Fermilab

Closeout Presentations

Director's
CD-2/3a Review
of
the NOvA Project

June 4-6, 2007

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Table of Contents

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Executive Summary

Technical

The NOvA collaboration has prepared a draft Technical Design Report (TDR), estimated cost, and schedule for an 18 kton neutrino detector to be located in Northern Minnesota that will detect the appearance of electron neutrinos in a beam from an upgraded NuMI muon neutrino source at a power level of ~700 kW at Fermilab. The draft TDR is a quite comprehensive document describing an ~30% design of the NOvA detector and the proposed accelerator and NuMI upgrades (ANU).

A well-advanced design for the Far Detector Building has been prepared. The DOE is entering into a Cooperative Agreement with the University of Minnesota (UMN) to finish the design and build the building (and operate the facility once it is complete and perform HEP Research).

A NOvA R&D program is underway to address key technical questions prior to placing major component procurement contracts.

Cost

The initial roll up in Cobra of the RLS from Open Plan for the detailed cost estimate of NOvA results in a total project cost (TPC) of $297.4M including a contingency of 31% overall. The present cost estimate for the 18 kton scope seems generally to have quite a sound basis, but needs to be scrubbed carefully by the NOvA team to identify errors, duplications, and other problems.

The Site and Building cost increased by 24% (to $57.M) from CD-1 (with a 25 kton detector) till now. The increases were due to increased HVAC, crane, and electrical utility capacity (all driven by technical requirements, eg the detector plane bonding glue) and University of Minnesota (UMN) Project Management support.

Modest increases in the detector cost were due to Electronics Production, Near Detector Assembly, and Project Management. There was a significant decrease in the estimate for PVC Extrusions.

The ANU costs have increased ~10% since the Super NuMI (SNuMI) Director's Review.

Schedule

The NOvA schedule shows initial data taking beginning with the 1st super block in September 2011 and an April 2013 completion. The ~6000 line construction schedule in Open Plan has been resource loaded (RLS) with logic included and yields a critical path that includes the Far Detector Building, block pivoter, and detector module assembly. The ANU upgrades will be finished in time to meet the NOvA scheduled beam requirements.

The far detector assembly schedule (the long pole in the tent) extending over four years is thought be reasonable. A 100% contingency on labor for this task is included to allow double shifting if needed to maintain the schedule. The schedule shows detector site and building final design beginning late this fiscal year, road work at the beginning of Spring 2008, and excavation and concrete work beginning in the Summer 2008. The CD-3a request also includes long-lead time detector items and specific ANU component procurements.

Management

There has been a $260M cap placed on NOvA by the Office of Management and Budget (OMB). So, the detector size will need to be scaled down to fit under this cap. The "scrubbing" of the 18 kton cost mentioned above and the descoping will need to be completed prior to a DOE Lehman CD-2/3a Review. This review is presently scheduled for July 17-19.

A reasonably well staffed (for this stage of the project) NOvA project team is in place and responsible for accomplishing the TDR and this initial schedule and cost estimate. They must now accomplish the scrubbing and descoping to achieve a self-consistent scope, detailed schedule, and sound cost estimate for a $260M NOvA. Rough scaling calculations indicate this would result in about a 14 kton detector mass.

Many of the "management documents" needed for DOE projects at the CD-2/3a stage have been prepared in draft form, including:

- Acquisition Strategy
- Project Execution Plan
- Project Management Plan
- Security Vulnerability Assessment Report
- Procurement Plan for NOvA Cost Drivers
- Risk Management Plan
- Integrated Safety Management Program
- Configuration Management Program
- Quality Assurance Program
- Environmental Assessment and
- Environmental Assessment Worksheet.

Some additional work and significant effort will be required to bring this suite of documents current with the to-be-developed $260M NOvA scope, cost, and schedule. Finally, a polished (EIR ready) full set of information for the DOE Lehman CD-2/3a Review will need to be provided ~ 1 week prior to that review on an easily accessible and User-friendly webpage.

1.0 Introduction

A Director's CD-2/3a Review of the NOvA Project was held on June 4-6, 2007. The charge included a list of topics 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. A response to recommendation(s) is expected and actions taken will be reported on during future reviews.

2.0 Science

Primary Writer: Heidi Schellman

Contributors: All

Executive Summary

- The proposed detector technology has outstanding background rejection and > 30% detection efficiency for ν_e appearance.
- The Near and Far detector configurations are very well optimized to the physics goals.
- Concern: The physics sensitivity scales with sqrt(mass*efficiency*time*pot)
  - Descoping from 25 kT to 18 kT reduces the physics sensitivity by 22%*, reduction to 14 kT reduces the sensitivity by 39%.

(* this factor also includes a reduction in the pot assumption from 6.5 to 6.0 E20/year.)

Findings
The NOvA experiment is intended to:

- detect muon-electron neutrino oscillations with sensitivity more than an order of magnitude greater than the present experiments. In particular, to measure the mixing angle sin^2 (2 theta13) with a sensitivity of 3 sigma at sin^2 (2 theta13) > 0.01.
- to use the differential effects of passage through matter on neutrinos and anti-neutrinos at long oscillation lengths to determine the mass hierarchy for neutrino species.
- to perform precision measurements of the 'atmospheric' neutrino mixing by detecting the disappearance of muon neutrinos at a far detector.

To do this requires:

- A high intensity neutrino and anti-neutrino beam, with beam energy spread comparable to the energy modulation expected in neutrino oscillations.
- A high mass neutrino detector located at
  - the first maximum in the sin^2 (Delta M_23^2 L/E) oscillation peak for 'atmospheric' neutrinos
  - with as much matter between the beam origin and the detector as possible to maximize the matter effects.
- The ability to distinguish muon->electron neutrino interactions from

- fake electron neutrino signatures from neutral current events and cosmic ray interactions and

- from contamination by electron neutrinos in the muon beam. This can only be done by understanding the beam spectrum itself as the final state signature is identical to the oscillation signal.

- The collaboration have designed and optimized a detector/system to perform this measurement using the high intensity NUMI beamline currently running at Fermilab. It will be upgraded to 700 kW by the time NOvA begins data taking. The NOvA collaboration will locate their 18 kT liquid scintillator far detector 12 km off of the NUMI beamline axis 810 km from Fermilab in order to achieve a maximally monochromatic neutrino beam at the first oscillation maximum. A 218 T near detector will be located at an angle of 14 mRadians off of the NUMI beamline at Fermilab.

Comments

- Detector

  - Neutrino detectors with sufficient segmentation and little dead material can distinguish pi0 production in neutral current (NC) muon neutrino interactions from Charged Current (CC) electron neutrino interactions with good resolution. The collaboration have chosen to optimize their detector for rejection of NC backgrounds by making it ~70% active and using liquid scintillator as the active medium. Backgrounds from cosmic ray photons are reduced by a concrete and barite overburden and by the short NUMI beam pulse. The reconstruction efficiency for nu_e within the fiducial region is ~ 31% with background rejection of 3:1000.

  - The energy resolution of the detector needs to be small enough that detector resolution does not significantly broaden the measured beam energy beyond the 25% beam spread. For electron neutrino CC events, the baseline design achieves 6% resolution for all events and 4% resolution for quasi-elastic interactions. For muon neutrino events the event energy resolution requirement for precision measurements of the atmospheric neutrino parameters is 4%. The resolutions for both nu_e and nu_mu interactions are well within the design criteria.

  - Understanding of electron neutrino contamination in the beam itself requires a 20 T fiducial volume near detector, which samples the beam before oscillation. The collaboration has decided on a fixed 218 T near detector located in a new enclosure off of the NUMI access tunnel.

  - Optimizations of the detector design and reconstruction algorithms have been done using full simulations of the beam and the detector response.

General conclusion - the detector performance and location parameters have been well optimized to maximize the physics impact of the experiment. The remaining parameter is the product (mass x efficiency x running time x neutrino flux) which is largely determined by the resources available.

- Fiducial mass
    - The far detector configuration presented for this review has been reduced from 25kT mass at the time of the 2006 CD1 review to 18 kT mass using the same detector technology. The beam flux assumed is now 6.0 10^20 pot/year for 6 years, while some earlier proposals assumed 6.5 10^20 pot/year.
    - The collaboration have defined a figure of merit S/Sqrt(B) where S is signal for sin2 2theta_13 at the Chooz limit of 0.1 and B is the background from beam contamination and other interactions misidentified as electron neutrino interactions. A figure of merit of 30 corresponds to a 3 sigma sensitivity to sin^2 2theta_13 > 0.01.
    - Assuming an equivalent six year running time the change in beam flux assumption and fiducial mass lowers the optimal FOM from 33 for a 25 kT detector, 6.5 10^20pot/year and a 6 year run to 27 for an 18kT detector and 6.0 10^20 pot/year. We were not certain if the improvements in algorithmic efficiency and background rejection were included in the numbers given in the TDR so these may be underestimates.
    - We heard that a further reduction in mass to 14kT may be necessary to stay within the cost envelope. This would reduce the FOM to below 25 for a 6 year run.
    - However, if one states this in terms of sensitivity to sin^2 2theta_13, the sensitivity to the physics observable for a 6 year run changes from 0.0094 at 25 kT to 0.012 at 18 kT to 0.014 at 14 kT.
    - Addressing decreases in mass by increasing the running time implies a substantially longer run which may not be feasible.
- **Observation** - sections 4 and section 6 of the TDR are currently inconsistent in their estimates of the sensitivity. Section 6 needs to be updated to reflect the new baseline pot/year and mass numbers as well as the improvements in algorithms.

Recommendations

1. The mass and flux estimates in the TDR need to be made consistent.
2. **The continued shrinkage of the NOvA far detector is an area of concern**. The collaboration needs to come up with a consistent plan which allows the project to reconcile the cost guidance with maximal physics sensitivity.

3.0 Site and Building (WBS 1/2.1)

Primary Writer: Karen Hellman

Contributors: Jeff Sims

Findings

- The site preparation and access road drawings for the Ash River Trail site have been prepared by Burns and Mcdonnell and are 95% complete. The remaining 5% design effort includes revising the excavation plan for the building to match the current plans for the detector hall concrete design. The review committee was provided with review comments and resulting responses and actions from comment and compliance and QA reviews for the site access road design. Several comments contained within these reviews were from the University of Minnesota (UM) stakeholders, which confirms that the future site owners have been involved in this design effort.

- The Ash River site building drawings are between 30% and 55% complete and have been prepared in FESS Engineering. The design team plans to issue these design drawings for a comment and compliance review of all stakeholders in the near future. NOvA plans to complete the structural concrete drawings within FESS Engineering and couple them with the site preparation and access road scope to ensure the excavation and structural concrete work is fully coordinated.

- CD-3a approval will be sought for the site preparation and access road scope along with structural concrete scope. These packages are planned to bid concurrently in the first quarter of FY 2008. This methodology is being implemented to support issuing the contractor Notice to Proceed in the third quarter of FY 2008.

- A cooperative agreement is being developed between DOE and U Minn to support construction of the building by U Minn. This will clarify many open logistics questions regarding final design and construction.

- The technical requirements for the facility have been modified since the CD 1 review. These changes have resulted in substantial increased cost for the facility and its systems.

- Extensive risk assessment documentation has been completed for most of the major elements of construction.

- The team has three independent cost estimates completed and is prepared to perform reconciliation between them. This is a conscientious action being taken to incorporate the best available information into the project estimate.

- The team has performed Monte Carlo analysis to assess adequacy of contingency.

- A review of the Basis of Estimate document revealed many actual quotes and bids for proposed work. This information is dependable to support the pricing proposals and assigned contingencies included in the project.

- The project has developed an excellent option for wetland banking. This appears to be a low cost opportunity to manage the mitigation of wetlands needed by the project.

- NOvA intends to construct a space to contain the near detector in the Minos cavern downstream of the Minos access shaft. A preliminary design exists and the design team is prepared to proceed with selecting a consultant to further develop the concept to obtain a more accurate construction estimate.

Comments

- The Cooperative Agreement between DOE and U Minn is not yet complete. This document is needed to allow further development of MOAs and responsibility matrixes.

- The Environmental Assessment process is not complete. The EA has been prepared to include the work for the Ash River site and the work planned at Fermi Lab. The EA will require public review by Illinois, Wisconsin and Minnesota. This document should be finished and sent out for comment as soon as possible. It is our assumption that the decision on the Environmental Assessment must be complete prior to initiation of work on either site.

- The site preparation and access road plans do appear to be substantially complete. Coordination of the building excavation and structural concrete is key to keeping the project on schedule and minimize change orders so the reviewers concur with the approach to complete the structural concrete drawings and include that scope in the initial procurements done under the UM CA. We suggest the site borings and rock coring data be shown on the site preparation and access road drawings for completeness.

- Activities required to support the requirements of CD-3a include successful completion of the Lehman review in July, followed by an External Independent Review (EIR date to be determined), and finally the ESAAB approval of CD 2/3a in the fourth quarter of FY 2007. These activities are not currently shown in the schedule.

- A drill down on the Open Plan schedule revealed inconsistencies between Open Plan and the Basis of Estimate data book (specifically WBS 2.1.2.3.5.1.1, 2.2.2.3.5.1.2, 2.1.2.3.5.8.3, 2.1.2.3.5.8.5). These documents should be reviewed and reconciled for consistency.

- The review team feels NOvA should retain the services of a consulting firm in the near future to continue the development of the near detector excavation in the Minos Hall.

Recommendations

3. It is recommended that the project develop a responsibility matrix that exhibits the various requirements and responsibilities of the individual team members related to the construction and oversight of the road, site and facility.

4. It is important to further develop the schedule incorporating the activities leading to an approval of CD-3a.

4.0 Commodities – Scintillator/Fiber/PVC (WBS 1/2.2, 1/2.3 & 1/2.4)

Primary Writer: Linda Stutte

Contributors: Joe Ingraffia

Findings

- Commodity items are estimated to account for approximately 40% of the Total Estimated Cost (TEC).
- For all three commodities, actual solicitations were issued, and fixed pricing (indexed and subject to various escalators identified) proposed by suppliers was used as the basis of estimates. A more recent quote on mineral oil pricing is available but is not currently used in the cost and contingency estimate.
- The scintillator is made by combining purchased components, the largest being the mineral oil. A change since the last review is that the mixing is done by a commercial vendor, instead of in-house. Most items can be competitively bid, except for the wave shifters, for which only one viable source has been identified.
- At this time there is only a sole supplier identified for the wave-length shifting fiber. Pricing is known to be not strongly dependent on the concentration of the dye.
- Since the last review, the 16-cell extrusion was chosen as the baseline for forming the PVC extrusions due to the high cost of manufacturing a 32-cell die and resin flow problems encountered during R&D for the 16-cell prototype. The costs of the production dies are included in the contract with the extruder.

Comments

- The terms “Purchase” and “Procure” are used in many different ways throughout the project planning documents, representing different segments of the procurement process
- Continuing to request estimates from the same suppliers for dwindling quantities could have a negative affect on estimates and final pricing proposals.
- Extensive QA/QC procedures were presented for each commodity at appropriate stages of the acquisition process. Onsite project QA reps will be located at production sites when appropriate.
- Shipping and handling costs for the extrusions seem to be well developed.
- The Level 2 managers did not have time to review and correct the Open Plan documents before the Review.

Recommendations

5. Scrub the costs and schedules in Open Plan.
6. Develop a standard procurement milestone plan to use across the commodities.
7. Use the current pricing estimate available for the mineral oil and recalculate the contingency.

5.0 Extrusion Module Production (WBS 1/2.5)

Primary Writer: Alan Bross

Contributors: Heidi Schellman

Findings

- The module construction team presented the latest status on the design, test and performance of the PVC modules. The presentations covered the module design, factory machines, tooling, module production and the photodetector interface. Currently the production concept has work performed at two factories, one located at Fermilab and one located in Minnesota.

- The module consists of 32 cell PVC extrusion assemblies made from two 16 cell extrusions that are glued together, a bottom seal assembly, a top fiber manifold and seal assembly, WLS fibers and the optical connector/interface to the readout APD. There are two different types of modules: Vertical and Horizontal. They differ in the mechanical structure of the extrusions: the vertical have thicker walls for strength. So far only horizontal extrusions have been fabricated at full scale.

- The raw 16 cell extrusions are first delivered to the Fermilab factory where they are unpacked, entered into the database (via bar-code ID), visually inspected and measured (thickness, width, and length) and sorted according to the measurements. All measurements are entered into the database. A 32 cell module is then made by gluing two 16 cell extrusions together. The 32 cell module is then cut to length and abraded near the ends to facilitate gluing in subsequent assembly steps. At this time the cutting is done by hand using a circular saw with a carbide tip and an edge guide mounted on the module. The completed modules are then stacked in groups of 30 wrapped and shipped to the Minnesota Factory. Designs for pallet movers (commercial air) lifting fixtures, rolling tables and gluing tables are complete and have, for the most part, been tested (not yet for full length for gluing table).

- The 32 cell extrusions modules are delivered to the Minnesota factory by truck on pallets of 30. The Minnesota factory will be located off-campus at a rented facility of approximately 60k ft^2. At the Minnesota facility, the 32 channel extrusion assemblies are first stacked, interleaved with 3" spacers, in preparation for all operations. The top fiber manifold assembly is then put on the 32 channel extrusion. This assembly includes the WLS fibers (strung in each of the 32 cells), side and center seals, raceways, fiber cover, snout and the optical connector and the manifold cover. The WLS fibers are routed to the optical connector during this step. There are various glue steps in this operation with the resultant assembly being liquid tight. The optical connector gets its diamond polish (fly-cut) at this time. Liquid scintillator fill, vent and drain ports are in this assembly. After the top fiber manifold assembly is complete and all glues cured, the end seal is glued to the other end of the extrusion cells. Two glue systems are used in both the end seal and fiber manifold. 3M 2216, a 2-component epoxy, is used to form the barrier seal between the scintillator and the outside world. It is inert and does not affect the scintillator properties nor are its properties affected by the scintillator. The second adhesive is Devcon Plastic Welder. It is structurally strong and provides the main strength to the bonding system. It is not in contact with the scintillator. If it comes in contact with the scintillator it will affect the scintillator performance. Its properties also appear to be altered when it gets in contact with the scintillator. The barrier glue, 2216, prevents this from happening. After cure the completed module is tested for leak tightness (using pressurized gas and a bubble detector) and fiber continuity. The completed modules passing test are then packed and made ready for shipment to the NOvA site. The current concept is that modules that fail testing are not repaired. A very low failure rate is required and is the current expectation.

- The PVC module team has evaluated the health and safety aspects of factory operations and presented a good plan to assure the health and safety of all personnel involved with the production. They have paid particular attention to lifting fixtures and are working on a detailed training program for all personnel. Issues due to glue fumes will be dealt with by providing appropriate ventilation.

- Major productions risks have been identified, but we have not seen a detailed risk register for this WBS project element.

- Since the CD-1 review, the estimated cost for the PVC modules has increased from $13.8M to $21.1M. The cost increase is entirely due to labor increases. [Note, the CDR-1 review committee commented that they thought the labor estimates at that time were thin and asked the team to re-evaluate their labor estimates.]

Comments

- The committee commends the PVC module team on the excellent progress that they have made since the CD-1 review. Most factory machine and tooling designs are complete and procedures are well developed. Concerns regarding the End Plate and Fiber Manifold gluing/seals have been addressed. Regarding the End Plate seals, we note that the team has now performed 57 trial seals on 16 cell extrusions. The procedures have now stabilized and the last 10 trials sealed successfully. Obviously this is still a small sample and must be monitored carefully during production for the prototype in order to guarantee that there are no subtle problems occurring at a small level. The team should make sure that all operations are controlled as tightly as possible so that production errors are minimized. Automation should be implemented where ever possible.

- The interference between vertical and horizontal fiber manifolds in some regions of the detector is still a concern with the clearance in these areas only being a few mm. This clearance seems tight to the committee.

- We feel that the space in the Wide Band Hall is far from optimal for NOvA operations. Given the nature of the work required for the PVC extrusion processing, the current layout for Factory 1 (WBH) requires a great deal of otherwise unnecessary handling of the extrusions, including a move of 20 vertical ft. from the loading dock to the pit and back up again. The estimate given by the NOvA team was that approximately $1M in labor could be saved if an optimized layout for Factory 1 were available. Local leasing costs for industrial space are low enough that a local offsite factory staffed by Fermilab personnel may be cost effective.

- It was noted that construction for the Minerva Detector does not end until 9/30/2009 according to Minerva's current project plan. This only leaves 1 month between Minerva finishing and NOvA production start. In addition there are some significant modifications to the Wide Band Hall that need to be done to accommodate NOvA operations. This overall schedule (Minerva/NOvA) seems excessively tight.

- There are a great many dies/molds that need to be procured for production of the varied components (optical connectors, seals, covers, etc.) and these parts often have long lead times. The production team will have to maintain close coordination with procurement in order to guarantee that there are no unexpected delays caused by parts delivery delays.

- The cost estimate is sound given the amount of information (engineering drawings, vendor quotes, etc.) that went into the B.O.Es. The contingency level is appropriate for this stage of the project. The reviewers felt that the contingency on the labor for Factory 1 was somewhat low, however.

Recommendations

8. Fully automate glue application to the end seal extrusion

9. Reconsider the location of Factory 1 in the Fermilab Wide-Band Hall. Consider leasing a facility with enough space to incorporate both Factory 1 production activities and the needs for interim storage.

10. Consider improving the fixturing for cutting the 32 cell assemblies to length. Even with an edge guide, cutting by hand with a circular saw can still lead to an irregular edge. This could lead to sealing problems. The current procedure does raise some safety concerns.

11. Prototype and test as soon as possible the baseline method (packed desiccant) for insuring that the sealed gas volume surrounding the APD (interface region between the APD module and the PVC module optical connector) remains dry and prevents any possibility of condensation on the APD or fiber surfaces. Some thought should be given as to how a dry N_2 purge could be added if the desiccant concept does not work well enough.

12. The team should make use of the evolving 3D model of the detector to better evaluate if there will be an interference between vertical and horizontal components in some parts of the detector.

13. We recommend that a purchasing expediter be added to the NOvA Project Office Staff at the appropriate time.

14. Increase contingency on labor for Factory 1 to 50%

15. Given the potential problems that might occur if the scintillator comes in contact with the Devcon PlasticWelder, we recommend that the team perform additional tests (hydrostatic) on the barrier seal to get an estimate on the expected volume of scintillator that might come in contact with the Devcon adhesive.

6.0 Electronics, Trigger DAQ (WBS 1/2.6 & 1/2.7)

Primary Writer: Jonathan Lewis

Contributors: Eric James

Findings

- Light from the NOvA scintillator will be collected with a segmented Avalanche Photodiode (APD) containing 32 pixels that map onto the 32 cells of a single detector module. A minimum ionizing particle at the far end of a detector module (with respect to the readout electronics) will yield a signal of 20 photoelectrons. The APD will be operated with a gain of ~100. The gain is sensitive to temperature and bias voltage variations. The APD will be read out by a Front-End Board (FEB) that contains an ASIC that integrates, amplifies and multiplexes the signals; a 12-bit ADC to digitize the signal; and an FPGA to sparsify and format the data. The FEB also will control the Thermo-Electric Cooler (TEC) used to maintain the APD operating temperature of –15°C. With these conditions a signal-to-noise of 10:1 is expected. Data will be sent from the FEBs to 64-channel Data Concentrator Modules (DCM). These collect the data in large packets. In order to build events, the 228 Data Concentrators use a time-stamp to send data to a single processor that is used primarily as a buffer for the data. A farm of processors is used, with each processor collecting data in one-second intervals. The interconnection between the concentrators and the processors will be achieved using commercial gigabit ethernet switches. The trigger consists of having the processor farm nodes extract data from the buffer memory based on the cycle time of the Fermilab Main Injector. Total burdened and escalated costs for front-end electronics and the data acquisition system are $22M and $4.3M, respectively, including 44% and 27% contingencies.

- The NOvA team is requesting CD3a approval for APD and ASIC production and for packaging the ADCs which have already been purchased.

Comments

- The NOvA Front-End and DAQ group presented several well-prepared talks during the breakout session. The group has a clear understanding of the requirements for the subproject and how to achieve them.

- There has been substantial progress since the Director's CD-1 review. The prototypes of the APD, ASIC, FEB, and DCM are near to the final design and have been validated for much of the needed functionality. COTS items (e.g. power supplies, coolers) have been identified and costed. There is a well-developed plan for slow controls. Prototyping of APD housings is also at an advanced stage.

- There was no risk analysis for the subproject.

- There are many discrepancies in WBS. Many of the tasks do not have the correct predecessors. Many of the BOEs were not available in the BOE book or did not have the correct activity ID corresponding to the WBS.

- The WBS did not include reviews prior to purchase of production quantities of custom elements.

- NOvA has done a buy/build analysis since CD1 and decided to include the APD carrier in the contract with Hamamatsu. This is one reason for the increase in the expected cost.

- Data were shown for 15 prototype APDs. Two clearly missed the 5nA maximum dark current at 25°C for all channels. 4 had average dark current near 4nA, indicating it is likely that the chips did not meet the specification.

Recommendations

16. Complete and document a full risk analysis for the APDs. The risk analysis should include the possible mitigations for higher dark current such as lower operating temperature or changes to FEB parameters to enable NOvA to achieve the 10:1 noise specification.

17. A risk analysis is needed for the FEB and DCM. Because the production is scheduled to be late in the project, parts may become obsolete. It is necessary to consider the relative merits of purchasing components early against the possibility of needing to redesign the boards.

18. A system integration test including fully functioning APD, TEC and FEB is necessary to demonstrate the performance of the APD prior to making the purchase of the requested CD-3a items.

19. The WBS needs scrubbed to reflect the updated plan for APD assembly:
    - Remove references to carrier board manufacture
    - Unify nomenclature for “housing”, “module”, etc.
    - Include module assembly either as a separate step or with testing at CalTech and Minnesota.

20. Include reviews prior to purchase of production quantities. The approval of the designs and quote packages should be milestones for the level 3 subprojects.

21. The WBS should be scrubbed to have proper dependencies. For example, the vertical slice tests should depend on completion of testing of included devices with a review to follow.

22. The acquisition schedule for the APDs needs to be clarified. The vertical slice test was reported to be delayed. The schedule shows the APD pilot production for use on the IPND to be occurring 8/07 through 1/08. Given the uncertainty in

APD qualification and the negotiations with Hamamatsu, there is some danger that the APDs become a critical path item for an IPND run beginning in 10/08.

7.0 Far and Near Detector Assembly (WBS 1/2.8 & 2.9)

Primary Writer: Richard Boyce

Contributors: Pat Hurh, Charlie Cooper

Findings

- The Near Detector is described to be a 215 metric ton mass detector, 4.2 m x 2.9 m x 16.2 m, fabricated from 496 modules and located in a new cavern carved into the side of the MINOS tunnel. The detector will include 3 plane block assemblies from the IPND and 28 new blocks fabricated at ANL. The blocks will be lowered into the MINOS tunnel via an entry shaft and rolled into the new cavern where it will be filled with ~30,000 gallons of liquid scintillator. The proposed excavated cavern design is not fixed yet and needs the installation group to determine access and other technical requirements which define the cavern size. The cavern excavation will begin at the start of the MINOS downtime in October 2010 followed by installation of the detector.

- The Far Detector is an 18kt mass detector fabricated from 1178 planes (593 V + 585 H) that are developed into 5 Superblocks. Each empty superblock is structurally stable and will be filled with liquid scintillator when bounded by a second superblock. The total volume of liquid scintillator is ~3,900,000 gallons and requires a special delivery system piped throughout the Far Detector building. The detector assembly group will prepare the hall infrastructure including electrical distribution, machine shop, control room, office area, shield wall and safety equipment. The assembly group will receive ~14,200 completed modules, transport them through the gluing stage, and stack them onto a pivot table alternating direction to form a 31 plane block unit. The pivot table will tilt and install the block unit, weighing ~330,000 lbs, vertically in its final location returning to begin assembly of the next block unit. Detector plane outfitting will follow including electronics racks and chillers, cable trays, chiller water loops, power and data distribution boxes. The total assembly process is projected to take ~2.8 calendar years beginning after beneficial occupancy of the new building in April 2010.

- Three detector prototypes are planned; the Integration Prototype Near Detector (IPND) which is close in size to the Near detector and will be fully outfitted with electronics and operated with NuMI neutrino beams. The Full-scale Assembly Prototype (FSAP) will be ~52' long, assembled of 8 planes and will be used to optimize assembly techniques, time and motion studies, adhesive dispenser, and handling. The Full-height Engineering Prototype (FHEP) detector will be fabricated out of two 31 plane blocks, ~52' long, will be filled with liquid, and used to measure deformation over an extended period.

Comments

- Safety considerations are high on the detector assembly engineering teams priority list as is evident in the thorough details of the Scintillator transfer facility and Block assembly and installation planning. This is a good thing.

- Block assembly and installation has a comprehensive plan detailing the labor and equipment needed to meet the project timeline. The work plan is for one 10 hour shift per day, 4 days per week, with two crews and two days overlap, Monday through Saturday. Breakdowns of manpower and task assignments were shown with a hiring plan up to the peak of 29 FTE at full production. While the number of technicians per task seems set to a minimum, as in 1 FTE for glue technician, it was mentioned that the crew bosses are working type foremen and will assist when needed. This is an area where a single illness or injury could jeopardize the production plan and should be evaluated to determine if there is sufficient coverage to sustain the full rate assembly. Production fatigue is an area of concern both in safety of personnel and in quality of the product; a rotation plan for personnel to different tasks may want to be considered.

- Routine maintenance and repair of assembly equipment for the Far Detector will be necessary to reduce the MTBF and maintain production rate. Development of a planned approach to servicing cranes and vacuum lifts (cranes require full load testing on a yearly basis), lubrication and maintenance of pivot table, adhesive dispenser, as well as the HVAC system required to maintain production is warranted and the impact on schedule, if any, determined.

- ES&H activities were clearly shown by the presenters and indicate that they are conscience to design safety into their systems as part of their engineering planning processes. A NOvA Safety Plan for the Far Detector assembly was presented calling for a Safety Committee containing members from Fermilab, U of M-ES&H, Detector Safety Officer and Detector Manager who would review equipment certifications, site inspections and operating procedures – excellent plan. However, a “minimum of yearly inspections to insure safe working conditions..” was one bullet in the slide, and while this is important it is significantly understated. Safety inspections and walk-through of a production facility should be done on a regular basis, weekly at a minimum, with daily morning tailgate meetings with workers to review tasks and procedures. An Integrated Safety Management (ISM) plan should be developed to be the core of your safety policy, ensuring DOE policies are met.

Recommendations

23. Perform a careful and detailed study of the detector assembly program with consideration given to programmatic impacts from normal equipment maintenance and worker safety resulting from the projects ISM plan. Included in this study should be a review of schedule impact due to equipment failure/repair as this will cause an alteration to the work planning process.

Technical (C. Cooper)

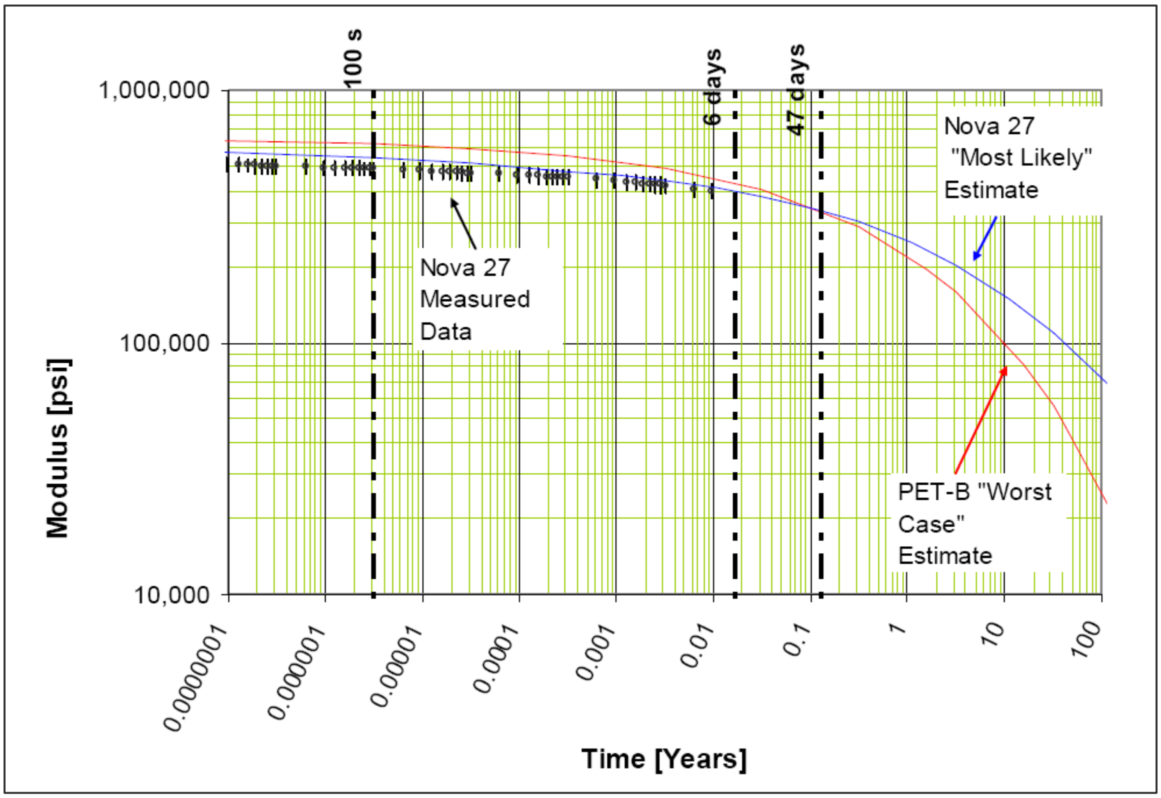
Findings:

<u>Near Detector& IPND Assembly</u>:

The near detector was not looked at extensively and the IPND was looked at less. The proposed cost of the near detector increased by about 4.1 million dollars since the last review. This was attributed to the fact that now a tunnel will have to be excavated for the detector. Across the board the M&S contingency was listed at 40% for all levels and the Labor contingency was listed at 50%.

Far Detector Assembly:

NOvA 27 Formulation is relatively new and the creep data is not yet obtained. If I understand correctly Formulation NOvA 27 is now the final formulation. The creep simulations are using data from PET-B Formulation and calling it a "worst case" scenario. Current data for NOvA 27 Formulation is worse than PET-B, but they predict that it will be better after 47 days of data are collected as seen in the graph below.



Comments:

Near Detector& IPND Assembly:

- I did not find out how the Near Detector contingency numbers were assigned but they seem somewhat arbitrary. Perhaps not as much time was put into the Near Hall Cost Estimation since the cost is 4 times less than the far detector. The scheduling for the near detector seemed ok to me but the excavation time seemed short and the procurement of the liquid scintillator filling equipment seemed long as the scintillator filling device should be transferred from the IPND. The cost and schedule estimates relied on the MINOS experienced staff for input.

<u>Far Detector Assembly</u>:

- If Formulation 27 is not set as the final formulation, then the final formulation needs to be set ASAP. I would not feel comfortable presenting the formulation 27 creep data information until at least 30 days of data were calculated. If the NOvA 27 Formulation actually has worse creep values than the PET-B formulation, then they would almost certainly have to change the formulation again. It is my feeling that since the formulation of NOvA 24 and NOvA 27 are similar in all ways except for a change from rutile to anatase TiO_2, then the creep properties will be similar if the particle size of the TiO2 is similar for both formulations.

- Some procedure needs to be implemented that triggers the level of review needed for each unit operation. The major items which need to be heavily peer reviewed in the far detector are: 1.) The Creep Analysis 2.) The vapor recovery system and the amount of MMA which is being produced 3.) The block pivoter and 4.) The Scintillator Distribution System.

- Some extensive hazard analysis has been done but more still needs to be done.

- Strain gauges need to be specified to see if the detector is creeping faster than expected.

- Minimal risk assessment has been done. Some hazard analysis has been done.

Scheduling:

- Scheduling for major components seemed reasonable except for some of them did not allow time for design review and none of them allowed for change from comments from the review process.

- It is hard to say how accurate the scheduling is without the risk analysis information. The budget did have 100% contingency for labor which would allow for 2 shifts to allow for some catch-up. The block pivoting device is scheduled under 2.9.1 and 2.9.4, which is confusing.

Costing:

- The cost of the far detector went down 4 million dollars since the last review and it is most likely from the mass being reduced from 25 ktons to 18 ktons.

- One specific error I found was that 2.9.1.1, the module lifting fixtures had 0% M&S contingency. The labor contingency was also listed as 100% in the WBS and 85% in the BOE.

Recommendations

Near Detector& IPND Assembly:

24. Reexamine the scintillator filling equipment and excavation time estimates.

25. Include more information in the BOE quotes including specific references.

26. "Scrub" the M&S and Labor contingency estimates.

Far Detector Assembly:

27. Set the PVC formulation as soon as possible if it is not already set at NOvA formulation 27.

28. Risk assessment needs to be done on all major unit operations.

29. Implement a system that triggers the level of review needed for each unit operation and start on major items listed in comments above.

30. The content in the BOE's needs to be improved to include the sources that the financial estimates come from and match them to WBS.

Technical (Feasibility and Design status)

Near Detector Structure

Findings:

- A good technical description of a 215 ton near detector sited in a newly excavated side cavern is given in the TDR.

- The module blocks are of identical construction as the far detector module blocks except for their overall size (much smaller) and are supported from the bottom.

- The muon catcher modules and steel plates are hung from a steel beam support structure. The design of these is currently at about the 15% level (mid-conceptual design phase), although the similarity to previous MINOS designs indicates no problems.

- The PVC extrusions will be shipped to FNAL for matching, then shipped to UM for assembly, then shipped to ANL for block assembly and finally back to FNAL for installation.

- It is hoped (planned) that 3 of the 4 blocks will be re-used from the prototype test in the MINOS service building.

- Stresses, deflections and creep strains should be minimal due the much lower scintillator column height (3 psi head).

- Common material moving methods will be used to install detector blocks (fork truck, wheeled block support frames).

- Secondary containment is achieved with commercially available containment materials and dams.

Comments:

- It should be noted that, due to the similarity to Far Detector construction, design assumptions and decisions should be re-evaluated during final design of the Near Detector to ensure applicability.

Recommendations:

None.

Far Detector Structure

Findings:

- The TDR (Chapter 17) adequately describes a current, cohesive conceptual design in the advanced state of analysis. On going prototypes and mock-ups are being used to verify the validity of this analysis. Although a design choice has been made for the support structure of the Far Detector, it is clear further evaluation and testing are required to gain confidence in that choice. Additionally, other support options will be pursued that may hold advantages (more economical, more flexible, higher confidence in stability).

- Creep tests using the current pick of PVC formulation (N27) are on-going. Further testing is required to confirm the use of the “worst-case” (PET-B) creep modulus used in FEA analysis is truly conservative.

- Adhesive peeling force (Devcon) is identified as the limiting factor for elastic stresses (as opposed to non-linear creep induced buckling) in the structure.

- Stresses in PVC need to be kept below 600 psi to stay in linear viscoelastic range such that using creep modulus test data is valid in models.

- Adhesive is modeled as spring elements and, in the model, does not contribute stiffness to the structure.

- Buckling of the horizontal module webs by block-to block and super-block-to-super-block interactions during creep induced vertical block buckling is currently predicted to be the primary failure mode at a time-under-load prediction of 20 years (the pronounced life-time requirement for the structure).

- The TDR describes the state of the structure design (as it exists now) adequately.

- The design status is at about 25% for building the described detector (if one combines conceptual design as part of the design).

- Independent peer review of engineering notes and independent committee reviews are planned.

Comments:

- We are encouraged that the Project recognizes the need for careful review of the structure by outside experts. Selection of expert reviewers is important to this process. Also, review committees should be charged with assuring consistency of assumptions across the various individual system analyses that affect each other.

- FEA seems to predict accurately the swelling in individual blocks and this will be confirmed with planned mock-up tests. FEA of interactions between blocks and super-blocks during buckling is complicated and not as well understood. One test (2 block test), close to full height is planned (with water) that may help gain confidence with interactions between blocks. However, the buckling will only occur after significant time (5-15 years) and, possibly, an upset event, so it is not clear that planned testing will confirm those analyses.

Recommendations:

31. Continue with current course of FEA analysis and prototype/creep testing to explore various loading conditions, sensitivities, and verification of analysis. This includes the close to full height 2 block test with water. The use of water is deemed satisfactory for these structural tests. Structural creep tests require long periods of data collection and the delay of starting such a test from contending with the ES&H and handling issues of large quantities of liquid scintillator should be avoided. Chemical interactions between PVC and the scintillator oil ingredients can be done in smaller stand-alone tests. If interactions are noted, then long term tests can be planned and performed at that time.

32. Investigate ways to accelerate block-to-block interaction tests that depend on creep and/or creep induced buckling (elevated temperature).

33. Plan a rigorous technical review (or series of reviews) of the base-line structure design utilizing external experts as soon as reasonably possible. This should include experts in the fields of plastic creep behavior, non-linear FEA, and buckling.

Far Detector Assembly Equipment (incl. scintillator filling)

Findings:

- Key assembly equipment is in the mid-stages of conceptual design (excepting the module vacuum lifting device which is in the final stages of detailed design).

- The TDR adequately describes the function and conceptual design of key equipment (vacuum lifter, glue dispenser, block pivoter, scintillator filling equipment).

- The design status overall of assembly equipment is gauged to be about 25%. There exists enough of a conceptual design in most cases to enable cost estimates. However, changes to design concepts are still possible and/or likely.

- Design status is not yet advanced enough to perform ergonomic studies.

Comments:

- Reliance upon design reviews and peer reviewed engineering notes is required.

- The block pivoter is to be assembled and tested in a "parking lot". The weight of a fully loaded pivoter is predicted to be nearly ½ million pounds. Some thought will obviously be needed to limit the testing to what a parking lot can endure.

Recommendations:

34. Continue to advance design and prototyping of key assembly equipment such that ergonomic and ES&H concerns can be addressed early in the design cycle.

Near Detector Assembly Equipment (incl. scintillator filling)

Findings:

- Common material moving methods will be used to install detector blocks (fork truck, wheeled block support frames).

- Secondary containment of scintillator will be provided everywhere via PVC "shroud" piping or commercially available dam systems.

Comments:

- None.

Recommendations:

None.

Cost, Schedule, Resources, & Risk management

Near Detector

Findings:

- No BOE or assigned contingency exists for any R&D activity. Contingency was "scoped" into original estimates (or contingency was scope?).

Comments:

- Construction activities (aside from site preparation) begin in spring of 2011, it appears that most efforts are not directed at these activities (justifiably). As such the only BOE for Mechanical Construction and Installation (1 M$) is the purchase of the Muon catcher steel (0.4 K$).

- Most of the work (Mechanical Construction and Installation) is using conventional, well-understood methods so contingencies (generally around 40-50%) are reasonable even though drawings and specifications are not completed.

Recommendations:

None.

Far Detector

Findings:

- No BOE or assigned contingency exists for any R&D activity. Contingency was "scoped" into original estimates.

- For construction activities BOE was provided generally at WBS level 4. This resulted in 21 BOE's.

- At least 1 level 4 summary task was supported with a BOE that did not cover all aspects of that summary tasks. BOE's for a subset of subordinate tasks were also provided. It was not at all clear which BOE covered which activities.

- Schedules provided for Far Detector assembly were based upon detailed procedures outlined in the TDR. BOE for assembly work fail to reference the TDR and other supporting documentation.

- BOE's are generally inconsistent in detail and content. Some are quite detailed and reference vendor quotes and sections of the TDR (and NOvA notes) (such as 2073; WBS 2.9.4.2). Others reference "attached" documents that were not provided (2060; WBS 2.9.2.1). While others provide little detailed source information at all (2057; WBS 2.9.1.2).

- Contingencies are appropriately high for many tasks since the tasks are at the conceptual design phase. 70 to 100 %. Labor cont is 100% across the board.

- Contingency guidance does not allow for more than 100% contingency.

- Far Detector Assembly has not performed "what-if" scenarios to assess schedule impact if key assembly equipment fails.

- Remote site may incur extra delay penalties when key assembly equipment fails.

- One slide was presented (Block Pivoter) that addressed risk analysis by presenting possible failure scenarios with accompanying solutions. Otherwise, risk analysis was not presented.

- Placement of modules into the block assembly has not yet been tested on a scale or intensity that supports schedule estimates.

- Although references to vendor quotes and catalog prices were listed in the BOE's, no copies or scanned images of those sources were provided.

Comments:

- It is not at all clear that BOE's have been produced at a resolution that instills confidence in a reviewer. My impression is that there is much more work that has gone into these tasks and their accompanying estimates than is reflected in the BOE's. Being an engineer that has experienced the "trenches" myself, I understand this predicament. However, that may not be the understanding of a DOE reviewer.

- The large number of 100% contingencies listed (especially for labor) indicates that the design status is at a relatively low level. While this may be accurate, it is of concern that 100% contingency actually means equal to or greater than 100% since no contingencies above 100% are allowed.

- The tie between BOE's and OpenPlan numbers is not solid. We found instances of discrepancies and confusion (if one adds up the BOE totals, minus contingency, it exceeds the cost of the roll-up by approx. 1 M$. And the BOE's are not all inclusive). Also, one BOE had listed M&S contingency at 100% where Open Plan listed it as 0%.

Recommendations:

35. Provide tie-ins between BOE and technical documents.

36. Increase resolution of BOE's (by writing more BOE's at a lower level or showing breakdown of estimates within those BOE's written to cover multiple WBS activities; in the latter case, clearly indicate on the multiple activity BOE's which activities or portions of activities are included).

37. Continue with planned assembly tests and studies (time-motion) to provide basis of estimate for schedules.

38. Perform risk analysis and "what-if" analysis to assess schedule and cost impact from downtime of key assembly equipment (glue dispenser, vacuum lifters, cranes, block pivoter, scintillation filling equipment, etc.)

39. Scrub the BOE's and RLS to attain consistency.

40. Write BOE's for R&D activities.

8.0 Accelerator Upgrades (WBS 1/2.0.1 & 1/2.0.2)

Primary Writer: Thomas Roser

Contributors: Rod Gerig

Findings

- The scope of the accelerator upgrade portion of the NOVA project is to increase the beam power of the 120 GeV beam from the Main Injector onto the NuMI target to 700 kW from the present level of 192 kW.

- The upgrade will build on the "Proton Plan" that aims at increasing the 120 GeV beam power to 320 kW. The required increase in the proton throughput of the Booster is planned to be achieved entirely as part of the "Proton Plan". The three times increase of the proton throughput of the Main Injector (MI) will be achieved by using the Recycler Ring (RR) for slip-stacking 12 proton batches from the Booster and reducing the MI cycle time to 1.333 s.

- The conversion of the RR from anti-proton to proton accumulation will require 5 new or refurbished kicker systems and two new 53 MHz rf systems. The reduced MI cycle time will need two additional 53 MHz rf systems and an upgrade to one of the quadrupole power supplies.

- Slip-stacking of 11 Booster batches in the MI has been tested with the quite good efficiency of about 92%. The beam losses are made up of 2.8% from beam in the injection gap, 2.7% of debunched beam, and 1.7% slow beam loss during the injection front porch. With the installation of the gap cleaner kicker and the collimators only the latter beam loss is uncontrolled. This is in line with the NOvA upgrade design number.

- The project responded to recommendations from the SNuMI review in November 2006. The responses were provided to this committee in a document entitled "Table of Recommendations for the Director's Preliminary Review of the Super NuMI Plan November 14 – 16, 2006." The project provided responses to six accelerator related recommendations that were considered to be related to NOvA. The recommendations, the responses and our comments on the responses are below.

1. Concerning the kicker modules, their impedance and the danger of electron cloud, the committee recommends reconsidering the inside coating of the ceramics in terms of resistivity and SEY (Ti, TiN …).

> **Response:** Calculations determined that coating is not required. See NOVA-doc-2116. 5/30/07
>
> **Comment:** We note that the referenced document does not satisfactorily address the recommendation. However, we are not overly concerned about instabilities

due to the experimental evidence of stable operation in the Main Injector with roughly the same intensities and kicker chambers.

2. There seems to be a trade-off between the number of bunches “notched” out in the booster and the stringent requirements on rise- and fall-time of the injection and gap clearing kickers – the specified 38 ns are based on 2 missing bunches. The committee recommends evaluating this trade-off and to prepare for a different number of “notched” bunches as a fallback solution.

Response: Decided to set number of bunches at 81 (of 84) and change kicker specifications accordingly.1/15/07

Comment: The recommendation has been followed. The results look promising.

3. Since slip-stacking to full intensity cannot be tested early in the RR, the committee recommends continuation of tests in the MI.

Response: Agree, will continue aggressively. Progress is shown in the MI Upgrades Overview breakout talk. 5/26/07

Comment: The committee is satisfied that Fermilab has made considerable progress in commissioning multi-bunch slip stacking in the MI. The improvement in efficiency is impressive (see comments elsewhere in our report). We encourage this work to be continued.

4. Due to the envisaged completely new type of operation of the RR without the possibility of relevant tests before the end of the Tevatron run, the committee recommends to consider at least fully simulating this new operation, including longitudinal and transverse beam dynamics.

Response: Will address as many aspects as possible with simulations. 12/12/06

Comment: Progress had been made, and the results are encouraging and support experimental data. However, we encourage the continuation of this work as well.

5. Concerning the change of BPM cables, the committee recommends: Assign a coordinator now who will manage the 2009 shutdown activities. Develop the installation plan, and examine what activities could be done in earlier shutdowns to ease conflicts due to multiple personnel working in the same areas and tunnel blockages. (Cables pulls and LCW pipe relocation are two obvious candidates for doing early.)

Response: A shutdown coordinator will be assigned in a timely way for the Accelerator Upgrades shutdown. Planning tasks for this shutdown are in the resource loaded schedule. A shutdown plan and detailed schedule will be made.

Comment: The committee believes this recommendation has not yet been followed, and continues to encourage its prompt implementation. We note that the recommendation addresses "earlier" (i.e., imminent) shutdowns which is the reason that we believe this should be done now.

6. It is unlikely that the losses of un-captured beam in the MI will be significantly reduced when 12 Booster batches are slipped stacked in the Recycler compared to now when 11batches are slip stacked in the MI. The collimation system for MI must be demonstrated to be effective for Phase I to be a viable design for producing 700 kW.

Response: The collimator design has been finalized and all the collimator parts have been ordered and are expected to arrive by June 8th. We expect to have the primary collimator and the four secondary ones ready for installation in MI during the shutdown of summer 07.

Comment: The response does not address the recommendation, but it is a requisite step. In general we were impressed by the loss analysis that is presented in the TDR, and therefore the theoretical demonstration of the adequacy of the collimator has been shown. This recommendation should remain open awaiting the experimental demonstration requested in the recommendation.

Comments

- The technical risk of the proposed hardware items is quite small and the presented level of contingency is quite large for items that contain little innovation or required R&D. Part of the high contingency is a reflection that parts of the design have not been frozen. The project should finalize the conceptual design as soon as possible and then review the required contingency of the engineering designs.

- The main risk is the control and handling of the beam losses in the MI and RR with this greatly increased proton throughput. The recent success with demonstrating slip-stacking 4.6e13 protons in the MI with 92% efficiency ameliorates this risk substantially. The part of the beam loss that would be uncontrolled when the gap cleaner and collimator are installed is in line with the design goal for the NOvA upgrade. The beam loss from debunched beam that would be collected by the collimator is about 2.5 times larger than the design. It is likely that this will be reduced through improved performance of the Booster or could be covered by adequate margin of the collimator system.

- The NOvA beam power upgrade heavily depends on the success of the preceding "Proton Plan" upgrade. Since this constitutes a significant risk the project is planning to follow the progress of the proton plan and compare performance with realistic simulations and further targeted tests at the MI.

- The scope of the project does not include either commissioning of the upgraded facility with beam or system integration testing. However, the CD-4 Closeout Definition states that "upgrades and modifications are installed and ready for initial operation". This requires complete system integration testing and this needs to be included in the scope of the project.

- We performed WBS drill-down exercises in several areas:

Drill down #1: RR injection and gap clearing kicker (WBS x.0.1.2.1)

A prototype kicker is being built under WBS 1.0.1.2.1. The final kicker is being built under 2.0.1.2.1. with the power supplies being built under 2.0.1.2.2. The cost of the kicker systems is about $8M including power supply. Following the WBS was straightforward and in the cases looked at, the BOE tables were consistent.

The project is planning to build prototypes of a number of kickers including the gap clearing kicker. The committee feels that gap cleaning is important and NuMI and NOvA would benefit from installation of a gap cleaning system in the MI. Whether this could be the prototype or the final magnet built early and then moved should be looked at by the project.

The long lead time items, the kicker ceramic chambers, are being purchased now using Fermilab operating money. They will be tested and then put into a spares status. The project will buy them out of spares using project dollars when they are needed. To further mitigate the risk, the designs have been modified so that all kicker chambers are the same cross section.

Drill down #2: RR30 Remove Electron Cooling and Rebuild the section the FODO lattice

Again the drill down was straight forward and passed all credibility tests that the committee could come up with. This drill down led to a look at a number of the other transfer line activities in the recycler as these were grouped in the WBS.

Contingencies are relatively high for many of these items which are familiar to the Fermilab team doing the work. We discovered that this is due to fluidity of the lattice design. Thus the contingency expects an increased number of devices and their installation. As soon as the design is frozen this analysis should be redone.

Drill down #3: 53 MHz system for the RR (WBS 2.0.1.1.2)

The drill-down was easy and didn't reveal any missing items. Vendor quotes were obtained for the major items but no copies were attached to the BOE. The cavity fabrication is planned to be done in-house at a labor cost of ~$1M. Outside fabrication could be considered for this item. No system integration testing is included. This should be included in the required labor resources.

Drill down #4: RR BPM cable and board procurement and installation (WBS 2.0.1.3.1)

The major item is a large quantity of heliax cable. This is a catalog item with low associated contingency. Again no system integration testing is included. This should be included in the required labor resources.

In all of these WBS areas the work is Fermilab in house work without major procurements that Fermilab has done many times and recently. The engineering estimates are therefore based on recent experience.

- The project is planning to build prototypes of a number of kickers including the gap cleaning kicker. The committee concurs that gap cleaning is important and NuMI and NOvA would benefit from installation of a gap cleaning system in the MI. Whether this could be the prototype, or the final magnet built early and then moved, should be looked at by the project. Even one year of operation in the Main Injector would justify this approach, and give credibility to the loss budget established for NOvA.

- The committee is concerned about the availability of technician manpower during the shutdowns, particularly the 8 month shutdown scheduled for October 2010. Our concerns relate to the possibility of people leaving Fermilab either by retiring, or because of fears related to Fermilab's future as the Tevatron shuts down. This is something the project will have to monitor and remediate as the time approaches. We note this is related to several of the high risk factors in the accelerator area.

- The installation of the MI collimators during the 2007 shutdown will require relocating LCW and bus work. This work will be done in such a way as to also accommodate the future RR extraction line. Good planning! This approach is what is suggested in recommendation 5 (above), although not thoroughly implemented. The project should continue to look for similar opportunities to advance NOvA work into earlier shutdowns, and the assignment of shutdown coordinator would expedite this.

- At the time of project base-lining the physics design of the accelerator modifications should be frozen and changed only under configuration control if needed. This would freeze the component count and reduce the contingency in those areas. If possible this should be done before the CD-2 review.

- The committee is satisfied with the projects justifications for the CD-3a procurements under this WBS element.

Recommendations

41. Include complete system integration testing in the scope of the project.

42. Complete the conceptual design as soon as possible and then review the contingencies used in the engineering designs.

43. Consider installing the prototype gap cleaner or the final magnet built early in the MI for early testing and use by NuMI. The gap cleaner can later be moved to RR.

9.0 NuMI Beamline Upgrades (WBS 1/2.0)

9.1 Beamline/Target Modifications

Primary Writer: Phil Martin

Contributors: Sayed Rokni

Findings

- The NuMI upgrades total $5.3M under WBS 2.0.3. This is split roughly equally between M&S and labor.

- The upgrades are spread over four subtasks: the primary proton beamline; the target, baffle and hadron monitor; stripline extension and shielding reconfiguration; and utilities.

- The shielding reconfiguration is the largest subcomponent.

Comments

- The primary proton beam modifications include moving quadrupoles from the A-1 line, power supply upgrades, and improved profile monitors. These tasks are all straightforward and carry appropriate contingencies of ~25%. Upgrades to the NuMI extraction kicker carry a slightly higher contingency of 30%.

- The major components of the target and baffle are being fabricated by IHEP under an MOU. Overall contingency of 47% appears reasonable.

- The shielding modifications are still under study. Various options have been discussed, including restacking the blue blocks (not favored due to ALARA concerns); fabrication of a dummy module into which T-blocks are inserted (the most expensive option, and the one that was costed); a simplified option using different T-blocks but no dummy module. This last option appears to be simpler and cheaper, and is currently under discussion. The ongoing design effort may be an indication of continued difficulty in obtaining sufficient engineering and design support.

- The steel required for the shielding reconfiguration has been costed as ordinary steel at ~$1/lb. A substantial cost reduction would be realized if continuous cast salvage steel can be procured at about $0.20/lb.

- The committee notes that in an ideal world, the NuMI project - having already designated three locations for the second horn - would have also provided the special modules for these locations, thereby avoiding the need to do this reconfiguration in an already activated area.

- The utilities modifications are primarily upgrades of water systems to handle the higher power beam. The cost estimates for these appear reasonable.

Recommendations

44. Pursue the use of continuous cast salvage steel for the shielding reconfiguration. Also see if some or all of the steel might be available on site at minimal cost.

9.2 Shielding

Primary Writer: Phil Martin

Contributors: Sayed Rokni

Findings

- Radiological safety issues for the NuMI beam line have been considered; the areas of concern include: prompt radiation levels outside of berm shielding, penetrations, labyrinths, bypass tunnel, concentration of radionuclides in groundwater and surface water, air emissions and dose due to residual radioactivity.
- The NuMI Shielding Assessment has been recently updated to 500 kW; the project recognizes that it needs to be updated further to address NOvA operations.
- Results from radiation measurements, empirical data and the experience gained in operation of NuMI form the basis that the project has used to evaluate the radiological conditions that can be expected during NOvA operation.
- The earth shielding thickness for NuMI extraction line is sufficient for NOvA operation for normal and accident scenarios.
- Estimated concentration of radionuclides in groundwater, surface water, and dose to air emission are extrapolated from NuMI operations and are below applicable limits.
- Fermilab seems to have made good progress in understanding the issue of detectable concentration of tritium in the surface water.
- Residual activation levels and personnel exposures during the shutdowns have been estimated. The activation levels in the target hall are already significant for NuMI and will increase for NOvA.
- NuMI is planning several measures to minimize dose to personnel from activated components and materials. These are plans for upgrade of Work Cell; and there is a Radioactive Component Removal Plan to address short-term storage of components.

Comments

- While the upgrades in the NuMI target hall are listed as off-project, their successful completion is essential for NOvA.

Recommendations

45. Prepare a status report on the issue of tritium in the surface water, and discuss why this issue does not pose a risk to the project when beam power to NuMI is increased.

10.0 Cost

Primary Writer: Bill Boroski

Contributors: Dean Hoffer

Findings

- The total project cost estimate (with an 18 kiloton Far Detector) is $297.4 million. This includes $227.8 million in fully-loaded base costs and $69.6 million (or 31%) in contingency.
  - Construction component: $217.2 million
    - *Base = $161.2 million; contingency = $56 million*
  - OPC component *(accelerator/detector R&D, coop agreement, etc.)*: $80.2 million
    - *Base = $66.6 million; contingency = $13.6 million*

- For reference, the TPC estimate presented at the CD-1 review (March 2006) was $273.4 million, including $200.9 million in fully-loaded base costs and $72.5 million (or 36%) in contingency.
  - Construction component: $259.8 million
    - *Base = $188.6 million; contingency = $71.3 million*
  - OPC component: $13.6 million
    - *Base = $12.3 million; contingency = $1.3 million*

- The current estimate includes Accelerator and NuMI upgrades (ANU), Accelerator and Detector R&D, and funds for the Cooperative Agreement with U-Minnesota to construct the Ash River site and buildings. The project team has updated and refined various line item costs. Some deliverables (e.g., far detector site and building) have been shifted from construction to OPC.

- The project has a detailed WBS that is used to describe and capture the required work. Estimated costs are defined at appropriately low levels in the WBS.

- The project has well-defined contingency analysis rules that are applied by the PM, Deputy, and Level 2 managers. Distinct rules are defined for labor, M&S and schedule contingency.

- The project has implemented a Basis of Estimate (BoE) process that is used across the project. To date, 328 BoE documents have been prepared. Each document is assigned a unique identifier number, versioned for configuration control, and stored for easy access in the online NOvA document database, Doc-DB. References to BoE documents are contained in the WBS. These appear mostly at the deliverable level and are intended to provide a quick reference to cost basis documentation.

- The cost estimate has been developed and revised using a combined top-down/bottoms-up approach by the project office staff and Level 2 managers.

Comments

- The cost estimate was very recently updated by the project; the version presented for review was less than 48 hours old. The project team acknowledges that it has had limited time to scrub the cost estimate for accuracy and completeness. The Project Manager noted that through a quick review by "a few people for a few hours", the project team has already found approximately $6.5 million in errors that incorrectly increase the project cost.

- The new cost estimate includes a $10 million increase to reflect new pricing information on two cost elements: the HVAC ventilation upgrade for the Far Detector hall and APDs from Hamamatsu. A $10 million change based on two line items indicates a certain level of volatility in the cost estimate.

- The project has identified 4 major cost drivers that account for 50% of the total project cost. These include the Far Detector Hall, Liquid Scintillator, PVC Extrusions, and WLS fiber. Furthermore, we heard that small changes can have large effects due to volumes required (e.g., $333K change in project cost for every $1/barrel change in the price of crude oil). We commend the project for identifying these large cost drivers and for applying appropriate contingency to address the risk. The project should continue to monitor these areas, as well as other project areas for new cost drivers that may appear as project construction progresses.

- The review committee spent a short time drilling down through the WBS, in an attempt to independently determine accuracy and completeness. A number of WBS elements were selected at random for the drill-down exercise. In nearly every case, problems were identified in the cost estimate. Theses included omissions in costs, undocumented cost bases, and links to BoEs that were incorrect. The fact that a quick drill-down uncovered numerous problems suggests that further work is needed by the project to produce an accurate and defensible cost estimate suitable for baseline consideration.

- In establishing relationships with sole source vendors for PVC extrusion production, the project should clearly define ownership of tooling (e.g., dies) if the tooling is paid for using project funds. This may preclude future cost and schedule issues should problems arise in the vendor relationship.

- A reasonable number of BoEs have been developed by the project and used to develop the cost estimate. Given limited time and resources, a graded approach was applied to first develop BoEs for the more costly items (guidance was given to focus first on items with estimated cost > $1M). However, a quick sampling of BoE documents revealed discrepancies and some duplication (e.g., same information contained in the BoEs for WBS elements 2.9.4 and 2.9.4.3). The project office should review all BoEs for accuracy and completeness, and verify that they are correctly matched to line items in the WBS and cost estimate. Recognizing the amount of work required by the project staff in a short time period, the committee suggests that the project consider seeking additional resources to help with the BoE review process. This may free up Level 2 managers to concentrate on further scrubbing the cost estimate. Finally, over time, BoEs should be developed for all deliverables in the WBS.

- An overall contingency of 31% for the TPC appears reasonable. A quick review of contingency levels in various parts of the WBS suggests there may be some inconsistency in the manner in which contingency values are being set by the various Level 2 managers. In addition, there are concerns that the level of contingency established for some subprojects (e.g., Liquid Scintillator and PVC Extrusions) may be on the low side given volatility in the commodity markets. In the process of scrubbing the cost estimate, the project office should review contingency levels for adequacy and consistency.

- The project acknowledges, and the committee concurs, that volatility in commodity mineral oil prices imposes a cost risk on the project. A reasonable model has been developed and implemented to project the cost of mineral oil based on historical data, DOE price projections, and industry indices. The current cost estimate is based on a unit cost of $2.98/gallon, based on December 2005 vendor quotes for 6.6 million gallons. New price data is available as of May 2007, with a quoted price of $3.33/gallon for 3.7 million gallons. The project showed that indexing works in the existing model, using 2005 data, but the committee suggests updating the model with the more recent May 2007 data.

- The current plan includes two factory assembly operations: a Fermilab factory that will perform incoming QA on the PVC extrusions and glue together (2) 16-cell extrusions into 32-cell extrusion modules; and a Minnesota factory that will install fibers into the modules, glue on manifolds, and perform QA (fiber throughput and leak tests). The current production model requires the transportation of extrusions from the vendor in Manitowoc, WI, south to Fermilab, then north to Minnesota. The cost estimate includes 78 trips south at ~$4800/trip and 76 trips north at a cost of ~$7100/trip (including contingency). Combining the two operations into a single factory in Minnesota could result in a potential transportation cost savings of as much as $660,000. Combining factory operations could result in further cost savings through economies of scale.

Recommendations

46. Complete a thorough and rigorous review of the newly revised cost estimate to verify the accuracy and completeness of the June 2007 estimate prior to baseline consideration.

47. Review the cost basis for each element in the WBS to ensure that 1) BoE documents are correctly matched with WBS line items; and 2) each BoE contains the appropriate and necessary information to support the cost estimate.

48. Verify that peer and independent design reviews are incorporated into the WBS at the appropriate level and properly costed.

49. Review the level of contingency assigned to WBS line items by Level 2 managers to ensure that labor, M&S and schedule contingency rules are being applied uniformly across the project.

50. Update the price projection model for mineral oil, using May 2007 vendor cost data of $3.33/gallon.

51. Perform and document a cost-benefit analysis to determine the potential cost savings of combining PVC module assembly production into a single factory site in Minnesota.

11.0 Schedule

Primary Writer: Dean Hoffer

Contributors: Bill Boroski

Findings

- The schedule presented by NOvA reflects the scope of building and installing a 18kton detector at a Total Project Cost (TPC) of $297.4M. The schedule presented for baseline does not meet the DOE guidance to not exceed a TPC of $260M

- The NOvA presented a Resource Loaded Schedule (RLS) in the scheduling software tool Open Plan from Deltek.
  - The schedule presented has 6,126 lines, with 4,394 lowest level activities and 474 milestones.
  - The schedule has a total of 89 milestones without a Predecessor or a Successor. (20 without a Predecessor and 69 without a Successor)
  - The schedule has a total of 862 activities without a Predecessor and/or a Successor. (41 without a Predecessor, 441 without a Successor and 380 without a Predecessor or Successor)
  - The schedule has a total of 347 activities and milestones that have constraint dates (target dates) assigned. (209 activities and 138 milestones)
  - The schedule has a total of 1,138 activities that has a duration ≥ 60 work days.
- CD-4 Milestone completion date is 4th Quarter 2013 with a projected schedule completion date of June 2013, which has a float of approximately 7 months.

- Per NOvA's Preliminary Project Execution Plan (PPEP) and Preliminary Project Management Plan (PPMP) a tiered milestone system is to be used, which includes Critical Decision, Level 1, 2 and 3 milestones. The NOvA schedule has 474 milestones with 319 milestones without the tier identified.

- The NOvA schedule does include some design review activities. Per NOvA's Project Engineer has a plan for engineering design reviews, which needs to uniformly implemented and included in the schedule.

- Schedule contingency is being included in the schedule by building it in to specific milestones and then monitor the float. The schedule contingency process is identified in the Contingency Analysis Rules for NOvA document section 2.5.

- Some Resource Leveling has been performed on the NOvA schedule.

- No single page master schedule for the entire project or for individual subprojects with the critical path was available.

- 328 Bases of Estimates (BOEs) were available at the time of the review. Guidance for initial generation of BOE's was to concentrate on items $1M or greater. The BOE's for the Accelerator & NuMI Upgrades subproject have been completed and the other subprojects are at different stages of BOE development. A standard form for documenting the BOE was used and the completed forms with associated reference documents are stored and controlled in NOvA's docdb repository. Binders with BOEs were available during the review. Some NOvA team members saw the BOE binders for the first time in the review breakout sessions. NOvA plans to continue to create BOE's for the other activities that do not presently have one. There are some existing BOE's that need additional documentation and the numbers (hours/dollars) need to be reconciled between the BOE and the schedule.

- The WBS Dictionary exists in the Draft Technical Design Report (TDR) Section 7 for Level 2 and 3 of the WBS. WBS Definitions exists in the NOvA Open Plan Schedule that gives more detail than the WBS Dictionary. These definitions exist at varies levels of the WBS from Level 3 to Level 6.

- Milestone Definitions exists in the NOvA Schedule for the Accelerator & NuMI Upgrades subproject but not for the other subprojects.

- A draft NOvA Risk Management Plan document exists and per the Deputy Project Manager has been partially implemented. The Accelerator & NuMI Upgrades and Far Detector Site & Building subprojects have completed the more detailed bottom-up risk analysis. The other subproject a top-down risk assessment has been performed that identified the high level key risks. The project recognizes that the more detailed bottom-up risk analysis needs to be done by the Level 2 Managers. The currently identified risks are recorded in a Excel Risk Registry and will be migrated into WelcomRisk software by Deltek.

Comments

- The NOvA project recognizes that the schedule needs to be scrubbed to validate the content since the schedule was completed less than 48 hours before the start of the review. The review committee agrees with that assessment. Some of the obvious areas that need to be scrubbed are as follows:
  - Schedule mechanics that includes appropriately assigning predecessors and successors to activities and milestones and minimize the number of constraints (target dates) used. With the lack of predecessors/successors and having constraint dates the true detailed critical path may not reflected in the schedule.
  - Evaluate the long duration activities to determine if they can be broken up into small duration tasks with specific deliverables or that there is adequate existing milestones to measure the long activities progress. This is import to improve accuracy of status and measuring progress and critical on earning value for Earned Value Reporting.

  - Evaluating that appropriate number of milestones exists that progress can be monitored and assign the milestone tier level.
  - Evaluate the engineering review activities in the schedule and determine if additional ones need to be added and resource load.
  - Utilize WBS Definitions in the schedule notes field for lower level WBS activities where appropriate.
  - Complete Milestone Definitions for all the project milestones.
  - Incorporate any activities and associated cost that result from mitigation plans that are identified after the more detailed bottom-up risk assessment has been completed.
  - After completing scrubbing the schedule for the items listed above, assess the resource need vs. the availability of resources and perform resource leveling where needed. This helps in increasing the likelihood that the activities can be completed in the timeframe scheduled and minimize variances in Earned Value Reporting.
- In addition to scrubbing the existing schedule for errors, revising the schedule to bring the TPC to meet the OMB guidance not to exceed $260M is a significant effort on its own.

- The schedule showing the entire project critical path was not available to the committee via the webpage, but one was generated when requested. A detailed critical path for the entire project and by subproject should be made available to the review committee ahead of the review. Additionally a one page master schedule with critical path should be generated and available to the review committee.

- The NOvA project has created many more BOEs since the Director's CD-1 Review and the standard BOE form that is now being used has greatly improved consistency of the type of information to be included in the BOEs. Additional BOEs need to be generated, existing ones validated and insure that the BOEs and the schedule match.

- The content of the WBS Dictionary appears to be adequate at Level 2 and 3 of the WBS. It is strongly suggested that the WBS Definition notes field are utilized in the schedule to describe the activities at lower levels of the WBS be more consistent. This type of detail helps to insure that there is a common understanding of the work to be performed by the person that generated the activities and the person that has to do the work. It also helps when the person that generated the activities is no longer around to explain what was meant by the short activity description.

- The milestone definitions that exist in the schedule for the Accelerator & NuMI Upgrades subproject should be applied to the entire project. By documenting the definition of milestone it will be commonly understood what has to be completed in order to claim that the milestone is complete. This is especially important when milestones are being used to monitor project progress and especially if milestone completion trigger earning value as part of a Earned Value Management System (EVMS).

- The Risk Management process that has been implemented to date looks to be following NOvA's Risk Management Plan, but at the stage of baselining a complete risk assessment with mitigation plans need to completed for the entire project from the bottom-up as well as the top-down that has been performed.

Recommendations

The following recommendations are to be completed prior to the DOE CD-2/3a Review.

52. The schedule is to be scrubbed to reduce cost, including modifying the detector size, in order to meet the OMB guidance not to exceed a TPC of $260M.

53. To insure schedule quality scrub the schedule for the items listed in the first Comment in this schedule section.

54. Complete the detailed bottom-up risk assessment including mitigation plans for the complete project. Incorporate the mitigations in the cost and schedule where appropriate.

55. Assess at which level in the WBS the BOEs should be generated. Complete all the BOE's for the project. Compare the content of the BOEs with the data in the schedule and insure they match (Similar Recommendation issued from the Director's CD-1 Review of NOvA).

56. Generate and maintain a one page master schedule with the critical path.

12.0 Project Management (WBS 1.9 & 2.10)

Primary Writer: Mike Lindgren

Contributors: Ed Temple

Findings

- An overview of the project and cost drivers was given by project management. With the inclusion of the ANU subproject there are now 10 fully staffed subprojects, including the one for project management, which has a cost of $5.7M.

- The project presented the review committee with the documents required for DOE CD-2 review

  - TDR, EA, AS, QA, RM, etc.

- The PPEP and PPMP needed for CD-1 were made available

- No single page master schedule with critical path was shown for either the overall project or the subprojects.

- Formal change control is planned but not currently implemented.

- Earned value reporting not yet implemented in monthly reports, which have been done for some time in narrative form.

- No draft MOU's or SOW's were shown to the committee

- The project office staffing is projected to be 7.5 FTE's in FY'08, and 8.0 FTE's in FY'09-FY13. There is no contingency on PO labor, and no costs included for external expertise for consulting or reviews.

- No response to previous directors CD-1 review recommendations was shown.

Comments

- The project should be commended for their continued rapid progress towards baselining the NOvA project. The project team is a strong and experienced one, and they have all the tools in place to successfully manage the project. There are many requirements for a baseline review, and it is clear the team is aware of their responsibilities and has worked hard to meet them. The Technical Design Report and other project management documents are largely complete, but will need additional efforts to make them ready for a baseline review. The project team presented their materials in a relatively unified format, and the website organization was a significant improvement over previous reviews. Unfortunately, the review team was somewhat hindered in preparations for the review by many of the review materials only becoming available the morning of the review. This will probably not be acceptable for a DOE baseline review. The production of monthly reports on a routine basis is excellent, and needs only the addition of earned value reporting to be in the final format needed for the duration of the project. The project team did an excellent job of answering all the reviewers' questions.

- Management of the Ash river construction has dual authority lines in the organization chart shown. Project planning depends on an MOU between Fermilab and the University of Minnesota which has not yet been drafted. Responsibilities of the Project Manager and the Federal Program Manager would benefit from additional clarification. Fermilab, project management, University of Minnesota, and DOE roles and responsibilities, especially with regards to safety and contingency utilization, would benefit from such an MOU.

- The PPEP scope range showing a 20kt detector and a 6 year run should be updated as needed and developed into a PEP prior to any baseline review. The DOE Dep. Project Director is shown in the text but is not in the organization chart, and that should be corrected.

- The PPMP should be updated to reflect the current proposed baseline, references to the PMSD should be deleted, and it should be developed into a PMP prior to a baseline review.

- It is important to put at least draft MOU's and SOW's in place soon. Understanding of the resources being planned on by the project, and committed by the collaborating institutions (including Fermilab) will avoid misunderstandings and put the project labor planning on more solid ground.

- The Environmental Assessment covers both Fermilab and Minnesota and includes information for up to 1.5 MW of beam power. Figure 4.2 says NuMI tunnel is 650ft below mean sea level, which does not sound right.

- The Risk Management Plan is appropriate for this project, but the implementation should rapidly become more complete. The Risk Registry formulation is adequate, and the migration to WelcomRisk is a good move. The Level 2 managers have not had time to complete risk assessments for their subprojects.

- The Project Engineer has a good plan for engineering design reviews, which need to be uniformly communicated to lower level managers and shown in the RLS. Some funding in 2.10 will probably be needed to pay for these kinds of reviews if they are to be successful and widely used.

- The Project has a large number of procurements and is working closely and well with Fermilab's procurement people. The addition of an expediter in the project office to work with them and the project might reduce schedule slippages.

Recommendations

57. It is important to have a draft MOU begun between Fermilab and the University of Minnesota to supplement the CA.

58. Prepare draft MOU's and SOW's for institutions planning on doing work for the project so that responsibilities and labor resources commitments are clearly understood.

59. Finalize both PEP and PMP prior to a baseline review.

60. There needs to be detailed balance of funding and cost by FY by the baseline review in the project management documentation.

61. The project office needs to work with the L2 managers to complete the implementation of the Risk Management Plan.

62. Complete the TDR and scrub all CD-2 related documentation to reflect the current project status and scope.

63. Consider adding an expediter to the Project office.

64. Include costs in WBS 2.10 for external reviewers/consultants, labor contingency, and an expediter.

65. Preparation of materials for the baseline review should begin early enough that the reviewers have adequate time to prepare for the review.

13.0 Charge Questions

Technical

13.1 Are the technical specifications clearly stated and documented?

The technical specifications are clearly stated and documented in the TDR.

13.2 Can the design be built? Does the design meet the technical specifications? Is it a reasonable design?

The accelerator and NUMI upgrade design meets the technical specification, is reasonable and can be built.

The detector technology chosen is reasonable, very well optimized and meets the technical specifications, with the exception of the fiducial mass for the far detector which is driven by cost considerations.

13.3 Does the baseline design meet the project's objectives (mission need)?

The baseline design meets the project objectives, however we note that cost driven reductions in the fiducial mass have decreased the physics sensitivity by 20-30% unless the running time is increased beyond six years.

Cost

13.4 Is the Work Breakdown Structure (WBS) appropriate for the project scope?

The WBS is well-developed and broad in scope. It encompasses all significant project activities and appears to have an appropriate level of detail to accurately develop the project cost estimate and a realistic timeline for project completion; and to establish a baseline against which to track future performance. The WBS is still undergoing active development as the cost estimate is revised and scrubbed.

13.5 Do the cost estimates for each WBS (or cost) element have a sound documented basis and are they reasonable?

The project is still in the process of documenting the cost basis for all WBS elements. At the time of the review, Basis of Estimate (BoE) documents had been developed for 328 of the WBS elements. These BoEs contain information such as assumptions, labor estimates, commodity price projections, and vendor quotes. The project has taken a graded approach in documenting the basis for the cost estimate, by initially focusing on generating BoEs for items with estimated costs of $1M or more. BoEs for some subprojects (Accelerator and NuMI Upgrades) are substantially complete. BoEs for other subprojects are in various stages of development. There are no BoEs for remaining R&D activities. The information contained in many of the existing BoEs seems reasonable, but further scrubbing by the project is needed to validate the accuracy of the information in the BoEs, to verify that the information is sufficient to provide a reasonable basis for the cost, and to verify that they are accurately mapped to deliverables in the WBS.

13.6 Does an obligation profile exist? How does it compare with the funding guidance?

The Project Manager presented the current cost profile for the project. The cost profile shows projected costs on an annual basis, compared to the DOE funding profile. Project costs through FY10 fall within the funding guidance profile. Projects costs in FY11-13 exceed the funding guidance profile. This reflects the fact that the current TPC estimate of $297.4 million exceeds the DOE funding guidance to not exceed a TPC of $260 million.

<u>Schedule</u>

13.7 Is the schedule well developed and appropriately structured by specifying relationships, predecessors, successors, critical path, resource loaded, etc?

The schedule is well developed for a TPC of $297.4M but it can not be assessed for a schedule that is required to have a TPC of ≤ $260M. The schedule needs be scrubbed to correct some structural issues and a detailed bottom-up Risk Analysis completed before it can be determined if the schedule is adequately developed.

13.8 Are the durations for the activities and overall schedule reasonable and achievable with the assumed resources?

One forth of the activities has duration's ≥60 work days, which is not a desired state. The project needs to evaluate if the activities can be broken down to small tasks with specific deliverables or if adequate milestones exist that can demonstrate progress. After completion of the detailed bottom-up risk assessment is completed and changes incorporated and the schedule is scrubbed to meet the $260M TPC guidance, an assessment can then be performed to say if the schedule is reasonable and achievable.

13.9 Does the schedule contain appropriate levels of milestones, sufficient quantity of milestones for tracking progress and do they appear to be achievable?

There are 474 milestones in the NOvA schedule. By shear number of milestones sufficient quantities may exists for tracking progress, but since 319 milestones have not been assigned as a Level 2 or 3 tier the analysis could not be completed.

13.10 Does the schedule include activities for design reviews, including assessment of the design's readiness for procuring prototypes, preproduction and production materials?

The schedule does include some activities for design reviews, but the Project Engineer has a plan for engineering design reviews, which need to be uniformly implemented and included in the schedule.

<u>Management</u>

13.11 Is there an appropriate management organizational structure in place to accomplish the design and construction?

The management structure is complete, and should be adequate to manage the design and construction. The University of Minnesota management of the Ash River site was not looked into in detail, but they have extensive experience in construction projects, and we assume that if the roles are responsibilities are clearly defined that successful completion of that part of the project should be accomplished.

13.12 Is the organization structure well documented, responsibilities defined and appropriate for the scope of work?

Yes

13.13 Are there adequate staffing resources available or planned for this effort?

Yes, addition of an expediter to the project office would be beneficial.

13.14 Is there a funding plan available or proposed to meet the resource requirements to realize the project?

No, the funding profile does not match the resource requirements presented by the project

13.15 Has a Risk Plan been developed, risks identified, risks analyzed, risk responses planned/implemented, risk monitoring/control process established and do they seem appropriate?

There is a risk management plan in place, but it is not fully implemented by the project.

Procurement

13.16 Have the critical procurements been identified and are they included in the schedule with adequate lead time built in?

Critical Procurements have been identified. However the terms procure, purchase, etc. are used to identify different sets of activities in the procurement process. In some cases it appears that the activity includes production or delivery. Standard procurement milestones should be employed for consistency

13.17 Have critical make vs. buy decisions been evaluated in conjunction with the scope and is that reflected in the baseline cost estimate, schedule and technical risk plan?

Since the last director's review the decision to change strategy from in-house scintillator mixing to contracting for the service was made. Is it possible to have the extruder undertake the initial assembly tasks of gluing 2 16 cell extrusions together and final end cuts at the extrusion factory before skidding/wrapping/shipping?

13.18 Are the Project designs final and procurement packages prepared to the degree appropriate to order materials and initiate construction as scheduled?

All of the major commodities have been ordered in small batches, and the formulations adjusted to a degree that they can be contracted for. Procurement plans should be developed for each major procurement which specifies procurement milestones, acquisition strategy (competitive/sole source), phased funding, options, blankets with delivery orders, sources etc. The construction (3a) procurements are sufficiently defined, while designs for equipment for far detector assembly has not been completed.