Issued April 23, 2012

Fermilab

# Final Report

# Director's Independent Conceptual Design and CD-1 Readiness Review of the LBNE Project

## March 26-30, 2012

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# Executive Summary

This Director's review was designed to elicit the assembled committee's opinion on two primary questions. The first focus of the review was to perform an independent Conceptual Design review of the LBNE project to verify that the design is technically adequate, and should achieve the Project's scientific goals. The second focus was to perform a CD-1 Readiness review, with a focus on the project's cost, schedule, management, and ES&H.

The committee finds that the Conceptual Design for the LBNE project is sound, and should achieve the Project's scientific goals. Our determination is that the level of technical detail across the entire breadth of the LBNE project is sufficient to address the question of overall capability to achieve the scientific goals, as appropriate for this stage of the project. There are a number of components of the project that have advanced well beyond the conceptual stage.

The committee is confident that the LBNE project can be ready for a CD-1 review on the time scale given to the committee, the summer of 2012, if issues related to the funding profile and the resulting schedule are resolved. The management systems and documentation for the project are appropriate for a CD-1 review.

Given the breadth of the LBNE project, and the wealth of documentation associated with the project, the committee examined selective portions of the documents to evaluate the quality of the information. Our finding is that the technical information, costing information, task level duration estimates, Value Engineering information, etc. is of high quality.

## General Comment

The opinion of the committee is that the overall integrated schedule for the LBNE project needs further attention prior to undergoing the CD-1 review. The Review Team found that a number of the sub project schedules had rapid changes in funding profiles, resulting in inappropriate schedule constraints. This led to sub project schedules with undesirable delays between phases such as design and final procurement and fabrication, as well as often late and hence constrained schedules for installation, testing, and commissioning.

## General Recommendation

The Laboratory, Project and DOE should establish the agreed upon funding profile for the purpose of the CD-1 review. The integrated schedule for the entire LBNE project must then be optimized.

# 1.0 Introduction

A Director's Independent Conceptual Design and Critical Decision 1 Readiness Review of the Long-Baseline Neutrino Experiment (LBNE) Project was held on March 26-30, 2012. The focus of this review consists of two parts, the first part is an Independent Conceptual Design Review and the second is a Critical Decision 1 (CD-1) Readiness Review to ensure that all the requirements for CD-1 per DOE O 413.3B are satisfied. The charge included a list of topics and specific questions to be addressed as part of the review. The assessment of the Review Committee is documented in the body of this closeout presentation.

Each section in this closeout presentation is generally organized by Findings, Comments and Recommendations. Findings are statements of fact that summarize noteworthy information presented during the review. The Comments are judgment statements about the facts presented during the review and are based on reviewers' experience and expertise. The comments are to be evaluated by the project team and actions taken as deemed appropriate. Recommendations are statements of actions that should be addressed by the project team. The remainder of this presentation has the answers to the review charge questions.

The LBNE Project is to develop a response to the review recommendations and present it to the Laboratory Management and regularly report on the progress during the LBNE Working Group Meetings (WGM). A response to recommendation(s) is expected and actions taken will be reported on during future reviews.

# 2.0 Technical Design

## 2.1 Detectors

### 2.1.1 LAr Far Detector

#### 2.1.1.1 LAr - Cryogenics and Cryostat

## LAr - Cryogenics

### Findings

- The LBNE collaboration proposes to build and operate a 33 kton fiducial mass Liquid Argon (LAr) TPC located 4850 ft underground in Lead, SD. The detector would consist of two membrane-type cryostats containing a total of 50 kton liquid argon at 1.13 bar abs pressure with LAr and LN2 cryogenic services located between and on top of them.

- Three 75 kW nitrogen refrigerators (nominally 60 - 65 kW), two operational (one per cryostat) and one spare, will re-condense the argon vapor in the two cryostats, maintaining the liquid level and pressure in the TPC cryostat. Coldboxes and compressors will be underground. This refrigeration system is presented as standard equipment.

- There has been extensive testing of materials in the Material Test Cryostat (MTC) and of liquid argon purity in the Liquid Argon Purity Demonstrator (LAPD). These facilities have resulted in valuable information about materials for use in a LAr TPC based on the issue of electron lifetime, and also information about the ability to purify argon.

- The Review Team heard the concept of a single contract for cryogenic system and cryostat. But there is already a mention of breaking that up.

- An ODH analysis results in a cavern fatality rate of 3.6x10-7, fatalities per hour ODH class 1, including consideration of active ventilation.

- Value engineering studies offer options for cost reduction by means of alternate cavern locations, options for eliminating the liquid argon delivery to the 4850 ft depth by means of argon vapor transfer, locating compressors on the surface and other possibilities.

- A risk assessment identifies a few key issues such as cryostat and cryogenic system procurement from a very limited selection of vendors and a unique ODH analysis.

- The electron drift velocity is a factor 1000 faster than the predicted convection movements in the argon bath.

- The cryogenic system can deliver cooling power by means of stored LN2 underground for a period of 29 hours in case of a power failure when electronics and the circulation pumps are stopped under these conditions.

- It is stated that the argon flow leaving the cryostat via the safety valve in case of a cooling power failure can only be vented to the surface with the help of the ventilation of the Oro Hondo shaft.

- In case an under-pressure is created in the cryostat, a mechanical device will provide an air-inlet into the cryostat to assure that the pressure is not dropping below acceptable limits.

- It is stated that safety valves needed to protect the liquid argon cryostats are available on the market fulfilling the requirements: max leak rate before opening < 10(-6) mbar l/sec; opening pressure: 1.25 bar abs; max cryostat design pressure: 1.35 bar abs.

- It is stated that the proposed VE LAr-016 (vapor only transfer to the cavern rather than liquid) would not create a longer filling time of the cryostat, although the delivered liquid argon has to be evaporated at the surface and re-liquefied in the cavern.

- It is stated that the LAr purification system, as foreseen for the final installation, will be validated on a reduced scale in the LAr-1 prototype.

- The BOE covering the cryostat and cryogenics system at 4850 ft. is based on very detailed 800 ft. estimates. The 800 ft. figures have been modified based on the cost to transport the equipment and manpower to the lower depth (+30%) and on the estimate of the cost covering the installation of piping and pressure reducing stations from the surface to the cavern (+ 14 M$).

- The cryostat / cryogenics system has been foreseen to be operational over a 20 year period.

## Comments

- In general, LAr-1 should consider prototyping as much of LAr-FD as possible. For example LAr-1 could include an argon condenser of the type similar to that envisioned LAr-FD. Installation of the TPC arrays may be done as similar to that envisioned for LAr-FD as possible.

- In the proposed VE the Review Team suggests considering the possibility to create argon gas at any temperature between RT and 87 K to be used during the cool-down of the cryostat. In this way the mechanical stresses during cool down can be better controlled.

- The Review Team suggests studying the way in which an empty and cold FD cryostat can be kept cold over a period of several months by circulating cold gas.

Perhaps the heaters in the bottom of the LAr-FD cryostat (already present for warm-up) would be useful for vapor cooling during hold cold, cool down, etc.

- The cryogenic system and cryostat are sufficiently different in terms of required skills and experience that separate contracts for them would make sense.

- The presented value engineering and the risk mitigation concepts provide good basis for continuing the work.

- The argon condensing regulation could be simplified by inverting the condenser system: have the argon condensing on the outer surface, while nitrogen boils on the inner surface. In this case only a regulation of the nitrogen level (constant) and pressure (constant) is needed to regulate the argon pressure/level under all possible heat loads (once liquid argon is present).

- The circulation pump inlet should be designed to minimize flow velocities in the nearby sensitive volume, which could be high enough to adversely influence the performance of the TPC.

- The cryostat / cryogenics system has been foreseen to be operational over a 20 year period. Provisions will be needed for maintenance of all equipment necessary to run these systems, for example periodic testing of safety valves.

- Emptying a full and operational cryostat in the testing phase may present certain risks which should be carefully considered.

- Study hydrostatic head effects for the nitrogen compressors at the surface in order to assure that liquid nitrogen at the correct temperature can still be supplied.

- It is suggested to contact suppliers of nitrogen refrigerators in the early stage of the project to discuss the requirements: a nitrogen refrigerator is needed, not a nitrogen liquefier, which means that a cooling cycle different from air separation or nitrogen liquefaction should be applied.

- It was stated that the eventual implementation of VE LAr-016 would not have any effect on the filling time of the underground cryostats. Since the evaporation and re-liquefaction processes must be added to the filling process, this statement has probably to be revised.

- The cryostat and cryogenics cost and schedule documents are based on very detailed and very well documented figures for the 800 ft. level;

- The adjustments made in schedule and cost between the 800 ft. and the 4850 ft. level seem to be appropriate.

## Recommendations

1. Continue to work through the implications of the deep detector location. In particular, investigate failure modes. For example, consider failure modes of the pressure reducing system for liquid transfer, review assumptions in the ODH analysis such as the flow restriction at the surface, etc., with respect to the deep cavern location.

2. Place at least part of the nitrogen liquefiers (for example compressors) at the surface, if possible.

3. Due to the very small operational margin in the cryostat gas pressure, study the cool-down, filling, normal operation and warming-up procedures in the early stages of the project (for example in LAr-1).

4. Cryostat cool-down temperature uniformity requirements should be developed. Cryostat cool-down temperature uniformity should be analyzed and then compared to these requirements to limit excessive thermal stresses in the cryostat and TPC arrays. Since the proposed VE LAr-016 foresees the liquefaction of argon in the underground area, it could also be foreseen that argon gas at any temperature can be delivered by this system to be used during the cool down of the cryostats.

5. Try to eliminate all possibilities which could lead to the opening of the mechanical under-pressure device protecting the cryostat against under-pressure via air-inlet. A controlled heater system could do such a job, avoiding for example that the air inlet will be opened during the commissioning of the cryogenic system.

6. If the VE LAr-016 is approved, one should study the increase of the liquid nitrogen storage capacity in the underground area. During the review in November 2010, the reviewers recommended increasing the foreseen nitrogen storage such that a period longer than 40 hours could be covered. The actual period foreseen is 28 hours. The VE LAr-016 would make the project even more dependent on the underground stored liquid nitrogen volume in case of power cuts, etc.

7. LAr cryostat relief valve leak-tightness and functioning should be validated on LAr-1.

# LAr - Cryostat

## Findings

- The LBNE collaboration proposes to build and operate a 33 kton fiducial mass Liquid Argon (LAr) TPC located 4850 ft underground in Lead, SD. The detector would consist of two membrane-type cryostats containing a total of 50 kton liquid argon at 1.13 bar abs pressure with LAr and LN2 cryogenic services located between and on top of them.

- Prototyping includes a 35 ton LAr cryostat without TPC arrays (LAr35) and a 1 kton cryostat (LAr-1) with full TPC capability, both at Fermilab.

- The Review Team heard a required leak tightness specification for LAr35 of 10-6 mBar*l/sec. Fermilab built a membrane wall mock-up in early 2011 and confirmed that the NH3 is a suitable method to leak check membrane cryostats, reaching a sensitivity of 1.2x10-7 mBar*l/s for individual leaks. The NH3 leak check method checks locally for leaks on the membrane surface but does not provide an integrated leak rate of the system.

- The Review Team heard about only two possible vendors for the membrane cryostat procurements, and one of them has not agreed to Fermilab's procurement terms.

- The Review Team heard the concept of a single contract for cryogenic system and cryostat. But there is already a mention of breaking that up.

- A risk assessment identifies a few key issues, such as cryostat and cryogenic system procurement from a very limited selection of vendors and a unique ODH analysis.

- All functional operational cases affecting the cavern concrete liner have been transferred by the FD group to the CF group.

- The BOE covering the cryostat and cryogenics system at 4850 ft. is based on very detailed 800 ft. level estimates. The 800 ft. figures have been modified based on the cost to transport the equipment and manpower to the lower depth (+30%) and on the estimate of the cost covering the installation of equipment relating the surface with the cavern (+ 14 M$).

## Comments

- In general, LAr-1 should consider prototyping as much of LAr-FD as possible. For example LAr-1 could include an argon condenser of the type similar to that envisioned for LAr-FD. Installation of the TPC arrays may be done as similar to that envisioned for LAr-FD as possible.

- The cryogenic system and cryostat are sufficiently different in terms of required skills and experience that separate contracts for them would make sense.

- The presented value engineering and the risk mitigation concepts provide good basis for continuing the work.

- Try to resolve the problems between GTT and Fermilab so as not to enter into a possible single vendor situation.

- The cryostat / cryogenics system has been foreseen to be operational over a 20 year period. Provisions will be needed for maintenance of all equipment necessary to run these systems, for example periodic testing of safety valves.

- Emptying a full and operational cryostat in the testing phase may present certain risks which should be carefully considered.

- Provide a specification to the supplier regarding cleanliness of the delivered cryostat.

## Recommendations

None

### 2.1.1.2 LAr - TPC/DAQ/Electronics

## LAr - TPC

### Findings

- The primary design goals identified for the TPC are a signal to noise ratio of at least 9:1 and distinguishing electron showers from photon showers.
- Three wire planes per module are chosen for redundancy and improved tracking performance.
- The readout of the photon detection system is now based on silicon photo-detectors as opposed to photomultiplier tubes.
- Issues related to the mechanical requirements for the APA assemblies are still being investigated.
- The plan presented for the LAr1 prototype incorporated a mix of components intended for use in the far detector and components specific to the LAr1 implementation.
- A reasonable plan was presented for the assembly of the TPC components into the final detector configuration.
- The total cost for the LAr TPC is approximately $50M.
- The total cost for the APA assemblies is approximately $23M or 44% of the LAr TPC cost
- The schedule duration for the installation the TPC components, filling of both cryostats with LAr and initial testing was approximately two years.
- Within the TPC installation time frame, the duration for filling each cryostat was six months, and the time to transfer the entire volume of LAr from one cryostat to the other was three months.
- The time presented for testing the first completed TPC was given as 20 days.
- Of the $15M total direct cost for the APA assemblies, $10M is labor.

### Comments

- With respect to previous reviews, the committee finds greatly improved linkage between the stated physics goals and the detector requirements.
- Up to this point there have been no studies on the need for or development work on an in-situ calibration system. Some effort should be made in this direction.

The Review Team understands that this is at least a partially a reflection of the recent decision to site the detector at the 4850 level.

- The number of people noted to be working on APA/CPA development was much smaller than that for the electronics development. The Review Team noted that five out of six TPC subgroup leaders have yet to be identified.

- There were inconsistencies within different presentations regarding the relative scheduling of the LAr1 prototype and the design schedules for items such as APA modules. These inconsistencies need to be reconciled.

- The utility of LAr1 prototype effort as related to the final detector design was not easily discernible.

- Further studies are warranted for light-yield issues related to the photon detection system. A question was raised as to whether silicon photo-detectors should be used on both ends of the light guides.

- Further specification of the needed precision for placement and alignment of the APA/CPA modules in the far detectors is necessary.

- Given scope of work for the installation of the TPC, and the significant fixed fraction of 15 of the total 24 months constrained by the cryogen effort, further vetting seems warranted.

- The twenty days allotted for the checkout of the first completed TPC seems very short.

- The Review Team examined in detail the costing of the APA assemblies. The Review Team found the documentation for these estimates had the appropriate level of detail. The Review Team found the cost estimates credible and reasonable.

## Recommendations

8. The committee encourages the use of as many components intended for the far detector in the LAr1 prototype as possible. For example, the Review Team thinks the entire cold electronics signal chain installed at LAr1 should use the same components as those intended for use at the far detector.

9. To amortize the considerable investment in the LAr1 prototype, recommend that the plan incorporate provisions for iterating on the design and testing of the final components.

10. The Review Team recommends that an additional round of vetting be performed on the TPC installation and checkout schedule. The Review Team suggests that a document that lists the scope and goals of the checkout procedure be generated.

## LAr - DAQ

### Findings

- The proposed DAQ system is based on extrapolation of existing designs using commercial products to the extent possible.

- The DAQ system relies on a software based trigger applied to the event data post-collection.

### Comments

- The hardware choices seem very reasonable.

- The development of trigger algorithms should be a high-priority item for the LAr1 prototype so that these can be tested and tuned on cosmic ray data.

- No specific information on the plans or implementation of the slow controls systems was presented.

- Lack of detail regarding slow controls implementation plans could be reflective of the current limited level of human resources assigned to this task.

- The timing requirements need to be spelled out more clearly. The two requirements that were given (absolute timing of better than 2.5ms and alignment of the front-end timing inputs at the nanosecond level) seemed to be at odds with information from other presentations.

- Very little was presented regarding the development of the triggering algorithms and the detector simulation required for this effort.

### Recommendations

11. As noted in the December 2011 review software development, even though it is not charged directly to the project, needs to be incorporated into the project schedule to quantify and track the necessary effort since it is crucial to its success.

## LAr - Electronics

### Findings

- Both amplifier/shaper and ADC front-end ASICs have been designed, fabricated, and tested at Brookhaven.

- Both commercial FPGA and digital ASIC designs are being considered for reading out the data.

### Comments

- Development of the front-end chips is in a very advanced stage (much beyond what would normally be expected for a CD-1 review).

- The test results presented for the CMOS front-end ASIC were impressive.

- The question of analog and digital transistor lifetime in a cold environment has been very thoroughly investigated and is not an issue. The agreement observed between theory and measurements was impressive.

- The tests that have been done to cold-cycle fully stuffed printed circuit boards and the observed lack of an effect on their performance was comforting (along with the reported operational experience from the ATLAS calorimeter).

### Recommendations

None

### 2.1.2 Near Detector Complex (NDC)

#### 2.1.2.1 NDC - Cryogenics and Cryostat

## NDC - Cryogenics

### Findings

- A cryogenic system and cryogenic skids based on MicroBooNE are envisaged for the NDC TPC. MicroBooNE predicts about a 3.5 kW heatlaod to the LAr TPC cooled by about 90 liters/hour of LN2 from a storage vessel.

### Comments

- Cryogenic system risk appears to be low since it is so closely based on MicroBooNE experience.

- Cryogenic system scale is quite small compared to the LAr FD.

### Recommendations

None

## NDC - Cryostat

### Findings

- The concept for the near detector includes a LAr TPC surrounded by a magnet.
- The near detector TPC active volume is envisaged as 4.0 m x 1.8 m x 1.8 m (18 ton LAr) in a MicroBooNE type of cryostat with foam insulation, foam supports and LAr secondary containment.
- An 80 cm x 80 cm x 200 cm TPC prototype will primarily test tracking n a magnetic field, which is the primary difference from MicroBooNE.

### Comments

- Cryostat system risk appears to be low.
- Cryostat scale is quite small compared to the LAr FD.

### Recommendations

None

### 2.1.2.2 NDC - TPC/DAQ/Electronics

## NDC - TPC

### Findings

- A reference design was presented which is expected to change based on the results of the significant simulation effort needed to further refine the requirements for the near detector.

- The reference design is based on the Minerva (muon identification system) and MicroBoone (TPC) detectors.

### Comments

- The Review Team does not understand why 5 mm TPC wire spacing was under consideration.

- The approach outlined for the development of the near detector design was clearly presented and appropriate for this stage of the project.

- The schedule as presented for the NDC prototype appeared aggressive.

- The Review Team was presented a reasonable reference design for the near detector. The Review Team did not spend significant time vetting the cost estimates as the design is likely to evolve, although the Review Team notes that the range of costs for the options presented were within the overall costs (including contingency) for that presented for the reference design.

- The back loaded funding profile for the procurement, assembly, and commissioning phases jeopardizes the likelihood that the detectors could begin operation in 2024.

- The risk assessment methods and application seemed appropriate given the stage of the project.

### Recommendations

None

## NDC - DAQ

### Findings

- The DAQ system relies to a large extent on the use of commercial hardware with an architecture similar to other systems already in operation and that proposed for the far detector.

- The relative timing accuracy requirement between the near detector and the far detector was reported to be on the order of 10 ns.

### Comments

- The Review Team is confident that the proposed system can meet the needs of the ND.

- The timing requirements as stated in the ND DAQ talk differed from those shown in the FD DAQ talk.

### Recommendations

None

## NDC - Electronics

### Findings

- Assuming that a TPC detector is employed it will make use of the electronics designed for the far detector.

- The muon identification system can use electronics similar to those used in the T2K and Minerva experiments.

- The beam monitoring system consists of Michel, Cerenkov, and Ion detectors.

### Comments

- There were no details given in the beam monitoring presentations about electronics.

### Recommendations

None

## 2.2 Beamlines

The conceptual design of the beamlines is complete, appropriate for the conceptual design phase, and likely to meet LBNE requirements. Risks have been identified and largely mitigated. Value engineering has been applied where appropriate. All present level 4 sub-system designs draw on the extensive experience of the managers and their staff with construction and operation of the NuMI facility. The Review Team sees no significant deficiencies or omissions within the conceptual design.

### 2.2.1 Primary Beamline

#### Findings

A single beamline design based on extraction from MI-10 was presented, following the consolidation of multiple options considered last fall. All presentations addressed the requirements of the current design.

- Radiological issues
    - All radiological calculations are based upon a 2.3 MW design.
    - A comprehensive set of radiological requirements for the primary beam were presented including limits on dose to public and dose to workers.
    - Doses at the site boundary are an order of magnitude below requirements. Administrative limits for protection from longitudinal muons are required at no more than 2 full beam pulses lost per day from primary beam at apex of beam line.
    - The primary beamline shielding design is determined by the accident condition, assumed to be two full beam pulses lost per hour.
- Lattice Optics
    - A robust design based individual optical modules is used for transverse beam size and dispersion control.
    - A flexible final focus design was presented that can handle a range of final beam sizes from 1 to 3 mm sigma for all energy ranges and beam powers.
- Magnet/Magnet Installation
    - All magnets designs are based upon existing Main Injector magnets, with the Lambertsons and a C-magnet reused from the Tevatron. There are no concerns with these magnets.
    - A new trim dipole are being designed with a 2” gap.

  - Extraction kickers are of the NOvA KDB design. This design address concerns with availability of long ceramic pipes identified at previous reviews.

- Magnet Power Supplies
  - Power supplies are a combination of new supplies and re-used Tevatron supplies.
  - New quadrupole supplies will be of a design currently in use at Fermilab.

- Beam Loss Modeling
  - All modeling was done with 2.3MW beam. Beam loss modeling is based on 1% of beam in the halo. However, halo definitions were somewhat ambiguous.
  - Based on modeling, the tolerance for normal operational beam loss is set at a few x E-6, leading to 50 mrem/hr residual activation.
  - Benchmarking of losses in the NuMI transport line with profile monitors and in-tunnel scarecrow radiation detectors shows losses measured at the E-6 level.
  - A single 2.3MW loss point in a magnet, due to a dipole error is expected to raise the temperature of the beam pipe to 2500K, above the melting point.

- Vacuum
  - The conceptual design is consistent with existing ring and transport lines at Fermilab.

- LCW
  - The LCW system for the primary beam will be a stand-alone, closed loop system similar in design to current operational systems at Fermilab.

- Instrumentation
  - Instrumentation design for the primary beamline is based upon experience with the existing 400 kW NuMI operations and the 700 kW NOvA upgrade.
  - Although existing profile monitors are deemed acceptable for LBNE operations up to 2.3 MW, none of the monitors may be left in the beam permanently. This does not seem to present a major issue. R&D continues on profile monitors.

- Although the present NuMI design single plane split plate pick up works fine, the current choice for the BPM pick up is a dual plane button pick up.

## Comments

- The justification of use of a dual plane button, rather than split-plane, BPM was not clear to the Committee. It is possible that the dual plane will provide increased accuracy on the beta function measurement and/or redundancy against a BPM failure. It is speculated that the dual plane BPM may be less expensive than the split-plane, even when accounting for cost of the additional electronics. In either event the justification for the choice should be documented.

- The Committee supports continued R&D on both 1D and 2D profile monitors for high intensity proton beam monitoring.

- The rationale for the two pulse beamline accident condition that forms the basis of shielding calculations is documented and under review in the Fermilab ESH Section. This may require Director sign-off.

- There is some concern about the interface between the beamline vacuum and primary beam window interface with regard to necessary beamline vacuum specification and leak rate of the window. This is not necessarily a problem, but an example of necessary interface handshaking between level 4 tasks.

- The lattice optics and beam loss presentations seemed to use different transverse emittance fractions and values for aperture evaluation and loss evaluation. All values seemed to be conservative and there is no issue with the aperture. It would be helpful if a consistent emittance definition (geometric or normalized, rms or 99%) fractions and consistent numbers were used.

- The trim dipole design has a gap of 2 inches, even though installed next to a quadrupole with 3 inch beam pipe.

## Recommendations

12. The gap of the new trim dipole magnet should be opened up to 3 inches to match quad beam pipe diameter.

13. A prototype for the dual plane BPM and associated readout electronics should be completed in a timely manner.

### 2.2.2 Neutrino Beamline

#### Findings

- Alternative designs are being maintained in several areas including: 1)graphite (baseline) vs Be as the target material; 2) the length of the decay pipe, 200 m (baseline) vs 250 m; and 3) decay pipe filled with air (baseline) vs He.

- Extensive modeling of beam loss and associated radiation/activation levels has been carried out. There has been substantial development of the MARS code, including benchmarking, since the last review. All modeling is based on a beam power of 2.3 MW and considers both routine operations and accident conditions. Requirements in terms of air and water activation, dose at the surface, and off-site dose are all met in the neutrino beamline facility design.

- A six cell morgue is designed to contain activated spent components. This is believed to be sufficient to contain components consigned to the morgue over a two year running period at 700 kW. After two years components will have to be moved to longer term storage (not within the LBNE scope).

#### Comments

- The conceptual designs of the target, horns, and beam absorber are based on the NuMI/NOvA/MiniBoone experience and look to be adequate.

- Design of the remote handling facilities for target and horn components look to be adequate (with the exception of long term storage needs).

- The decay pipe length and diameter have been optimized in balance with the far detector mass, based on sensitivity to $\square_{13}$.

- Requirements for eventual upgrade to 2.3 MW have been appropriately identified and integrated into the design.

- No requirements were specified for lifetime of consumable components (targets, horns). Rather lifetime assumptions have been made and integrated into the facility uptime requirement.

- An annular air-cooled double pipe solution decay pipe has been adopted as the baseline decay pipe configuration. This seems a sensible choice as it is simple, efficient, and plays an important role in the tritium mitigation strategy. Concepts for air cooling of a He filled pipe exist, and will be further developed in the future.

- The ground water protection strategy appears to be very robust: concentric decay pipe with air cooling, dehumidification, sufficient concrete shielding to limit activation of water outside the decay shield, a triply redundant geo-membrane with leak detection, and backup mitigation in place.

- The LBNE design produces air emissions from all sources at 30-50% of the Laboratory allowed limit. The Laboratory will need to take account of this while defining the complementary, concurrent, physics program.

- LBNE is assuming that the laboratory will provide (off-project) operational facilities and components: most notably long term storage facilities for highly activated components and all component spares. Details need to be worked out.

- The six cell morgue is most likely not capable of accommodating the short term storage needs associated with 2.3 MW operations.

- Hydrogen embrittlement in high radiation environments has been an issue in the past at Fermilab. Avoidance of hardened steel in high radiation environments has been adopted in the design of many of the beamline systems, but is nowhere explicitly documented as a requirement.

## Recommendations

14. Now that $\theta_{13}$ is known, the optimization of the decay pipe geometry should be revisited.

15. The committee suggests that LBNE consistently refer to a specific upper limit on tritium and $^{22}$Na concentrations as the design goal, rather than referring to "non-detectable".

16. The Committee suggests that any assumptions relative to lifetimes of consumable components should be documented as such.

### 2.2.3 System Integration

#### Findings

- Four systems (controls, interlocks, alignment, installation coordination) have been identified which bridge the primary/secondary beam boundary and are covered by the integration task.

- Both Controls and Interlocks will be handled by existing Accelerator Division departments. The envisioned hardware and software utilize proven components; no development is foreseen. These systems are continually upgraded and maintained; obsolescence is not an issue. As such, the LBNE system will integrate into the infrastructure extant at the time.

- A beamline interface matrix was presented which provides a mechanism to document the scope at the interface between any two WBS level 4 systems. These documents are signed by appropriate level 4 (and above managers). This was presented as a work in progress.

    - To date 100 interface documents have been identified, 18 have been completed, and 8 have been signed.

- Installation Coordination is organized following the successful NuMI model. Lessons learned from NuMI have been incorporated.

- Absolute and relative tolerances are scaled from NuMI. These will be tightened only if (yet to be completed) physics simulations indicate the need.

#### Comments

- The presentation of tolerances was not always consistent. Tolerances contained within the CDR do not define whether they are 1σ, 95%, 100%, etc.

- The interface matrix is an excellent idea. At present it is not fully implemented and is restricted to scope definition. It might prove useful to expand to include cross-systems requirements, and to consider implementing on other LBNE sub-projects.

- Installation and alignment rely heavily on the successful NuMI experience. However, fifteen years will have elapsed between NuMI and LBNE. This raises a general concern as to whether experience will exist within the staff once the LBNE installation phase is initiated.

- The NuMI alignment tolerances pushed the envelope of what was possible. If the scaling from NuMI to LBNE proves to be inadequate, the current plan cannot be readily modified. Thus it is important to check the adequacy of the scaled tolerances with proper physics simulations.

## Recommendations

17. Follow through on complete implementation of the interface definition process, including integration of cross-system requirements. Also include interfaces to existing facilities such as the Main Injector vacuum and LCW, and off-project connections.

18. Tolerance measures should be clearly defined, e.g., ±0.450 mm (3σ).

19. Priority should be given to confirming NuMI-scaled alignment tolerance requirements with physics simulations.

## 2.3 Conventional Facilities (CF)

### Summary

Conventional Facilities design elements were reviewed for both the near site and the far site. The design elements were derived from experiment design requirements communicated by technical teams over the last two years and now being documented in IBM Rational Doors, a requirements management tool.

Design documentation, project risks, cost estimates and related schedule plans are at a level of development beyond what would be expected for a conceptual design. In many cases, the LBNE conventional facilities are at a Preliminary Design stage due to the thoroughness of the documentation.

Design of facilities has gone through multiple iterations and previous reviews. There has been significant effort and banked savings from Value Engineering. This has led to an optimized project design and execution schedule. Architect / Engineering (A/E) and Construction Management (CM) resources have been utilized to review and estimate the project. In several cases, independent cost/schedule estimates based on different methodologies were reconciled via interaction between the estimators.

Below are a few metrics on the documentation presented during the review:

| Quantity | Near Site MI-10 Shallow | Far Site LAr 4850 L |
|---|---|---|
| Supporting Technical Documents posted | 18 | 19 |
| Additional Supporting Documents posted | 12 | 17 |
| BOEs/Cost Books | 16 | 13 |
| P6 Schedule Activities | 392 | 323 |
| Level 2 & 3 Requirements | 31 | 32 |
| Specification & Parameter Tables | 6 | 8 |
| VE Proposals Initiated | 10 | 3 |
| VE Proposals Participated | 7 | 7 |
| Drawings | 86 | 75 |
| CF Risks in Risk Register | 9 | 4 |
| Additional CF Risks | 3 | 8 |

In order to reduce cost uncertainty, it would be greatly beneficial to CF design, scheduling, and cost estimating efforts to have timely decisions on technical systems design options such as decay pipe length, muon range-out, helium cooling of the decay pipe, and cryogens delivered to the far site detector either as a liquid or a gas.

## 2.3.1 CF – Near Site

### 2.3.1.1 Near Site - Civil/Site Work

#### Findings

- Near Site Conventional Facilities (CF) Scope includes the design, procurement, and construction of facilities necessary to support the project components. This includes roads, buildings, and utility distribution.

- The near site CF provides for a 700kw Beam. However because of a potential beam upgrade to 2.3MW, enclosures and systems that cannot efficiently be upgraded have been designed for the higher beam intensity. Costs for incorporating CF design features consistent with a future beam power upgrade to 2.3 MW are documented in project VE documents contained in Docdb record 5780. The CF cost impact of this requirement is roughly $7.5M.

- The Near Site Infrastructure and Service Buildings are 34% of the CF stated costs. Building designs have been developed for the four building locations. Site development includes roads, parking areas, and drainage. Main Injector utilities that are impacted by the embankment are relocated. New utilities include Industrial Cooling Water, Domestic Water, Sanitary Sewer, Electrical Duct Banks and Communications Ducts. The designs are substantially developed for this stage of the project and are appropriate for the necessary development of related cost estimates and schedules..

- Design documentation is at a level of development beyond what would be expected for a conceptual design. In many cases, the LBNE conventional facilities are at a Preliminary Design stage due to the thoroughness of the documentation.

- Experts in beamline systems such as remote handling, shielding, magnets, targets, and related subsystems have been consulted to in order to determine interface requirements. At this time no official interface documents exist, however the IBM Rational DOORs requirements management tool has been utilized to flowdown science requirements to facility requirements.

- The presenters stated a Responsibility Interface Requirements matrix is under development.

- The CF design has been optimized to the requirements through extensive Value Management over the past year.

#### Comments

- The deep foundation to support the beamline tunnel on the embankment has been investigated utilizing finite element modeling. There is a high level of confidence that the beamline can be supported adequately within the settlement tolerances of a proton beam. However this deep foundation system is expensive. Engineering

funding should be appropriated to examine the possibility of eliminating these deep foundations. This would involve additional geotechnical engineering for the current design (smaller embankment) and a detailed look at the schedule to determine if the time dependent settlements can be exhausted prior to beamline installation.

- An Environmental Assessment is in progress; however documentation was not available for review at this time. The project team stated that NEPA and Cultural Resource Surveys are being developed based on the current conceptual design. This is true for both the Far Site and the Near Site buildings and infrastructure. Timeliness of these assessments may be important to the project schedule.

## Recommendations

None

### 2.3.1.2 Near Site - Rock Excavation

#### Findings

- The rock excavations are dimensionally adequate and can be constructed in a satisfactory way. The excavation layouts have not been optimized for constructability but this is planned for Preliminary Engineering.

- Initial geotechnical subsurface site investigations have been performed and soil and rock conditions are favorable.

- Supporting documents prepared by expert consultants indicate that rock open cut, shaft, tunnel, and detector hall excavations are designed for construction by drill and blast methods with a conservative level of rock dowels and shotcrete as ground support measures.

- Pre-excavation formation grouting at the top-of-rock interface for shaft construction has been included in the cost estimate. This is a prudent and effective ground improvement measure to mitigate the risk of construction delay.

- Conceptual design has incorporated several lessons learned from NuMI. For example, a geomembrane is used to control groundwater seepage around the decay pipe rather than a collect and pump system. There is included budget for greater-than-typical QA/QC during construction.

- An LBNE schedule delay in 2011 has allowed VE studies to be performed to reduce shaft construction costs at the Absorber Building. The VE process is well defined and documented.

- The risk of encountering differing site conditions associated with excavation is understood and documented in the risk register. Appropriate mitigation measures including contractual provisions and contingency budget are identified.

- The excavation schedule prepared by a subject matter expert appears adequate and achievable.

#### Comments

- A geotechnical site investigation is scheduled to be completed before Preliminary Engineering. Consider a phased Site Investigation approach that includes an additional phase between Preliminary Engineering and Final Design.

#### Recommendations

None

### 2.3.1.3 Near Site - Buildings & Infrastructure

#### Findings

- Design documentation is at a level of development beyond what would be expected for a conceptual design. In many cases, the LBNE conventional facilities are at a Preliminary Design stage due to the thoroughness of the documentation.

- Cost estimates for near site conventional facilities have been independently checked and validated by A/E Jacobs Engineering.

- Fermilab relies upon FESS, an in-house engineering organization for project life cycle management. The organization relies upon contracts with design A/E firms to execute larger projects. FESS will lead the Near Site design and construction efforts for LBNE. FESS plans to utilize one or more A/E's to facilitate preliminary and detail design and a CM early in the design process to review constructability. This approach should allow for meaningful influence to the design and minimize potential change orders later in the project. This approach should also increase construction bidder comfort level and lower perceived risk/cost during bid process.

- Conceptual design drawings reflect interaction between FESS and the technical teams. For example, layout of the target hall remote handling areas are based upon technical team estimates of technical component size. Also, labyrinths are incorporated that account for air pressure equalization and avoidance of line-of-sight in areas of high radioactivity.

- The LBNE ventilation and water pumping systems are designed based on proven experiences from NuMI. Experience shows that the condensate from the HVAC system contains tritium and slight amounts of nitric acid. The LBNE design includes mechanisms to capture condensate; thus reducing inflowing of contamination into the sump water.

- Recommendations from AON specify requirements for smoke control, stairwells, ventilation, egress paths, sprinklers, fire detection and alarm systems, emergency and standby power systems, emergency preparedness, breathing apparatus, and check-in / check-out personnel control. These features are reflected in the near site CF design.

- Multiple Value Engineering options have been identified, investigated, and in some cases incorporated. An example was utilizing a centralized morgue location (6 cells) vs. individual morgues (~24 cells). The project-wide VE process saved the LBNE program > $100M.

- The construction costs for all Near Site activities are estimated at $241.1M in FY2010 dollars; the near site TPC is $278.8M in FY2010 dollars.

- The user power loads are not entirely known at this time, but are estimated at 2 MVA. House power loads are better defined based on current understanding of LBNE equipment needs (4.95 MVA). Of the house power loads, chillers and HVAC systems encompass most of the load requirements. The Beam Group provides a pulse power requirement of 6.2 MVA to 7.6 MVA RMS.

- Standby power is required for life safety systems, mechanical pumping systems, and cranes in hot handling areas (no loads may be left dangling due to power outage). Each building has a standby 250kW diesel generator. LBNE 30 has an additional back up 150kW generator.

- Electrical transformers have been sized for the predicted load with little additional capacity. There is a general program risk being carried related to scope changes. This would address design changes that could result in increased electrical demand and associated increases in cost.

- The 700 kW beam design has a 218 kW cooling requirement which is accounted for in the conceptual design. The system will require expansion to 674 kW if a beam upgrade to 2.3 MW is realized.

- A clear, documented risk management process is in place. Risks were identified and assessed for probability of occurrence at the subproject level. A clear impact ranking based on schedule, cost, scope and ES&H/Quality has been defined.

## Comments

- Consider having the engineers or control account managers include explanations of environmental, safety, and health features in their presentations so that this is not all left to the ESH manager. Having the task leaders present this subject will give more credence to the features being designed-in. Coordinate this with ESH presentations.

## Recommendations

None

## 2.3.2 CF – Far Site

### 2.3.2.1 Far Site - Civil/Site Work

#### Findings

- Multiple refurbishing subprojects were presented for upgrading the three (Ross, Yates, and Oro Hondo) shafts required for access and operations of the Far Site. Additionally, upgrades required to meet MSHA codes were identified for the head frame structures. It was noted that OSHA doesn't cover this type of work; so where OSHA does not have applicable guidance, MSHA requirements will govern.

- Ross Shaft refurbishment will begin in FY12. The initial portion of the work will be funded by the Sanford Site Operations and not LBNE. Analysis of the shaft found that 75% to 89% ground support beam replacements would be required for payloads of 4,000 – 8,000 lbs. As the project requires 12,000 lb payloads, a modified strip and re-equip is being pursued.

- The Oro Hondo Shaft will be refurbished to allow for upgraded ventilation, installation of cryogen piping, cryogen PRV stations, related utilities, and permanent hoisting facilities to support cryogen operations and maintenance.

- The 3650-4850 Winze was identified as new construction. It will be a 1200-ft long and 13-ft diameter shotcrete lined, borehole. Utilities and cryogen piping will be anchored to support brackets bolted into the shaft wall. Stand by generators are planned for emergency egress.

- A summary of shaft refurbishment by shaft type is as follows: Yates (all LBNE), Ross (part SDSTA part LBNE), Oro Hondo (all LBNE), 3650-4850 as part of the Oro Hondo (all LBNE).

#### Comments

- There is an MOU being developed between Fermi and SURF and may possibly include LBNL. This would define responsibilities, line safety, construction approach, cost sharing. There are milestones in the schedule that identify non-LBNE funded work for shaft rehabs. It should be made clear where these milestones may impact LBNE tasks or require LBNE action to continue work (for shared activities such as the continuation of Ross Shaft rehabilitation).

#### Recommendations

None

### 2.3.2.2 Far Site - Rock Excavation

#### Findings

- The LAr cavern is located in the Poorman Formation (amphibolite schist) intruded by discontinuous rhyolite dikes. The rock excavations are dimensionally adequate and can be constructed in a satisfactory way.

- There is no site-specific geotechnical data (drillholes or in situ testing) at the LAr cavern location. The team recognizes the need for a site specific geotechnical site investigation. A previous reconnaissance geotechnical site investigation focused on the discontinued Water Cherenkov Detector option identifying favorable conditions. .

- Analysis of existing geotechnical data shows favorable in situ stresses (sub-vertical sigma 1). Occasional spalling is expected but rock bursts are considered unlikely based on test data and past mine experience.

- A/E Golder Associates created a geotechnical design model consisting of the following ground support elements: cable bolts of 10-13m length, 3 m long split-spac$^{e}$ resin encapsulated rock bolts, wire mesh, and 100mm shotcrete. Smaller rooms and drifts are supported with bolts and shotcrete. Ground support is controlled by foliation and jointing.

- Data from existing facilities and other experiments (e.g. Davis Campus, No 6 Winze, etc.) are used to calibrate the geological model and the larger scale assessment of geological structures.

- Estimated excavation volumes are: 4850 LAr cavern volume = 183,000 cy, other excavations = 63,000 cy for a total of 246,000 cy.

- A logical cavern excavation sequence was presented that levels manpower. Plans, cost estimates, and schedules derived by the excavation designer have been reconciled with the CM.

- The design has considered potential impacts due to air blast and vibration. Cost estimates include a fulltime Blast Engineer on site. Geotechnical and other instrumentation monitoring are planned.

- The critical path of the excavation schedule in the LAr cavern is through cable bolt and rock bolt installation and not spoil handling so Ross shaft skipping capacity is adequate.

- Rock waste handling options for disposal locations were presented. Value engineering trade off analyses by site location, disposal distance and environmental considerations were used for down-selecting the presented approach.

- Ventilation is sized based on previous DUSEL PDR assessments for the maximum number of pieces of diesel excavation equipment. That value was selected as conservative since the PDR was based on the much larger WCD large cavern.

- The excavation schedule utilizes the last three months of Ross shaft renovation for mobilizing the excavation contractor.

## Comments

- Concrete septum walls include a middle mat of #11 bars at 6 inch centers located at the neutral axis. Review load requirements that require this reinforcing as there may be savings for lesser amounts of reinforcing steel.

- The Environmental Assessment and initial conversations with local environmental jurisdictions have indicated existing permits can be used by LBNE for rock dumping in the open cut. The schedule should be updated to clearly show the expected milestone dates for completion of required EA/NEPA/Cultural Resources. Construction tasks tied to this event should also clearly show program impact if delay is encountered.

## Recommendations

20. Review the impact of the Environmental Assessment on schedule. Show where it fits in the critical path schedule. Determine the schedule impact if it is late along with the necessary workarounds.

### 2.3.2.3 Far Site - Buildings & Infrastructure

#### Findings

- Fresh air ventilation from the Yates and Ross shafts of 300,000 cfm and 215,000 cfm are provided to the LAr Cavern for excavation and operation respectively. During operation, the 215,000 cfm is sub-divided to 45,000 cfm of fresh air for the experiment hall and 170,000 cfm of air utilized to provide cooling to experiment systems. The HVAC system will supply 45,000 cfm of conditioned supply air at 68F. That amounts to one air exchange per hour (single pass through system) in the experiment space. Operations ventilation far exceeds that 15,000 cfm assumption utilized in the experiment ODH analysis. The centrifugal fan at the Oro Hondo shaft has capacity well beyond the design airflows.

- The Electrical/Power Distribution is fed by a 230kV transmission line from Black Hills Power. Redundant feed points lead to reliable, high-quality power. Power available from Oro Hondo (20 MVA) and Ross (30 MVA) substations currently exceed LBNE requirements. A dedicated feeder in Ross shaft will be installed for LAr and 4850L systems for LBNE. All underground transformers are dry type (no oil filled).

- Areas of refuge (AOR) have been established for fire and life safety requirements. The sizes of areas are designed for appropriate head counts. A 96 hr occupancy time limit is utilized with emergency air provided through $O_2$ bottles and $CO_2$ scrubbers.

- In VE investigations, alternate cryogen delivery shafts were evaluated as a potential low cost option to the rehabilitation of the Oro Hondo Shaft.

- VE has been identified, evaluated, and in some cases implemented for Far Site design items. Savings for those selected VE items have been incorporated into the design (e.g. single long excavation for two 20 kton detectors). A total of $217M VE savings are accounted at the Far Sight to date.

- NEPA CATEX is already in place for current site support and early science. An updated EA is underway; currently being led by Fermilab.

- The Far Site Conceptual Design was performed by the same A/E firms that completed the DUSEL PDR which was used for reference in the development of this Conceptual Design. The constructability of the design has been vetted by a CM firm. In addition, the Engineering Cost Estimate was reconciled with a Cost Estimate performed by the same CM Firm to further add fidelity to the Construction Cost Estimate.

- Architectural assessments were performed by A/E HDR to determine the condition of existing buildings and site. Several buildings will require upgrades to be in compliance with current codes and permits. SURF has identified the need

to meet National Historic Preservation requirements due to several historical structures on site.

## Comments

- Make sure that presentations for surface address space allocations for technical systems equipment (e.g. compressors / Dewars) and affirm the handshake of requirements. This comment could be considered more broadly for all presentations that need to confirm interface relationships with technical systems.

## Recommendations

None

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## 2.4 Technical Design Charge Questions

### 2.4.1 Are the science goals and physics requirements clearly stated and documented? Do the science goals and physics requirements meet the objectives described in the LBNE Physics Research Goals? Have the science goals and physics requirements been adequately translated into technical performance requirements and specifications?

Yes, the science goals have been explicitly stated in terms that reflect the primary mission of the experiment. In most cases high-level physics requirements have been translated into more specific requirements and specifications that are documented at levels 3 and 4. The level of specification, while not complete, is adequate for the conceptual design stage. Some work remains in documenting requirements flow down into Doors.

### 2.4.2 Is the design technically adequate? Is the design likely to meet the technical requirements needed to carry out the scientific goals?

Yes. The requirements were clearly described, and the design is technically adequate to meet those requirements. It is noted that the primary beamline assumes an accident scenario that has not yet been accepted.

### 2.4.3 Can the design be constructed, inspected, tested, installed, operated and maintained in a satisfactory way?

Yes. In many cases (beamlines, targets, and certain detector components) the proposed project components are relatively simple extensions of designs validated in previous projects. For other components outside resources (A/E's) have been appropriately utilized to validate the concepts. The plans for construction and installation are well developed and contain a significant level of detail given the current pre CD-1 status of the project and recent decision to move the detectors deep underground.

### 2.4.4 Is there adequate supporting documentation to support the conceptual design and the transition to developing the preliminary design?

Yes, documentation is thorough and is beyond traditional conceptual design. The conceptual design report is complete and organized in a fashion that maps cleanly onto the WBS structure.

### 2.4.5 Are the risks (on technical, cost, and schedule basis) of the selected base design approach and alternatives understood and are appropriate steps being taken to manage and mitigate these risks? Have areas been identified where value engineering should be done? If value engineering has been performed is it documented?

Yes. The risks (on technical, cost, and schedule basis) of the selected base design approach and alternatives are understood and appropriate steps are being taken to manage and mitigate these risks. Value engineering has been demonstrated and the documentation of VE is available.

### 2.4.6 Are the project organization and lines of responsibility clearly defined and sufficient to ensure the successful engineering and design of the project? Are the design interfaces between the Accelerator Systems, Experimental Facilities, and Conventional Facilities groups understood and well enough defined to ensure a coordinated effort and an integrated design? Is there a reasonable plan in place for implementing configuration management to ensure changes to the technical requirements/specifications are controlled and communicated to all affected groups?

The project is well organized. Collaboration between groups was evident. There is good communication between far site team and FNAL. Systems Engineering is taking steps to capture required linkages into the configuration management system. A concern noted is that software, necessary as a key component in the design and development of the detectors, is currently not within the project organization.

# 3.0 CD-1 Readiness

## 3.1 Detectors

### Findings

- Documentation required for CD-1 was presented.

### Comments

- All documentation required for CD-1 is available and are of sufficient quality for CD-1.

### Recommendations

21. The schedule requires revision based on funding availability and profile prior to CD-1 review.

## 3.2 Beamlines

### Findings

- The Conceptual Design Report is ready for a CD-1 review.
- The suite of documentation required for CD-1 is nearly complete.
- A risk management process is in place, documented via a risk matrix.

### Comments

- The primary source for specifications and parameters are LBNE notes and the CDR. The rudimentary configuration management system in place is adequate at the moment. However, as the project progress a more formalized approach will have to be developed.
- The cost estimate is credible at the conceptual level.
- The schedule is not credible. Many funding profiles feature large dead spaces: engineers completing designs and nothing happening until a procurement is initiated five years later. This is largely a result of constraints imposed by the funding profile rather than technical demands.
- The project does not have capability of tracking costs at level 4 of the WBS. So the Review Team was unable to get a comparison between the budgets and the actual costs to date.

### Recommendations

22. During a CD-1 review slides should consistently indicate whether information presented is relative to 700 or 2300 kW.

## 3.3 Conventional Facilities

### Findings

- Overall the LBNE Conventional Facilities is prepared for CD-1. Design, cost and schedule documentation is at a level of development beyond what would typically be expected at the conceptual design level. In many cases, the LBNE project is at a Preliminary Design stage due to the thoroughness of the documentation.

- A 142k square footage has been approved by DOE for LBNE use. This quantity appears to be sufficient for the current Near Site facility design. Space banking at the Far Site is not currently assumed to be applicable due to LBNE facilities at SURF being on non-DOE property.

- Presenters have stated the head of FESS has signed off on direction Fermilab will be pursuing regarding LEED approach for non-office buildings. Project intends to incorporate DOE sustainable design /best practices, but realizes it may not be able to meet all goals for LEED Gold certification. This approach appears to make sense for this type of project. Most buildings are estimated to have occupancy less than 1 FTE which should make LEED not applicable.

- Acquisition Plan identifies preliminary engineering and final design to be completed by one of several A/E firms already under contract to Fermilab for the Near Site. Acquisition Plan for the Far Site identifies selecting a CM using a best value criteria and engaging the CM during preliminary design to perform a constructability review.

- A clear, documented risk management process is in place. Risks were identified and assessed for probability of occurrence at the subproject level. A clear impact ranking based on schedule, cost, scope and ES&H/Quality has been defined.

- Assumption used for the project schedule is $180M maximum funding per year.

- There are approximately 715 schedule activities in CF schedule.

- Contingency applied to the schedule is estimate uncertainty + scope change opportunities. Risk contingency and project manager's top down contingency is not included. The near site has lower estimate uncertainty as it is mainly standard construction methods.

- The level 2 manager for CF demonstrates good understanding of cost / schedule basis documentation.

- Labor and material costs, crew sizes, productivity, schedule durations and logic, and contingencies for rock excavation and related activities are reasonable and within the range of typical values for projects of this size and complexity at this level of design.

## Comments

- It would be greatly beneficial to CF design, scheduling, and cost estimating efforts to have timely decisions on technical systems options – decay pipe length, muon rangeout, decay pipe filling/cooling, cryogens delivered as a liquid or gas,

- Finalization of the technical systems requirements that interface to CF should be done before CD-1.

## Recommendations

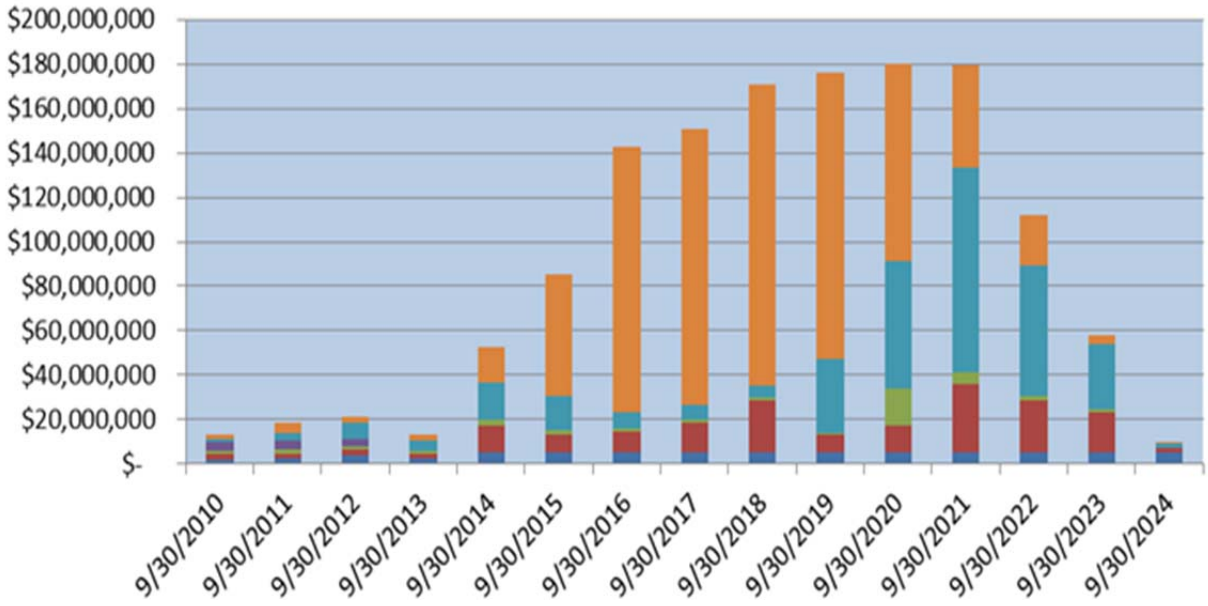
None

## 3.4 Project Management

### 3.4.1 Cost

#### Findings

- The LBNE project has a TPC of $1,542M, which includes a 41% contingency (($448M.) The project identified and presented three levels of contingency: estimate uncertainty, risks and top-down uncertainty. The project has applied 25% contingency for estimate uncertainty ( $272M), 5% risk contingency ($50M) and 12% for top-down contingency ($126M.) The current TPC includes actuals from FY10 and FY11 spending. The cost range of the project is $1,150M to $1,750M based on the AACE cost range criteria table. All costs herein and as presented to the committee are in FY10$. A DOE approved funding profile has not been agreed to, but the obligation profile assumed by the project and presented for this review is provided below.




- The LBNE project cost estimate is supported by the BOE documentation and several independent reviews. The BOE documentation is consistent at the subproject level. The project team has concisely organized the BOE sheets and cost reports from the project accounting system Cobra according to WBS in a cost estimate plan document.

- The LBNE project schedule includes high-level milestones for major procurements within all the subprojects. The project team has done a good job of incorporating procurement task details into the schedule and was able to present an obligation vs. expenditure profile.

## Comments

- The LBNE project team did not present a clear process as to how the project plans to update the cost estimate of the project and integrate this information into P6 and Cobra as the project goes forward. Such a process would be very beneficial is and would streamline the process of updating the cost of the project.

- While the BOE documentation is mostly homogeneous at the subproject level, it was not presented consistently in the breakout sessions and appeared cumbersome. Not all individuals from the project that were answering the questions or running the software during the cost drilldown process appeared to be comfortable or confident in that situation. A consolidated approach and clear and uniform method needs to be rehearsed so that project presenters can efficiently walk through the documentation traces. The level of detail the project has completed was confusing to the committee in some areas as presented.

- The project has done a very good job of implementing a process to identify high-level project risks. Cost and schedule impacts for those risks are identified in the project management risk register. The project should revisit the risk process given that the current schedule has several gaps in the labor spread, which creates an unrealistic expectation of meeting the proposed labor demand.

- The project did not present the distribution of contingency within the current funding profile. It would be useful for the project to show the contingency in the funding profile and clearly label the amount of contingency for each type of contingency applied to the project cost.

- An obligation profile was presented; however, the project team should consider having the obligation profile reviewed by a procurement expert to determine the validity of the profile. The project should consider hiring a procurement manager/coordinator to assist with creating a more realistic procurement model. The manager/coordinator could oversee managing procurements throughout the project (at all facilities) and help with getting procurements through the approval process at all levels.

- It would be helpful if the project team showed the total FTEs, including M&S labor (i.e. augmented staff), working on various subsystems of the project so that reviewers recognize that adequate labor from all sources has been scheduled to achieve the project goals. Otherwise, it appears as if the project has not accounted for total labor needs, thus not fully estimated the true cost of the project.

- The project should put plans in place to fully define and account for the cost of spares.

- Project management should understand potential scope contingency and when it could be executed. Be prepared to discuss options, later in the project, for cost reductions (which would only be executed if costs start to increase).

- The project should consider revisiting how contingency was applied to the conventional facilities, rather than applying 30% at the Near Site and 35% at the Far site. Some aspects of conventional facilities may have less risk than others and this could potentially present a cost savings to the project.

- LBNE staff (when presenting material at CD-1) should be comfortable with and understand the impact to their schedules and cost profiles of any optimization process performed by the project office.

## Recommendations

23. Implement a process for updating the cost estimates for the entire project and integrating these new estimates into the P6 and Cobra systems seamlessly. Provide consistency across the project for how costs are integrated into the P6 and Cobra systems and keep communication about the costs flowing across the various collaborators on the project.

24. Present total FTEs, including M&S labor (augmented staff), working on various subsystems of the project so that reviewers recognize that sufficient labor from all sources has been scheduled to achieve the goals of the project.

25. Verify that cost information presented at the various levels of the project consistently identifies what that cost represents. Identify what is included in the number presented (i.e. base, overheads, cost estimate uncertainty contingency, risk event contingency, top down contingency).

### 3.4.2 Schedule

#### Findings

- LBNE schedule spans January 2010 to June 2025, including 1 year schedule contingency identified and held at the end of the project.

- The Resource Loaded Schedule (RLS) is composed of 6 integrated subprojects with a combined activity count of 6112. Of these activities, 5313 are labor/nonlabor unit loaded (87%) with costed and uncosted resources. A subset of these (667) is resource loaded to represent obligation requirements only.

- There are 549 milestones identified within the RLS. Milestones are developed at the project, internal/external, and subproject areas. Documents exist establishing the interfaces and mechanism of linking between these areas. However, a hierarchical level of milestones, rationale for schedule contingency associated within these levels, and major milestones associated with key prototype transitions are needed.

- The RLS contains 10,417 linked relationships, 801 open relationships (13%) and 190 constraints (3%).

- The LBNE Critical Path is defined as activities with total float of less than or equal to zero and runs from Conventional Facilities to Liquid Argon. Near Critical Path was presented as those activities with less than or equal to 30 days of total float.

- Multiple schedule iterations were developed after the initial, technically driven schedule was deemed unfundable. The current iteration results in a funding-driven, effort restricted schedule with an extended end date.

#### Comments

- Improvements have been made to the resource loading of the schedule based on previous review recommendations (costed and noncosted resources included). However, smoothing across all of the subproject levels is required for a realistic ability to execute.

- The funding-driven schedule creates significant and potentially unrealistic jumps in effort, deferred procurements, and out of sync prototype development in almost all of the subprojects. Recent efforts to rapidly adapt the schedule to changes in the funding profile have led to unworkable schedules for detector development and fabrication, specifically.

- The project team recognizes that tiered levels of milestones would help manage the project by the appropriate level of exception (internal, site office, HQ), clearly communicate internal interface handoffs (LAr1 to APA), and assist in depicting the level of schedule float required to confidently deliver the identified scope.

- Schedule consistency and ownership was not displayed below the WBS Level 2 during many of the subproject presentations.

- While significant strides have been made with regards to risk and cost, further analysis needs to be conducted as it applies to the schedule. Specifically, there was no justification for the 1-year of float that currently exists on the project, and there is a lack of "typical" schedule risk mitigations such as continuing resolutions (e.g., FY funding milestones are scheduled to start Oct 1, but new FY funds are subject to frequent delay; hence consider a reasonable, consistent and defendable assumption, perhaps in the range of several months.)

- It was not demonstrated that the project has split schedule contingency into technical schedule contingency and funding profile schedule contingency. The point is to show that you have identified the largest risks to the schedule (particularly on the critical path) and that the schedule and cost contingency is being directed to it based on those risks.

- Based on issues discovered in some subproject areas, additional schedule iterations should be performed for general housekeeping on task types, length of tasks, appropriate logic, and number of/ and reasons for constraints.

- In order to assist in depicting planned work to reviewers, it would be very helpful if the project team were to show Gantt Chart style graphs of the scheduled work during the schedule drill downs. This will show that the timing of the work coincides with the costs and highlights how the items on the critical path actually impact the integrated schedule.

## Recommendations

26. Once the funding profile is known, continue iterations on schedule across all subprojects to level unrealistic spikes/lulls in resource needs, procurements, and prototype development. Include a review of general housekeeping on task types, length of tasks, number of constraints, and logic links in this process prior to DOE CD-1 review.

27. Complete milestone hierarchy analysis, schedule float determination/justification, and addition of any missing major milestones prior to DOE CD-1 review.

28. Perform a schedule risk analysis and incorporate mitigations as needed into the baseline schedule to confirm the amount of schedule contingency proposed is adequate.

### 3.4.3 Management

#### Findings

- The LBNE project presented an integrated scope, cost & schedule range, risk assessment and supporting management plans for this pre-CD-1 FNAL Director's Review. The project received CD-0 approval on January 8, 2010, and has completed about 20% of the design according to the Project Manager. Through February 2012, the project has spent $37M against a notional TPC of $1542M (FY2010$).

- The project presented a CD-1 cost range of $1150M-$1750M. The preliminary TPC of $1542M includes $448M in contingency (~41%). All costs estimated in FY10$.

- The CD-1 proposed schedule range, with CD-4 proposed as 3Q FY2024, includes 12 months of float.

- There is no DOE-agreed funding profile for LBNE; the project has made assumptions that include the approved level of funding for FY2013.

- As described by the Preliminary PEP and PMP, the LBNE project consists of a large number of organizations with mutually supportive responsibilities for designing and constructing a very complex and expensive (>$1B) project. The respective roles and reporting relationships amid the 4 principal LBNE partners (FNAL, LANL, BNL, and LBNL/SURF), the LBNE advisory committee and the supporting scientific collaboration (a large number of laboratories and universities) are complex and present many interfaces.

- The LBNE project team has established effective communications and working relationships at this phase of the project with all of their participating partners, including the SURF at Lead, South Dakota. Relationships with LBNL and SURF are planned to be formalized in an MOU, but this document is not yet in draft form.

- The LBNE project team presented a well-developed set of management systems and project plans required for CD-1 that they have employed effectively to develop a cost estimate, an integrated schedule, Integrated Safety Management Planning and Risk Management, among other systems and documentation. These systems all appear compliant with DOE O 413.3B. A number of inconsistencies and areas to be updated were noted during review of these plans.

- FNAL management demonstrated strong commitment to a successful outcome of LBNE. A number of approaches to resource planning within FNAL and ensuring continuing support of the LBNE partners and collaborators in such a widely distributed collaboration were discussed with the LBNE/FNAL management team.

- The project has an active approach to risk management. Risks have been identified and mitigation plans have been developed and implemented. Detailed risk registries are available. The LBNE Risk management board (RMB) has been established and includes membership from project management and the L2 managers. The committee reviewed risks that have been identified by LBNE team members and discussed in detail at two risk workshops. The project office worked with each L2 manger, reviewed the risks and identified the ones (generally the med and high) to be managed by the project office. Lower level risks are managed at the subproject level and through the Project Risk Manager. The risk workshops were also used to develop mitigation plans.

- The project has a strong program of value engineering in place that has generated ~ $350M in savings/avoidance during the early design phases, as reported by the Project.

- SURF has a change control board for processing changes to current planned work, which is functioning smoothly according to the SURF Director. So far this is independent of LBNE change management but will eventually need to be folded in.

- There is effective although still informal coordination between LBNE and SURF on ESH and in other areas.

### Comments

- Although the project plan documents are clear, the understanding of the LBNE organization and roles as presented during this review by various levels of LBNE management varies.. It is particularly important to complete, before CD-1, the MOU that will describe the LBNL/SURF/FNAL relationships.

- The lack of an agreed funding profile and a $180M funding cap per fiscal year has created discontinuities in annual resource planning across the project. The project acknowledges that there have been only minimal attempts to level and plan realistic resource profiles at this stage.

- Once accepted for CD-1, the project should consider closely controlling changes to the reference scope/estimate/schedule as the design completes, including through early implementation of some level of formal change control. Such an approach can assist in managing potential growth in estimates and schedule as the design develops and the project proceeds to CD-2.

- Procurement planning is behind expectations for this stage of the project for what is needed to progress quickly post-CD-1. No advance procurement planning has followed beyond the broad draft Acquisition Plan; an LBNE Procurement specialist is needed now to work with the technical and scheduling staff.

- No comprehensive staffing plan was presented for this review. Such a comprehensive plan is crucial to ensure that the resources essential to making

required progress in all areas of the project following CD-1 are identified and a path to getting resources in place exists. Presentations of staffing plans should also include a means to demonstrate that appropriate management and technical experience/expertise exists within the project (biographies, etc.)

- An assessment of risks attendant to the de-selection of the WCD may be worth re-visiting. Additional risk mitigation planning should consider strategies to reduce risks through early awards of contracts, including items that could be considered for authorization in conjunction with each CD milestone/request approval. Consider developing risk burn-down plots to document the cost and schedule risk reductions that have already been made and to clearly identify upcoming milestones and funding usage targeted on further risk reduction. A list summarizing the ~ $350M of value engineering savings would be useful to show the work that has already been accomplished as well as identifying proposed VE items.

- The LBNE conceptual design includes components designed to accept a future beam power upgrade from 700kW to 2.3MW. Such an upgrade is not explicit within the Mission Need Statement/CD-0 documentation and entails added costs that may evolve/grow as the design develops.

## Recommendations

29. Complete all LBNE project participant MOUs before presenting the project for CD-1. Assess if sufficient clarity and understanding within the integrated LBNE staff exists regarding the key relationships of the participating labs, advisory committees and the scientific collaboration. Ensure that there is appropriate formality between participants, including contractually, that establishes unambiguous accountability for funds, safety and deliverables.

30. Get agreement with DOE on a funding profile well in advance of CD-1 reviews and ensure that the proposed cost/schedule/procurements/resources and plans are self-consistent.

31. Consider placing the CD-1 cost estimate/schedule/scope under some effective form of change control in order to manage potential cost and schedule growth.

32. Prior to CD-1, develop an integrated staffing plan that would permit smooth transition into post-CD-1 work, having already identified and prioritized needed skills and planned recruiting. Accelerate advance procurement planning with an assigned procurement specialist and develop other remaining near-term resource/staff needs for discussion and planning within the partnership institutions so that project and institutional budgets can be aligned.

33. Ensure that planned upgrade paths are clearly justified and associated costs are understood and appropriate to be included in the project.

### 3.4.4 ES&H

#### Findings

- ESH & QA requirements for CD-1 have been met.

#### Comments

- The Preliminary Hazard Analysis addresses the topics and scope to achieve CD-1 requirements. Several editorial changes that were discussed with the LBNE Safety Manager will be incorporated into the next draft of the document. Future iterations of the document should include additional information describing the integration of the DOE Labs and SURF. Some consideration should be given to dividing the PHA into 2 sections (those hazards present at FNAL and those present in South Dakota) or 3 sections (Beamline, Near and Far Detector.) The document must include the integration of all of the DOE and SURF facilities involved in LBNE. An indication of buy in/signoff by these entities should be included on the approval pages.

- LBNE poses QA coordination concerns because of the different QA plans at each of the DOE Facilities involved in LBNE. The LBNE QA Plan should identify how cross-Laboratory quality issues are resolved and how intra-laboratory deliverables will be managed with respect to quality needs. The document must include the integration of all of the DOE and SURF facilities involved in LBNE. An indication of buy in/signoff should be included on the approval pages.

- The LBNE ISMS document seems a bit Fermi-centric. It does not describe the reporting process for safety concerns, injuries, incidents, etc. across the DOE/SURF line or how these things are reported from facility back to LBNE management. The document must include the integration of all of the DOE and SURF facilities involved in LBNE. An indication of buy in/signoff by these entities should be included on the approval pages.

- A Draft Preliminary Security Vulnerability Assessment has been issued. An indication of buy in/signoff by both SURF and FNAL should be included on the approval page.

- A process is in place to comply with DOE O 451.1b Environmental Compliance Strategies.

- Presently, the SURF Director is filling in as the Acting ESH Director for the SURF Facility, and the SURF Engineering Manager is filling in as Acting Safety & Health Manager. Both individuals have strong management backgrounds but may lack the ESH expertise and background to develop and grow the SURF ESH Program. These dual assignments at SURF may not allow for the necessary time and focus that the ESH Director and Managers positions require. The need to fill these positions with qualified ESH personnel is critical in providing the necessary priorities and focus to the continued development of the ESH Program at SURF.

## Recommendations

34. Consider adding a Risk Analysis specific to ODH to the Preliminary Hazard Analysis. The topic has been analyzed by LBNE. This analysis is sure to undergo further reviews as systems, equipment and infrastructure become more clearly defined. ODH will continue to be a topic of discussion at future reviews. Presenting an ODH Risk Analysis in the PHA is a way to indicate the importance of the ongoing analysis.

35. The project should encourage SDSTA to put a high priority on placing ESH professionals in open management positions.

## 3.5 Charge Questions

### 3.5.1 Has the Project developed a quality resource loaded schedule that includes the entire project's scope of work and is it achievable?

Yes, the LBNE project team has developed a CD-1 quality resource-loaded schedule that includes the entire project's scope of work. However, the resource-loaded schedule as presented is not realistic due to the major gaps in the funding and labor profiles.

### 3.5.2 Are the estimated cost and proposed schedule ranges realistic, consistent with the technical and budgetary objectives, and justified by the supporting documentation? Has all the work been appropriately identified, estimated and scheduled, including the work associated with performing the preliminary design, final design and value engineering activities?

Yes, the estimated cost ranges are realistic and consistent with the budgetary and technical objectives and are justified by the supporting documentation. However, the schedule ranges are not realistic or appropriate for a technical design effort as the schedule is funding driven. The large gaps in the design and production aspects of the project are not realistic. All the work required for each stage of design and value engineering has been identified, estimated and scheduled.

### 3.5.3 Has the Project implemented a Risk Management Process by identifying risks, performing a risk assessment and started developing mitigation plans at an appropriate level for the CD-1 stage?

Yes. The project has an active approach to risk management. Risks have been identified and mitigation plans have been developed and implemented for cost but need to be further defined/implemented for schedule. Detailed risk registries are available and exceed the requirements for CD-1.

### 3.5.4 Is the Project Team adequately staffed and does it possess adequate experience to successfully carry out the Project?

Yes. The project team contains the needed experience and is acceptably staffed for this stage considering current tight budgets. With a large fraction ~(78%) of the project estimated cost in procurements rather than labor, experienced procurement personnel should be added to the project not later than CD-1 to support advance procurement planning for the next phase.

### 3.5.5 Is the current staffing level adequate to complete the work to achieve CD-2? If not, has the appropriate staffing level been identified in the schedule and has a staffing plan been developed to acquire the future staffing needs?

No. Project staffing plans are incomplete. Some LBNE staff reported concerns in being able to ramp quickly in technical positions post-CD-1 in order to complete the design. For CD-1, such plans should be developed and presented for the work planned between CD-1 and CD-2. The schedule resources appear to account for the total needed FTEs. The actual FTE requirements remain unclear until a viable budget scenario emerges. The current plan requires a large build up in staff over the next few years.

### 3.5.6 Are ES&H aspects being properly addressed given the project's current stage of development?

Yes, pending receipt of the DOE NEPA Memo of Determination as scheduled on July 14, 2012 The ESH deliverables for achieving CD-1 are all present. The current format of Project wide ESH documents may not fully reflect the necessary involvement and integration of the other DOE facilities and the SURF organization.

### 3.5.7 Is the documentation required by DOE O 413.3B in order and is the LBNE Project ready for a DOE CD-1 review?

The necessary documentation is in place. However, the proposed scope/cost/schedule reference is not self-consistent in resource plans and the schedule, largely due to funding profile changes and constraints. The required CD-1 documentation is well developed but also contains funding-driven inconsistencies that require correction before presenting for CD-1.

# Appendices

A. Charge

B. Agenda

C. Reviewer Writing Assignments

D. Reviewer Breakout Assignments

E. Reviewers Contact Information

F. Recommendations Table

Appendix A

# Charge

Director's Independent Conceptual Design and CD-1 Readiness Review of the LBNE Project
March 26-30, 2012

The Committee is to conduct a Director's Review of the Long-Baseline Neutrino Experiment (LBNE) Project. This review consists of two parts, the first part is an Independent Conceptual Design Review and the second is a Critical Decision 1 (CD-1) Readiness Review. The LBNE Project received CD-0 on January 8, 2010. LBNE anticipates receiving DOE Critical Decision 1 (CD-1) "Approve Alternative Selection & Cost Range" the summer of 2012.

The Long-Baseline Neutrino Experiment (LBNE) Project will build new facilities to enable a world-class program in neutrino physics focused on precision measurements of the neutrino mixing matrix via $\nu_\mu \rightarrow \nu_e$ appearance and $\nu_\mu$ disappearance measurements, with goals of determining the sign of the mass hierarchy and searching for CP violation in the lepton sector. It will: build a new neutrino beam at Fermilab directed towards a detector complex >1000 km away, currently planned to be in the Sanford Underground Laboratory at Homestake in Lead, South Dakota ; a liquid argon TPC detector deep underground at the far site to measure the properties of the neutrinos after they travel 1300 km through the earth; a near detector complex on the Fermilab site to measure the neutrino beam properties at the source; and conventional facilities at Fermilab and Sanford Laboratory required to support the beam and detector systems. The liquid argon TPC detector at the far site, in addition to measuring neutrino oscillation parameters, will also enable a broad program in proton decay and neutrino astrophysics. Fermilab is the lead laboratory for the overall LBNE Project. BNL and LANL are partnering with Fermilab to provide key elements of the Project.

The Independent Conceptual Design part of the review is to verify that LBNE's design is technically adequate and should achieve the Project's scientific goals. To meet the requirements for CD-1 the design has to be at the conceptual level or greater. The committee will make their assessment based on LBNE's Conceptual Design Report (CDR), drawings, specifications, and discussions with the project team.

For the CD-1 Readiness part of the review the Committee will focus on the project's cost, schedule, management, and ES&H. The project will present a Cost Range that the review and the committee is to assess and determine if it is appropriate based on the following factors: the scope of work; the maturity of the design; the Basis of Estimate (BOE); and the risks associated with the scope of work. The team will also look at the WBS – Work Breakdown Structure, WBS Dictionary, BOE – Basis of Estimate documentation, risk and contingency analyses, RLS – Resource Loaded Schedule, and time phased funding and cost profiles. The committee is asked to review each of these items, for quality, completeness, and accuracy. Furthermore, the committee is asked to review and assess the quality of and comment on the additional formal project management documentation required for CD-1 approval

The review committee is asked to address the following questions to assess the Project's progress:

<u>Independent Conceptual Design Review Charge Questions</u>

1. Are the science goals and physics requirements clearly stated and documented? Do the science goals and physics requirements meet the objectives described in the LBNE Physics Research Goals? Have the science goals and physics requirements been adequately translated into technical performance requirements and specifications?
2. Is the design technically adequate? Is the design likely to meet the technical requirements needed to carry out the scientific goals?
3. Can the design be constructed, inspected, tested, installed, operated and maintained in a satisfactory way?
4. Is there adequate supporting documentation to support the conceptual design and the transition to developing the preliminary design?
5. Are the risks (on technical, cost, and schedule basis) of the selected base design approach and alternatives understood and are appropriate steps being taken to manage and mitigate these risks? Have areas been identified where value engineering should be done? If value engineering has been performed is it documented?
6. Are the project organization and lines of responsibility clearly defined and sufficient to ensure the successful engineering and design of the project? Are the design interfaces between the Accelerator Systems, Experimental Facilities, and Conventional Facilities groups understood and well enough defined to ensure a coordinated effort and an integrated design? Is there a reasonable plan in place for implementing configuration management to ensure changes to the technical requirements/specifications are controlled and communicated to all affected groups?

<u>CD-1 Readiness Review Charge Questions</u>

7. Has the Project developed a quality resource loaded schedule that includes the entire project's scope of work and is it achievable?
8. Are the estimated cost and proposed schedule ranges realistic, consistent with the technical and budgetary objectives, and justified by the supporting documentation? Has all the work been appropriately identified, estimated and scheduled, including the work associated with performing the preliminary design, final design and value engineering activities?
9. Has the Project implemented a Risk Management Process by identifying risks, performing a risk assessment and started developing mitigation plans at an appropriate level for the CD-1 stage?
10. Is the Project Team adequately staffed and does it possess adequate experience to successfully carry out the Project?
11. Is the current staffing level adequate to complete the work to achieve CD-2? If not, has the appropriate staffing level been identified in the schedule and has a staffing plan been developed to acquire the future staffing needs?
12. Are ES&H aspects being properly addressed given the project's current stage of development?
13. Is the documentation required by DOE O 413.3B in order and is the LBNE Project ready for a DOE CD-1 review?

Finally, the committee should present findings, comments, recommendations, and answers to the above questions at a closeout meeting with LBNE and Fermilab's management. A written report will be provided within two weeks after the review.

Appendix B

# Agenda

Director's Independent Conceptual Design and CD-1 Readiness Review of the LBNE Project
March 26-30, 2012

**Note: Detailed Agenda at https://indico.fnal.gov/conferenceTimeTable.py?confId=5301#20120326**

## Monday, March 26

**EXECUTIVE SESSION –Comitium (WH2SE)**

| | | | | |
|---|---|---|---|---|
| 8:00 – 9:00 | AM | 60 | Executive Session | |

**PLENARY SESSION – One West (WH1W)**

| | | | | |
|---|---|---|---|---|
| 9:00– 9:15 | AM | 15 | Welcome | Pier Oddone |
| 9:15 – 9:30 | AM | 15 | Science Requirements | Mind Diwan |
| 9:30 – 10:15 | AM | 45 | Project Overview | Jim Strait |
| **10:15 – 10:30** | **AM** | **15** | **BREAK** | |
| 10:30 – 11:10 | AM | 40 | Conventional Facilities Overview | Tracy Lundin |
| 11:10 – 11:40 | AM | 30 | Beam Overview | Vaia Papadimitriou |
| 11:40 – 12:00 | AM | 20 | Near Detector | Christopher Mauger |
| **12:00 – 1:00** | **PM** | **60** | **LUNCH** | |

**PLENARY SESSION – One West (WH1W)**

| | | | | |
|---|---|---|---|---|
| 1:00- – 1:30 | PM | 30 | LAr TPC Overview | Bruce Baller |
| 1:30 – 2:00 | PM | 30 | Cost and Schedule Range & Cost Drivers | Jim Strait |
| 2:00 – 2:15 | PM | 15 | Cost and Schedule Methodology | Bob O'Sullivan |
| 2:15 – 2:30 | PM | 15 | Requirements Development | Elaine McCluskey |
| **2:30 – 2:50** | **PM** | **20** | **BREAK** | |

**PARALLEL PLENARY SESSIONS**

2:50 – 4:00 PM 70

Session 1: Detector – Black Hole (WH2NW)
Session 2: Beamline- Hornets' Nest (WH8X)
Session 3: Conventional Facilities- One North (WH1N)
Session 4: Project Management- Snake Pit (WH2NW)

| | | |
|---|---|---|
| 4:00 – 5:30 | PM | Subcommittee Executive Sessions – in Parallel Plenary Rooms |
| 5:30 – 6:30 | PM | Executive Session - (WH??) |
| 6:30 | PM | Dinner |

## Tuesday, March 27

**PARALLEL BREAKOUT SESSIONS**
8:00 – 10:00 AM 120
Session 1: Detector – See detailed agenda for rooms
Session 2: Beamline- See detailed agenda for rooms
Session 3: Conventional Facilities- One North (WH1N)
Session 4: Project Management- Snake Pit (WH2NW)

**10:00 – 10:15 AM 15 BREAK (actual break time vary by breakout session – see detailed agenda)**

**PARALLEL BREAKOUT SESSIONS - continued**
10:15 – 12:00 AM 75
Session 1: Detector – See detailed agenda for rooms
Session 2: Beamline- See detailed agenda for rooms
Session 3: Conventional Facilities- One North (WH1N)
Session 4: Project Management- Snake Pit (WH2NW)

**12:00 – 1:00 PM WORKING LUNCH (actual time vary by breakout session – see detailed agenda)**

**PARALLEL BREAKOUT SESSIONS - continued**
1:00 – 2:45 PM 105
Session 1: Detector – See detailed agenda for rooms
Session 2: Beamline- See detailed agenda for rooms
Session 3: Conventional Facilities- One North (WH1N)
Session 4: Project Management- Snake Pit (WH2NW)

**2:45 – 3:00 PM 15 BREAK (actual break time vary by breakout session – see detailed agenda)**

**PARALLEL BREAKOUT SESSIONS - continued**
3:00 – 4:00 PM 60
Session 1: Detector – See detailed agenda for rooms
Session 2: Beamline- See detailed agenda for rooms
Session 3: Conventional Facilities- One North (WH1N)

4:00 – 5:00 PM Subcommittee Executive Sessions – in Parallel Plenary Rooms
5:00 – 6:00 PM Executive Session - Comitium (WH2SE)

**Wednesday, March 28**

8:00– 9:00 PM 60 Response to reviewer questions – One West **(WH1W)**

**PARALLEL BREAKOUT SESSIONS - continued**
9:00 – 10:30 AM 90
Session 1: Detector – See detailed agenda for rooms
Session 2: Beamline- See detailed agenda for rooms
Session 3: Conventional Facilities- One North (WH1N)

**10:30 – 10:45 AM 15 BREAK (actual break time vary by breakout session – see detailed agenda)**

**PARALLEL BREAKOUT SESSIONS - continued**
10:45 – 12:00 AM 75
Session 1: Detector – See detailed agenda for rooms
Session 2: Beamline- See detailed agenda for rooms
Session 3: Conventional Facilities- One North (WH1N)

**12:00 – 1:00 PM WORKING LUNCH (actual time vary by breakout session – see detailed agenda)**

**PARALLEL BREAKOUT SESSIONS - continued**
1:00 – 2:45 PM 105
Session 1: Detector – See detailed agenda for rooms
Session 2: Beamline- See detailed agenda for rooms
Session 3: Conventional Facilities- One North (WH1N)

**2:45 – 3:00 PM 15 BREAK (actual break time vary by breakout session – see detailed agenda)**

**PARALLEL BREAKOUT SESSIONS - continued**
3:00 – 5:00 PM 120
Session 1: Detector – See detailed agenda for rooms
Session 2: Beamline- See detailed agenda for rooms
Session 3: Conventional Facilities- One North (WH1N)

5:00 – 6:00 PM Subcommittee Executive Sessions – in Parallel Plenary Rooms
6:00 – 6:30 PM Executive Session - Comitium (WH2SE)

## Thursday, March 29

**PARALLEL BREAKOUT SESSIONS - continued**
9:00 – 10:30 AM 90
Session 1: Detector – See detailed agenda for rooms
Session 2: Beamline- See detailed agenda for rooms
Session 3: Conventional Facilities- One North (WH1N)

**10:30 – 10:45 AM 15 BREAK (actual break time vary by breakout session – see detailed agenda)**

**PARALLEL BREAKOUT SESSIONS - continued**
10:45 – 12:00 PM 75
Session 1: Detector – See detailed agenda for rooms
Session 2: Beamline- See detailed agenda for rooms
Session 3: Conventional Facilities- One North (WH1N)

**12:00 – 1:00 PM WORKING LUNCH**

1:00 – 3:00 PM Subcommittee Executive Sessions/Report Writing – in Parallel Plenary Rooms
3:00 – 5:00 PM Executive Session/Report Writing - **Comitium (WH2SE)**

## Friday, March 30

| | | |
|---|---|---|
| 9:00 –1:00 | PM | Full Committee Executive Session Dry Run –**Comitium (WH2SE)** with Working Lunch |
| 1:00 | PM | Closeout Presentations – **One West (WH1w)** |
| 2:00 | AM | Adjourn |

Appendix C

# Reviewer Writing Assignments

Director's Independent Conceptual Design and CD-1 Readiness Review of the LBNE Project
March 26-30, 2012

| | |
|---|---|
| Executive Summary | Bill Christie |
| 1.0 Introduction | |
| 2.0 Technical Design | |
| 2.1 Detectors | |
| 2.1.1 LAr Far Detector | |
| 2.1.1.1 LAr - Cryogenics and Cryostat | Johan Bremer<br>Tom Peterson<br>Michael Geynisman |
| 2.1.1.2 LAr -TPC/DAQ/Electronics | Eric James<br>Sten Hansen |
| 2.1.2 Near Detector Complex (NDC) | |
| 2.1.2.1 NDC - Cryogenics and Cryostat | Tom Peterson<br>Johan Bremer<br>Michael Geynisman |
| 2.1.2.2 NDC -TPC/DAQ/Electronics | Sten Hansen<br>Eric James |
| 2.2 Beamlines | |
| 2.2.1 Primary Beam | Dave Johnson<br>Keith Gollwitzer<br>Tom Kobilarcik |
| 2.2.2 Neutrino Beam | Steve Holmes<br>Peter Kasper<br>Chris Polly |
| 2.2.3 System Integration | Peter Kasper<br>Tom Kobilarcik<br>All of Subcommittee |
| 2.3 Conventional Facilities (CF) | |
| 2.3.1 CF – Near Site | |
| 2.3.1.1 Civil/Site Work | Tom Lackowski<br>Jason Budd |
| 2.3.1.2 Rock Excavation | David Jurich |
| 2.3.1.3 Buildings & Infrastructure | David Taylor<br>Jason Budd |
| 2.3.2 CF – Far Site | |
| 2.3.2.1 Civil/Site Work | Tom Lackowski<br>Jason Budd |
| 2.3.2.2 Rock Excavation | David Jurich |
| 2.3.2.3 Buildings & Infrastructure | Jason Budd<br>David Taylor |
| 2.4 Technical Design Charge Questions | |
| 2.4.1 Are the science goals and physics requirements clearly stated and documented? Do the science goals and physics requirements | Steve Holmes<br>All |

| | |
|---|---|
| meet the objectives described in the LBNE Physics Research Goals? Have the science goals and physics requirements been adequately translated into technical performance requirements and specifications? | |
| 2.4.2 Is the design technically adequate? Is the design likely to meet the technical requirements needed to carry out the scientific goals? | Tom Peterson<br>All |
| 2.4.3 Can the design be constructed, inspected, tested, installed, operated and maintained in a satisfactory way? | Eric James<br>All |
| 2.4.4 Is there adequate supporting documentation to support the conceptual design and the transition to developing the preliminary design? | Chris Polly<br>All |
| 2.4.5 Are the risks (on technical, cost, and schedule basis) of the selected base design approach and alternatives understood and are appropriate steps being taken to manage and mitigate these risks? Have areas been identified where value engineering should be done? If value engineering has been performed is it documented? | Tom Lackowski<br>All |
| 2.4.6 Are the project organization and lines of responsibility clearly defined and sufficient to ensure the successful engineering and design of the project? Are the design interfaces between the Accelerator Systems, Experimental Facilities, and Conventional Facilities groups understood and well enough defined to ensure a coordinated effort and an integrated design? Is there a reasonable plan in place for implementing configuration management to ensure changes to the technical requirements/specifications are controlled and communicated to all affected groups? | David Taylor<br>All |
| 3.0 CD-1 Readiness | |
| 3.1 Detectors | Johan Bremer<br>All of Subcommittee |
| 3.2 Beamline | Steve Holmes<br>All of Subcommittee |
| 3.3 Conventional Facilities | Jason Budd<br>All of Subcommittee |
| 3.4 Project Management | |
| 3.4.1 Cost | Elmie Peoples-Evans<br>Jennifer Fortner<br>Pete Selgrad<br>All |
| 3.4.2 Schedule | Jennifer Fortner<br>Elmie Peoples-Evans<br>Pete Selgrad |
| 3.4.3 Management | Carl Strawbridge<br>Brenna Flaugher<br>All |
| 3.4.4 ES&H | Jim Lang |
| 3.5 Charge Questions | |
| 3.5.1 Has the Project developed a quality resource loaded schedule that includes the entire project's scope of work and is it achievable? | Pete Selgrad<br>All |
| 3.5.2 Are the estimated cost and proposed schedule ranges realistic, consistent with the technical and budgetary objectives, and justified by the supporting documentation? Has all the work been | Elmie Peoples-Evans<br>All |

| | | |
|---|---|---|
| | appropriately identified, estimated and scheduled, including the work associated with performing the preliminary design, final design and value engineering activities? | |
| | 3.5.3 Has the Project implemented a Risk Management Process by identifying risks, performing a risk assessment and started developing mitigation plans at an appropriate level for the CD-1 stage? | Brenna Flaugher<br>All |
| | 3.5.4 Is the Project Team adequately staffed and does it possess adequate experience to successfully carry out the Project? | Brenna Flaugher<br>All |
| | 3.5.5 Is the current staffing level adequate to complete the work to achieve CD-2? If not, has the appropriate staffing level been identified in the schedule and has a staffing plan been developed to acquire the future staffing needs? | Carl Strawbridge<br>All |
| | 3.5.6 Are ES&H aspects being properly addressed given the project's current stage of development? | Jim Lang |
| | 3.5.7 Is the documentation required by DOE O 413.3B in order and is the LBNE Project ready for a DOE CD-1 review? | Bill Christie<br>All |

*Underlined names are the primary writer(s).

Appendix D

# Reviewer Breakout Assignments

Director's Independent Conceptual Design and CD-1 Readiness Review of the LBNE Project
March 26-30, 2012

| Subcommittee | Breakout Subgroups | Members |
|---|---|---|
| Detectors | Cryogenics & Cryostat (D1) | Johan Bremer* -CERN<br>Michael Geynisman - FNAL Tom Peterson - FNAL |
| | TPC, DAQ, Electronics (D2) | Sten Hansen - FNAL<br>Eric James - FNAL |
| Beamlines | Primary Beam (B1) | Keith Gollwitzer - FNAL<br>Dave Johnson - FNAL<br>Tom Kobilarcik - FNAL |
| | Neutrino Beam(B2) | Steve Holmes*- FNAL<br>Chris Polly - FNAL<br>Peter Kasper - FNAL |
| Conventional Construction | None | David Taylor* - Sanford<br>Jason Budd – ANL<br>David Jurich - Consultant<br>Tom Lackowski - FNAL |
| Project Management | None | Carl Strawbridge* - Consultant<br>Brenna Flaugher – FNAL<br>Jennifer Fortner - ANL (Detector)<br>Elmie Peoples-Evans – FNAL (Beamline)<br>Pete Selgrad – BNL (CF) |

* Indicates Subcommittee Chair

Appendix E

# Reviewers' Contact Information

Director's Independent Conceptual Design and CD-1 Readiness Review of the LBNE Project
March 26-30, 2012

| | |
|---|---|
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Appendix F

# Recommendation Table

Director's Independent Conceptual Design and CD-1 Readiness Review of the LBNE Project
March 26-30, 2012

| # | Recommendations | Assigned to | Status/Action | Date |
|---|---|---|---|---|
| | **2.0 Technical Design** | | | |
| | **2.1 Detectors** | | | |
| | **2.1.1 LAr Far Detector** | | | |
| | **2.1.1.1 LAr - Cryogenics and Cryostat** | | | |
| | **LAr - Cryogenics** | | | |
| 1. | Continue to work through the implications of the deep detector location. In particular, investigate failure modes. For example, consider failure modes of the pressure reducing system for liquid transfer, review assumptions in the ODH analysis such as the flow restriction at the surface, etc., with respect to the deep cavern location. | | | |
| 2. | Place at least part of the nitrogen liquefiers (for example compressors) at the surface, if possible. | | | |
| 3. | Due to the very small operational margin in the cryostat gas pressure, study the cool-down, filling, normal operation and warming-up procedures in the early stages of the project (for example in LAr-1). | | | |

| # | Recommendations | Assigned to | Status/Action | Date |
|---|---|---|---|---|
| 4. | Cryostat cool-down temperature uniformity requirements should be developed. Cryostat cool-down temperature uniformity should be analyzed and then compared to these requirements to limit excessive thermal stresses in the cryostat and TPC arrays. Since the proposed VE LAr-016 foresees the liquefaction of argon in the underground area, it could also be foreseen that argon gas at any temperature can be delivered by this system to be used during the cool down of the cryostats. | | | |
| 5. | Try to eliminate all possibilities which could lead to the opening of the mechanical under-pressure device protecting the cryostat against under-pressure via air-inlet. A controlled heater system could do such a job, avoiding for example that the air inlet will be opened during the commissioning of the cryogenic system. | | | |
| 6. | If the VE LAr-016 is approved, one should study the increase of the liquid nitrogen storage capacity in the underground area. During the review in November 2010, the reviewers recommended increasing the foreseen nitrogen storage such that a period longer than 40 hours could be covered. The actual period foreseen is 28 hours. The VE LAr-016 would make the project even more dependent on the underground stored liquid nitrogen volume in case of power cuts, etc. | | | |
| 7. | LAr cryostat relief valve leak-tightness and functioning should be validated on LAr-1. | | | |
| | **2.1.1.1 LAr – TPC/DAQ/Electronics** | | | |
| | **LAr - TPC** | | | |

| # | Recommendations | Assigned to | Status/Action | Date |
|---|---|---|---|---|
| 8. | The committee encourages the use of as many components intended for the far detector in the LAr1 prototype as possible. For example, the Review Team thinks the entire cold electronics signal chain installed at LAr1 should use the same components as those intended for use at the far detector. | | | |
| 9. | To amortize the considerable investment in the LAr1 prototype, the Review Team recommends that the plan incorporate provisions for iterating on the design and testing of the final components. | | | |
| 10. | The Review Team recommends that an additional round of vetting be performed on the TPC installation and checkout schedule. The Review Team suggests that a document that lists the scope and goals of the checkout procedure be generated. | | | |
| | **LAr - DAQ** | | | |
| 11. | As noted in the December 2011 review software development, even though it is not charged directly to the project, needs to be incorporated into the project schedule to quantify and track the necessary effort since it is crucial to its success. | | | |
| | **2.2 Beamlines** | | | |
| | **2.2.1 Primary Beamline** | | | |
| 12. | The gap of the new trim dipole magnet should be opened up to 3 inches to match quad beam pipe diameter. | | | |
| 13. | A prototype for the dual plane BPM and associated readout electronics should be completed in a timely manner. | | | |
| | **2.2.2 Neutrino Beamline** | | | |
| 14. | Now that $\theta_{13}$ is known, the optimization of the decay pipe geometry should be revisited. | | | |

| # | Recommendations | Assigned to | Status/Action | Date |
|---|---|---|---|---|
| 15. | The committee suggests that LBNE consistently refer to a specific upper limit on tritium and $^{22}$Na concentrations as the design goal, rather than referring to "non-detectable". | | | |
| 16. | The Committee suggests that any assumptions relative to lifetimes of consumable components should be documented as such. | | | |
| | **2.2.3 System Integration** | | | |
| 17. | Follow through on complete implementation of the interface definition process, including integration of cross-system requirements. Also include interfaces to existing facilities such as the Main Injector vacuum and LCW, and off-project connections. | | | |
| 18. | Tolerance measures should be clearly defined, e.g., ±0.450 mm (3σ). | | | |
| 19. | Priority should be given to confirming NuMI-scaled alignment tolerance requirements with physics simulations. | | | |
| | **2.3 Conventional Facilities (CF)** | | | |
| | **2.3.2 CF – Far Site** | | | |
| | **2.3.2.2 Far Site - Rock Excavation** | | | |
| 20. | Review the impact of the Environmental Assessment on schedule. Show where it fits in the critical path schedule. Determine the schedule impact if it is late along with the necessary workarounds. | | | |
| | **3.0 CD-1 Readiness** | | | |
| | **3.1 Detectors** | | | |
| 21. | The schedule requires revision based on funding availability and profile prior to CD-1 review. | | | |
| | **3.2 Beamlines** | | | |

| # | Recommendations | Assigned to | Status/Action | Date |
|---|---|---|---|---|
| 22. | During a CD-1 review slides should consistently indicate whether information presented is relative to 700 or 2300 kW. | | | |
| | **3.4 Project Management** | | | |
| | **3.4.1 Cost** | | | |
| 23. | Implement a process for updating the cost estimates for the entire project and integrating these new estimates into the P6 and Cobra systems seamlessly. Provide consistency across the project for how costs are integrated into the P6 and Cobra systems and keep communication about the costs flowing across the various collaborators on the project. | | | |
| 24. | Present total FTEs, including contract labor, working on various subsystems of the project so that reviewers recognize that sufficient labor from all sources has been scheduled to achieve the goals of the project. | | | |
| 25. | Verify that cost information presented at the various levels of the project consistently identifies what that cost represents. Identify what is included in the number presented (i.e. base, overheads, cost estimate uncertainty contingency, risk event contingency, top down contingency). | | | |
| | **3.4.2 Schedule** | | | |
| 26. | Once the funding profile is known, continue iterations on schedule across all subprojects to level unrealistic spikes/lulls in resource needs, procurements, and prototype development. Include a review of general housekeeping on task types, length of tasks, number of constraints, and logic links in this process prior to DOE CD-1 review. | | | |
| 27. | Complete milestone hierarchy analysis, schedule float determination/justification, and addition of any missing major milestones prior to DOE CD-1 review. | | | |

| # | Recommendations | Assigned to | Status/Action | Date |
|---|---|---|---|---|
| 28. | Perform a schedule risk analysis and incorporate mitigations as needed into the baseline schedule to confirm the amount of schedule contingency proposed is adequate. | | | |
| | **3.4.3 Management** | | | |
| 29. | Complete all LBNE project participant MOUs before presenting the project for CD-1. Assess if sufficient clarity and understanding within the integrated LBNE staff exists regarding the key relationships of the participating labs, advisory committees and the scientific collaboration. Ensure that there is appropriate formality between participants, including contractually, that establishes unambiguous accountability for funds, safety and deliverables. | | | |
| 30. | Get agreement with DOE on a funding profile well in advance of CD-1 reviews and ensure that the proposed cost/schedule/procurements/resources and plans are self-consistent. | | | |
| 31. | Consider placing the CD-1 cost estimate/schedule/scope under some effective form of change control in order to manage potential cost and schedule growth. | | | |
| 32. | Prior to CD-1, develop an integrated staffing plan that would permit smooth transition into post-CD-1 work, having already identified and prioritized needed skills and planned recruiting. Accelerate advance procurement planning with an assigned procurement specialist and develop other remaining near-term resource/staff needs for discussion and planning within the partnership institutions so that project and institutional budgets can be aligned. | | | |

| # | Recommendations | Assigned to | Status/Action | Date |
|---|---|---|---|---|
| 33. | Ensure that planned upgrade paths are clearly justified and associated costs are understood and appropriate to be included in the project. | | | |
| | **3.4.4 ES&H** | | | |
| 34. | Consider adding a Risk Analysis specific to ODH to the Preliminary Hazard Analysis. The topic has been analyzed by LBNE. This analysis is sure to undergo further reviews as systems, equipment and infrastructure become more clearly defined. ODH will continue to be a topic of discussion at future reviews. Presenting an ODH Risk Analysis in the PHA is a way to indicate the importance of the ongoing analysis. | | | |
| 35. | The project should encourage SDSTA to put a high priority on placing ESH professionals in open management positions. | | | |