recommendation of the LBNC/NCG regarding whether the scope should be approved and the project should proceed to the next step will be submitted to Fermilab

management, which will issue a recommendation for the scale of funding for the Far Detector system. The findings of the LBNC and NCG Committees will be presented by their Chairs at the September 2018 RRB meeting, followed by the request by the Fermilab management to endorse the LBNC/NCG recommendations and the associated scale of funding for the DUNE Far Detectors. Further iterations on the scope may be requested by Fermilab management.

### **C. STEP 2: Approval of baseline design, cost and schedule**

The process for this step will follow the methodology and requirement corresponding to a baseline phase review process. In particular:

1. DUNE will provide a detailed engineering and physics description of the intended construction program for the Far Detector in the form of a Technical Design Report (TDR) to the LBNC and NCG, with the purpose of validating a baseline design and establish a firm cost and schedule for approval by the RRB. The TDR is expected to cover the entirety of integrated complex systems and not be limited to a collection of specific subsystems. A TDR should include:
  - Physics motivation and performance, with a discussion of the optimization of cost vs capability and of the performance benchmarks connected with the specific detector element and the global detector.
  - Detailed description and design of all the components of the Far Detector modules.
  - Detailed budget with a risk register, estimate of uncertainties, and a risk mitigation plan including scenarios for less than full funding.
  - Technical and scientific manpower required, and its availability at the participating institutions.
  - A detailed project management plan including the global organization of the work and responsibilities including WBS and work-packages, organization structures, distribution of responsibilities and decision-making processes, schedule and key milestones including project phases, review strategy and deliverables, and risk management, including proposed level of contingency on cost and schedule.
2. The DUNE collaboration will provide a separate, confidential appendix containing:
  - A money matrix that indicates how costs will be shared among the participating funding agencies. This will also include a list of institutes and countries contributing to each detector component.
  - A funding profile showing that funds will be available as needed to meet the costs and schedule.
3. The LBNC and the NCG will be responsible for the review of the TDR, assessing the scientific soundness as well as the technical, financial, and schedule viability of the project, convening technical subcommittees as needed. Approval is contingent on the

anticipated availability of adequate funding. A set of relevant benchmarks defining project success will be defined and agreed in the process.

4. Upon a positive review, the LBNC/NCG will recommend to the LBNF/DUNE RRB the acceptance of the technical design, cost estimate, and schedule as firm baselines for the project. Fermilab management will keep the RRB informed of progress throughout the TDR review process and, upon approval, the agreements will be drawn up and opened for signatures.

#### **D. STEP 3: Approval for construction**

The process for this step will follow the methodology and requirements corresponding to a construction phase review process. In particular:

1. The experiment, in consultation with Fermilab and the LBNC, will convene construction readiness reviews, to ensure that any open issues at the time of TDR approval have been resolved, and that the detailed plans for construction and integration are consistent with the baseline set by the approved TDR.
2. A successful review will inform the Funding Agencies that the experiments are ready to start construction spending. The experiment may request specific approval for the acquisition of long-lead-time items prior to full approval for construction.
3. Progress in construction will be constantly monitored by the LBNC and NCG through regular quarterly sessions and with dedicated in-depth reviews organized once a year for each experiment.

#### **E. STEP 4: Operations Readiness Review**

An Operations Readiness Review will be conducted. This process will be defined at a later stage.

Attachments:

1. Guidance for Technical and Costing Documents to the LBNC and NCG
2. NCG Guidance for DUNE Technical Proposals (forthcoming)