Fermilab

Closeout Presentations

from

Director's CD-1 Review

of

NOνA

February 28 – March 2, 2006

Physics

H. Schellman

Goals

- $3\ \sigma\ \sin^2 2\theta_{13} < 0.01$
- Determine Mass Hierarchy
- Precision $\sin^2 2\theta_{23}$, Δm_{23}

High level requirements

- A high intensity beam with low energy spread.
- A location at the first oscillation maximum and sensitive to mass effects
- Enough fiducial mass to see a signal
- Enough resolution and segmentation to reject NC backgrounds
- Enough overburden to reduce cosmic backgrounds to negligible
- A near detector to understand beam contamination – massive enough to see the very small ν_e signal

Technical consequences

- Location
  - Off axis from NUMI beam by 12 km, in the US
- Far Detector
  - Liquid Scintillator with high segmentation
  - Energy resolution of < 8% for events
  - 30 kT if running NUMI 5 yrs at 600 kW
  - 3 m overburden
- Near Detector
  - > fiducial 20 T @ at 1 km, mobile to map out line beam

Conclusion

- Design Optimization Studies are based on full simulation
- Optimization was done using FOM of S/Sqrt(B), varying many parameters.
- Design proposed is conservative and can meet the goals.
- CDR physics section could be made more ‘accessible’.
- question – 5 or 6 years? CDR says 6 on page 8, 5 on page 20.

3.0 Site and Building (WBS 1/2.1)

Findings

- A complete evaluation of the proposed sites has been finished. The project intends to move forward at the Ash River Trail site. Right-of-Way agreements will be needed from two landowners in order to access the site and any cost associated with this is assumed to be the responsibility of U of Minnesota along with the cost of procuring the land. These costs are not included in the TPC at this time.

- The Environmental Assessment Worksheet has been completed. Additional work will be required once decisions are made regarding the construction delivery method, construction management responsibilities and site ownership.

- The project has performed several extensive evaluations of many options with regard to the design of the facility, including an evaluation of structural systems for the roof over the detector area.

- Site maintenance and Security & Safeguards has been renamed Site Logistics. The scope has been more thoroughly developed since the last review and appears to be appropriate for this stage.

- It is assumed that building construction contracts will be procured and managed by U of Minn. Staff. The University would functionally report to the project office to maintain consistent project status reporting. This arrangement will be specified in a Memorandum of Understanding. The University will maintain responsibility for safety on the construction site. It is unclear at this time if the funding would transfer through Fermi to the University or if DOE will issue an RFP to provide the facility and land through a Cooperative Agreement.

Comments

- Overall building contingency is currently at 22%. While this is within the recommended DOE range for this stage of design, more contingency allocation would be appropriate. Once decisions are completed regarding construction delivery methods, land acquisition and construction techniques it could be reduced.

- Potential FY 07 PED funding delays will reflect directly in delays to the project schedule. Presently the road construction is planned to begin in May 2008. This will not occur if PED funding does not arrive until January 2008. Alternatives should be explored to maintain schedule.

- Detector Site and Building design is being performed by FESS staff. Consultants will be utilized to produce detailed design development and construction documentation. The project is currently exploring options to utilize a Design/Build delivery method. This requires a full review of advantages and disadvantages to assure all impacts are evaluated. Potential exists for limiting use of PED funds for Building and Outfitting design if this method is selected, according to 413.3, Chapter 16.

- Document Basis of Design – Requirements documents – code etc. Sustainability and Leadership in Environmental and Energy Design (LEED) is intended to be part of the design considerations. LEED checklist has not been completed at this time, and should be prior to CD1.

- Consider including the extra length on the facility as an option in the RFP. The extra length could be beneficial to operations and assembly.

- Consider alternative design for an emergency residency outbuilding to be used in the critical events (snow etc).

- Commissioning is not identified as an activity on the schedule or budget. Formal facility commissioning is critical to efficient building performance and confirmation of performance criteria. It is recommended to identify commissioning as an activity and allocate cost and schedule as appropriate.

- The building plans have discrepancies between disciplines. Even though this is an early phase, coordination of the documents should be sustained.

Recommendations

1. Conceptual Design Report for site and building section is incomplete. Sections should at least have drafts inserted prior to the CD-1 review. The WBS elements identified in the CDR do not coordinate accurately with other documents such as the Basis of Estimate and the Open Plan resource-loaded schedule.

2. Review of the Basis of Estimate and the building cost documentation shows inconsistencies in the WBS elements, pricing and activities. These documents need to be coordinated for flow through from one to the other. Detailed drill down cannot be completed if these documents do not work together.

3. Resolution of 1) amount and location of land to be purchased and 2) if U of Minn will construct and own the facility should be resolved very quickly, as this has the

potential to complicate ability to hire A/E firm for advanced conceptual design, and for solicitation for construction work (or alternatively, the design/build contract).

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

Findings

- Commodity items are estimated to account for approximately 50% of the estimated Total Project Cost.

- Almost all of the costs identified within these WBS elements are the costs of the materials, with minimal labor costs identified.

- For all three commodities, actual solicitations were issued, and fixed pricing (subject to various escalators identified) proposed by suppliers was used as the basis of estimates.

- The scintillator is made by combining purchased components. The largest ingredient being the mineral oil, which is on order with unilateral options for required quantities to meet the project needs.

- The production time required for the Wave-Length-Shifting (WLS) fiber (quoted as 44 months), is the critical path long-lead time item. At this time there is only a sole supplier identified for the WLS.

- During the R & D stage, the project is working with a 16 cell extrusion, for use in the Integration Prototype Detector. The current plan is to pursue the development of a 32 cell extrusion and all production plans are based upon that being successful. The vendor solicitation requested pricing (with escalators) for the full required quantity (based on 16 cell extrusions) as an option. Due to the new plan, the option for full production of 16-cell extrusions is not included in the current order.

Comments

- The Basis of Estimate tagging of elements by WBS does not match the WBS structure in the CDR. For example, the Basis of Estimate includes a WBS element titled Edge Stiffeners, which is not identified in the CDR.

- The WBS elements were not consistently defined in the commodity WBS's. For example, the WBS for scintillator "procurement" included the actual commodity costs; while the similar WBS element "procurement" for the extrusions did not. Rather, material costs for the extrusions were included in production.

- The Basis of Estimate did not include cost estimates for quality assurance or management (there were no labor costs in the Basis of Estimate). There are some items related to the total costs of the commodities which remain to be estimated, and included in the total costs. These include mixing system hardware for the scintillator, material handling equipment for the Iso-Tankers, for example.

- The individual WBS Level 2 managers did not "take ownership" of the Open Plan schedule or cost estimate. The project website had schedule snapshots, Gant charts, cost and contingency spreadsheets, budget histograms and labor histograms for each Level 2 subproject – these should have been presented to reviewers during the breakout sessions.

NOTE

- There is an apparent disconnect between the Far Detector Assembly plan to have 25 Iso-tankers of scintillator stored at the Far Detector, and the statement the Fermi local fire regulations required the filled Iso-Tankers be stored 8' apart.

Recommendations

1. The Basis of Estimate and the CDR need to be synched across the project

2. Finish flushing out the sections of the Basis of Estimate, to include the other elements of costs related to each commodity

3. The Level 2 managers should utilize the management tools available (i.e. Open Plan)

4. The CDR should include a discussion on the available alternatives, and how decision was reached to do much of the work in-house, as opposed to sub-contracting for theses services, such as mixing, assembly, etc.

March 2 2006

Director's CD-1 Review of the NOvA Project

Extrusion Module Production – WBS 2.5

D. Denisov, H. Schellman

Findings:

1. This part of the review covers WBS 2.5 (Extrusion Module Production) of the NOvA project.
2. NOvA Collaboration has presented a detailed plan for assembling the main unit of the NOvA detector, the extrusion module. The total number of modules in the detector is 24 thousand. Each module has 32 cells and size of 1.3mx15m.
3. Major parts of the modules are PVC extrusions, fiber manifold, WLS fibers, APD cookie, overflow reservoir and top/bottom seals.
4. There are two different types of modules with different wall thickness: vertical and horizontal. They are very similar in terms of modules assembly procedure.
5. Major parts of the modules are produced by outside vendors, including extrusions and WLS fibers. Parts are delivered to assembly sites where they are assembled into extrusion modules, tested, and then shipped to the detector location site for final assembly/installation.
6. Currently there are 3 assembly sites envisioned. Two are expected to be close to Universities participating in the Nova project and one at Argonne or Fermilab. All sites have similar equipment and expected to produce 12 fully assembled/tested extrusion modules per day. Sites located at Universities are planned to be rented warehouses equipped for modules assembly.
7. There is team of experienced experts with Ken Heller as Level 2 project manager in place. Most of Level 3 project managers are appointed and actively working on the project.
8. There is preliminary cost estimate for the WBS 2.5. The total M&S is $6.8M, labor is $2.8M with contingencies of 33% and respectively, 74% bringing the total cost to $13.8M.
9. The cost estimate is based on actual quotes from vendors as well as engineering estimates. Most uncertainty in the cost is related to the lack of a final design of the module and the resulting uncertainty in the labor needed for module assembly. A substantial amount of student labor at relatively low pay is expected to be the major assembly force for the extrusion modules.
10. NOvA presented preliminary schedule for the module assembly which requires a little less then 3 years for assembly and testing of the required 24 thousand modules.
11. There is WBS structure down to Level 6 with rather detailed coverage of most major project elements.

12. There is preliminary set of quality control procedures planned for testing parts of the modules before assembly and assembled modules before shipment to the NOvA detector site.
13. Appropriate attention is given to potential safety hazards such as glue fumes, lifting heavy objects and safety trainings for the work force which will consist mainly of students.

Comments:

1. The NOvA extrusion module is based on a conservative design with detector elements used previously in such projects as MINOS, CMS, CDF and D0.
2. An impressive amount of work has been accomplished by the Collaboration with studies of detector elements parameters and definitions of major specifications. In addition, cost and schedule estimates are advanced for the current stage of the project.
3. Most material and parts cost estimates are based on written quotes from vendors.
4. Labor estimates are based on experience with similar previous projects and detailed planning of work to be performed at an assembly sites. We were shown time and motion studies for some assembly procedures.
5. The cost estimate and contingency look reasonable.
6. The schedule is driven by delivery of parts from vendors (such as fiber, extrusions, etc.) as well as expected rate of modules assembly at production sites. The assembly rate could be increased by adding extra shift or setting up assembly factories with larger floor space and assembly areas.
7. The schedule looks reasonable.
8. Coordination between different parts of the NOvA project, which includes many vendors, groups, Universities, will require substantial effort in order to develop smooth running assembly factories. It is important that detailed technical specifications, especially for parameters which “link” different WBS’s together, like specifications of the extrusion sizes, be developed and agreed upon between all sub-projects.
9. The extrusions are not light tight. Much of the module exterior in the final detector is covered by other modules or black structural elements, but significant areas of white PVC will be exposed, these need to be made light tight in simple and reliable way.
10. Oil leaks from modules should be considered as one of the most serious potential failures. Current module leak testing methods cannot detect leaks at rates below 10^2 cc/yr/module. Items to be investigated are: higher accuracy methods for determining the leak rates, correlation between measured gas leak rates and oil leak rates, pressure for performing leak tests, the fraction of modules with observable leak rates. Study of potential problems caused by leaks which are below the testing threshold for 24 thousand modules over 10 years of operation will benefit determination of acceptable leak rate.
11. The details of transportation of assembled modules have to be understood. How damage due to vibration and/or temperature extremes during shipping can be avoided.

12. Modules should be leak tested at the detector site, this is part of a different WBS but the construction of additional set of testing equipment should perhaps be in WBS 2.5.
13. Value engineering for reliable glue joints, studies of potential aging of glue joints and other module parts is critical.
14. We were not certain that all of the seals and manifold materials have been tested to assure that they do not affect the scintillator.
15. Many items in the BOE are fully documented, with vendor quotes or detailed engineering estimates. Some remaining items still need to be brought up to this high standard.
16. The proponents noted that an additional expert in finite element analysis would be very helpful in finalizing extrusion module design.
17. The answers to the previous committee questions are satisfactory.
18. We were impressed with the knowledge, experience and level of commitment displayed by the Level 2 and Level 3 WBS 2.5 managers.

Recommendations:

1. The collaboration should concentrate on finishing the R&D stage as well as the design of detector elements and tooling required for extrusion modules production.
2. The R&D tasks to be accomplished should be well documented, including costs, with clear priorities set.
3. As the cost of extrusion module parts is relatively low, but module design is critical to the structural integrity and physics performance of the detector, we recommend that a substantial “safety factor” be included in the module design.
4. Add extra milestones to help monitor project progress. During assembly sites setup as well as during modules production. For example, first production module delivered, 10%, 50%, 100% of modules production accomplished.
5. Add to the cost estimate and schedule resources needed for safety documentation and training.
6. Samples of all module elements made of selected materials should be obtained as quickly as possible, prototype module(s) assembled and used to verify that detector parameters satisfy NOvA specifications.
7. Detailed quality control specifications and procedures should be developed for use during module production. Special care should be taken for leak checks.
8. Development of database to track assembly and testing of 24 thousand extrusion modules is needed.
9. Cost estimate has to be updated to include travel costs between assembly sites, vendors, Labs and Universities.
10. The schedule and cost estimate should continue to be updated as information from vendors and R&D studies become available.

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

Findings

Light from the NOvA scintillator will be collected with a segmented Avalanche Photodiode (APD) that has 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 Concentrators. These collect the data in large packets. In order to build events, the 384 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 costs for front-end electronics and the data acquisition system are $17.2M and $1.8M, respectively, with 50% contingency for WBS.

Comments

The reviewers and proponents met in breakout sessions for five hours of frank and constructive discussions. The proponents prepared informative presentations that provided background information demonstrating a good understanding of the technical challenges of the project.

The design for front-end electronics is based on mature technology with experience from other experiments (e.g. CMS), thereby giving a quick start to the project and providing strong support to cost and schedule estimates. Furthermore, although development of the customized APD may slip, the schedule that was presented does not put the electronics on the critical path for the integration prototype near detector or for project completion.

The lack of access to OpenPlan made it difficult to completely review the resource-loaded schedule for this project in detail. Nevertheless, the proponents presented a detailed list of system components with well-understood cost estimates. The labor estimates both for R&D and construction are based on past experience and appeared credible. The subproject cost is dominated by APD procurement. Labor in the construction phase is devoted almost entirely to testing of components produced by industry.

There was not a clear understanding of integration at sub-project boundaries, specifically the manifold/APD interface. This may be a result of the fact that the Level 3 manager for the APD task did not attend the review. It is important that these interfaces be understood so work can proceed expeditiously on both sides.

The requirements documents that were presented were informative, but could also be improved by adding missing sections, expressing requirements as imperatives, and removing implementation options.

While the development of databases needed for electronics and DAQ looked credible, it appeared that not all of the databases needed for NOvA construction have been identified. Also, the development of a hardware database should not wait for construction. The integration detector effort should be used to prototype all databases.

Recommendations

1. Better preparation is recommended for future reviews to give the proponents an opportunity to demonstrate their detailed understanding of NOvA electronics and the data acquisition system. We have the following suggestions:

    - Every L3 manager is encouraged to have a presentation prepared for breakout sessions, with an overview presented by the L2 manager.

    - Technical information should be consistent in the presentations.

    - Documents should be made easily accessible to reviewers

    - Subproject cost and schedule information (such as M&S and labor profiles) should be included in presentations or made readily available on the project website.

2. The collaboration should quickly identify and apply new individuals and groups to provide effort for 2.6.3 (Readout Infrastructure) and 2.7.4 (Slow Control).

3. The subproject management team should quickly develop a plan for the slow control system, in accordance with a recommendation from the previous Director's Review.

4. The two subprojects (Electronics and DAQ) have a common L2 manager and should develop more cohesive management integration.

5. Scrub the WBS to include missing dependencies and level resources.

6. Develop technical requirements for databases needed for the NOvA project.

7. The electronics subproject plans to have 5% electronics spares. The basis for this decision showing that 5% is both necessary and sufficient for a 6-year run should be documented.

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

Technical:

Findings

The Far Detector will have overall dimensions of 15.7 m by 15.7 m by 132 m. The Far Detector will weigh 30ktons and will be comprised of 64 blocks containing 31 planes each. There was mention of adding 75 additional feet to the building at a cost of 1.5 million dollars to help accommodate some of the assembly and storage issues.

Blended, tested, quality assured liquid scintillator arrives in a car-sealed ISO tank delivered by a semi truck. A number of ISO tanks are stored on site outside of the detector building. The liquid scintillator is pumped from the ISO tank to the detector at a rate of 150 gpm using a receiving system for the far detector and a similar system using 25 gpm for the near detector. The receiving system for the far detector allows for the inspection of the scintillator, removes entrained air, filters particulate, heats or cools the scintillator as needed, and has a buffer tank that allows for filling of the detector while swapping delivery tanks. The scintillator will be mixed offsite from detector locations (presumed at Fermi) in the ISO tanks and shipped to the detector sites.

A Block Raiser will be used as the method to position the assembled block in place for the far detector. The near detector will have a different method to handle placing the assembled blocks. There is question on when and where to test the block raiser.

Adhesive choice has an impact on work schedule and ventilation system design. The baseline adhesive was listed as 3M2216 and was said to have a safety factor of 5 for buckling. However a Devcon adhesive was discussed a great deal also. The Devcon adhesive has a sheer strength which was approximately 150% better but it contained a toxic solvent which the 3M2216 did not.

An adhesive dispenser will be used to apply the adhesive to attach the modules together and to attach the blocks together. The adhesive dispenser can't be defined until the adhesive is chosen.

Fire protection for the near detector and far detector will be accomplished using a fire suppressant foam that was suggested by the manufactures of the mineral oil which is the major component in the liquid scintillator.

Only one site was proposed for the near detector. The site is an existing tunnel which has size constraints. The near detector will receive assembled blocks instead of the assembled modules that the far detector will receive. It was presumed that the blocks for the near detector will be assembled at Fermi but not at the site of the detector.

Modules will arrive to the far detector site preassembled with end caps and fiber mounting manifolds already installed. There was discussion on how to ship the modules to avoid contamination and deformation. The stress on the end caps and the wire harness

manifold were examined and found to be negligible compared to the bonding strength of the adhesive used.

Much work was done on the structural analysis of the assembled block and it was found that the baseline thickness of 3mm for the PVC outer wall and 2 mm for the PVC inner web would have to be increased for the vertical planes. The suggested thickness for the vertical planes was 4.5 mm for the outer wall and 3 mm for the inner wall. The wall thickness needs to be increased to decrease the maximum adhesive shear stress. Mechanical means to decrease the shear stress on the adhesive were examined but abandoned. FEA was used to find that a maximal shear stress of 170psi will occur in the superstructure.

Work was done on the filling method for the liquid scintillator. There was a suggestion made that the horizontal modules could be rotated by 1% toward the manifold to prevent bubbles from getting trapped.

Comments

Technical:

Adhesive needs to be determined as quickly as possible to meet timelines. If the 3M2216 meets the design SF of 5 for buckling and over a SF of 4 for shear stress between the planes it seems like it should be used over the Devcon adhesive which has toxic solvent vapors. Adhesive choice will affect assembly and the building (exhaust required) requirements.

ES&H concerns have been considered carefully. Spill containment was accounted for in the mixing of the scintillator and for the scintillator in the detector. No mention was made of the solvent handling and storage for the solvent that would have to be used to clean the adhesive dispenser at least 1 to 2 times per day. Some more thought needs to be put into the fire suppression system used for the near detector. How will the existing system be removed or disabled. Are there other concerns because the near detector is in a more confined space than the far detector?

For the scintillator all contamination routes need to be identified. Possible contamination routes that have not been discussed are the end cap and wire harness manifold. The acceptable water content in the scintillator is defined as 30 ppm. Is there a way to remove water from the scintillator if is contaminated?

The adhesive dispenser will require solvent to be stored nearby to clean the nozzles out during downtime. It needs to be determined the amount and type of solvent that will be required to clean the nozzles. The storage location needs to be defined and all ES&H issues concerning the solvent need to be addressed.

The near detector is being viewed as a modification of the far detector in terms of assembly. Not as much work had been done on the near detector and there are many

items which need to be more fully discussed. The assembly of the data and water to the top of the near detector may have some issues due to the size constraints in the NUMI tunnel. There may be a need for welding in the tunnel. Are there some ES&H issues with this?

What effects will rotating the horizontal modules by 1 degree have on the stability of the superstructure?

Recommendations

Technical:

1. Determine which adhesive to use as soon as possible. This affects building design and assembly time.

2. Address ES&H and storage issues for the solvent that will be used for cleaning the adhesive dispenser.

3. Determine if the possibility of bubbles in the horizontal modules would warrant rotating the module by 1 degree. Determine what effect rotating the horizontal modules by 1 degree will have on structure stability and assembly procedures.

4. Reexamine all possible contamination routes for the liquid scintillator. Determine if there is a need and a way to remove possible contamination like water from the detector.

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

Cost and Schedule:

Findings

Cost and schedules have been prepared for the Far and Near Detector assemblies with supporting documents in the Basis of Estimate booklet. Much work has been done to date on assembly processes and work flow patterns. WBS elements have been defined to level 7.

The installation schedule for the Far Hall Detector was based on a 2 shift/day, 89 week installation timeline as outlined in NOvA-doc-594 using experience from the Soudan Underground Lab. The timeline uses a 5 day/week work schedule for assembly and uses the weekend for adhesive curing time for blocks prior to raising to final position. The weekend times can be used for contingency in assembly or for routine maintenance of assembly tooling. Staffing levels were shown to be up to 40 during full construction and maintained for a 1 year period.

The Far Hall Detector is located at the Ash River location approximately 35 miles from the nearest populated area which leads to long commute times for workers. Use of a 10 hour x 4 days/week schedule will be considered to maintain efficiency.

Comments

Cost and Schedule:

The detector assembly schedule was created by first using document 594, the engineer would then generate spreadsheets for effort per day, this is then input into Open Plan, and then the engineer would work with the schedule operator and link each task which ultimately leads to a printed document for review by the engineers. This is a cumbersome way to generate a schedule and with the limited ability of staff to access Open Plan it will lead to errors remaining in the schedule for quite some time.

It was noted that the detector assembly schedule details seemed inconsistent relative to overall costs. The Near Hall detector detailed schedule is 13 pages in length with a cost of $0.7M while the Far Hall Detector Assembly schedule is only 10 pages and a cost of $12.6M plus 100% contingency. The IPND, on the other hand, is 5 pages with a cost of $.5M and 0% contingency. The Far Hall detector schedule does not identify “outfitting” tasks such as installation of the electronic modules, cooling systems, etc. These schedules need to be reviewed to ensure maximum detail is included to allow proper tracking of effort, costs and critical path determination.

There were no design details shown of the Near Hall detector during the sessions, it was stated that the majority of the work was done on the Far Hall detector assembly. Presentations of Near Hall detector discussed assembly of the blocks away from FNAL

and lowering them into the tunnel onto rails. These individual blocks are then rolled into final position and secured and outfitted. The level of details in the schedule deserves layouts and drawings of the most current Near detector design and these should be included in future presentations to give validity to the design considerations used in the cost and schedule.

Much effort and thought was shown in the details of the liquid scintillator transfer from storage tanks into the detector modules for the Far Hall. A well thought out process to remove the air from the liquid and to maintain a constant temperature was shown. The transfer system is designed to fill 10 or more modules simultaneously and does not appear to be a limiting factor for detector completion; however the timeline of achieving the required QA/QC tests on the liquid before pumping into the modules may not have been considered.

Recommendations

Cost and Schedule:

5. Add additional tasks to the detector assembly schedule to cover the complete assembly process including electronics, cabling and cooling systems. The schedule should include task items for each of the assembly blocks to allow proper tracking and reporting rather then ganging blocks 9-60 in a single line. Add milestones as needed to monitor progress.

6. Obtain needed software or staff to allow NOvA personnel to view and work their schedules in a timely fashion.

7. Review detailed tasks for detector assembly and installation costs with goal of reducing the 100% contingency before the next review.

8.0 Project Management (WBS 1.9 & 2.10) M. Lindgren, E. Temple

Findings

The project presented a high level physics requirements talk, and project overview talk. The project overview talk covered the proposed design and alternatives to that design that had been investigated. It then covered optimization, risks, value management, the WBS, and the schedule. The WBS is broken into two parts, an R&D section and a Construction section. There are 9 level 2 subprojects, including one for Project Management. There are 7 level two managers, one from Fermilab, four from universities, and two from ANL, which covers all L2 subprojects (electronics and DAQ have one manager).

To Summarize;

1) The project has a WBS
2) The project has a resource loaded schedule
3) The management team is in place
4) The project has a PPEP, PPMP, and CDR
5) No Draft Acquisition Strategy was shown
6) Total cost for Project Management was shown as $4.9M with 0% contingency

Comments

The project is to be commended for their rapid progress in strengthening the Project Management team. The addition of a 2 Project Engineers and a Project Chemist, 2 Schedulers, a Budget Officer and a dedicated ES&H person greatly strengthens the Project office. The reviewers feel that getting these key people in place early is very good. Excellent progress has been made also in filling the L2 manager positions with competent and experienced people. The increase in R&D funding since the last review is a good thing. Answers were available to questions and recommendations from the previous review in most cases.

The Project leaders have worked hard to understand and comply with the DOE requirements that must be satisfied to be granted CD-1, especially with regard to alternative solutions and risk trade offs. The Conceptual Design Report, which is a requirement for CD-1, is largely complete, but must be finished in the next 2-3 weeks in order to be prepared for the DOE review in April. We feel this is possible, but is a challenge that must be taken up <u>immediately</u>. The PPEP and PMP are at similar levels of completion, and must be brought into consistency with the presented plans as soon as possible. The preliminary Hazards Analysis Report is in good shape and should be adequate for CD-1 review.

For the CD-1 review, it would be good if the website that serves documents to the reviewers had direct links to all the documents that they might need to access. A "two clicks" rule for document access would be good. Having the schedule information there in un-zipped format would also be a good idea. The uniformity of slides and presentations among the project team and subproject leaders was very good. It would be helpful to have the subproject WBS number, etc., in the footer for each presentation.

Recommendations

1. Update the PPEP and PPMP and make them consistent with the current plan.

2. Complete the CDR.

3. A plan for completion of the R&D, complete with decision points, needs to be made and entered into the RLS as soon as possible.

4. The Project Manager and L2 Managers need work hard to make the RLS a more integral and familiar component of their Project Management toolkit.

5. Assignment of Quality Assurance and Procurement oversight responsibilities should be made, either to someone already in the project office, or to new personnel.

6. The Project Managers should not be the Integration Coordinators, not because they are not qualified, but because they have too many other responsibilities to do that job also.

7. Roles, Responsibilities, and Authorities of the Project Engineers and Chemist need to be defined and entered into the PPMP.

8. The contingency for the Project Office does not need to be large, but should not be zero.

9. The Project should plan to begin monthly reporting in May 2006 so that it is a routine, well understood process by the time the CD-2/3a review happens.

10. Organization of the presentations for CD-1 should include pre-prepared breakout session talks and materials given to reviewers earlier, along with simpler website navigation.

10.0 Charge Questions

Technical

10.3 Has a Conceptual Design Report (CDR) been developed that includes a clear and concise description of the alternatives analyzed, the basis for the alternative selected, how the alternative meets the approved mission need?

Yes, the Project has a draft CDR. There are missing sections in chapters on conventional facilities, and the chapters titled ES&H Overview, Quality Assurance Overview, Risk Analysis, Stakeholder Input, and Cost Range and Schedule Range are missing.

10.4 Has the Project employed value management as early as possible in the project development and design process so recommendations can be included in the planning and implemented without delaying the progress of the project or causing significant rework of completed designs?

The Project has been employing Value Management in the sense of optimizing the cost of the design while still meeting the physics performance specifications. They have done a good job here in working through possibilities early in the planning process.

Cost

10.10 Does an obligation profile exist?

No obligation profile was shown.

Management

10.19 Is there an appropriate management organization structure in place with the responsibilities defined and documented for the scope of work?

There is an appropriate management structure in place. The roles and responsibilities of the project engineers still need definition. A person to do integration should be identified.

10.20 Does the proposed project team have adequate management experience, design skills, and laboratory support to produce a credible technical, cost, and schedule baseline?

Yes.

10.22 Is the documentation required by DOE O 413.3 in order and ready for Approval of CD-1?

No. There are sections of the PPEP and PMP that still use old cost figures and organizations that need to be updated, and the CDR is not yet complete.

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

Yes, the project management team as adequately staffed. Additional analysis of the travel required should be done to determine if the M&S funding for the Project office is sufficient.

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

No funding plan was shown to the committee.

10.25 Has Risk Management been performed which includes risks assessments on each potential design alternative as a factor in selecting which alternative is to be pursued?

A substantial amount of risk assessment and mitigation planning has been done. The project has done considerable work understanding technical and costs risks for this stage of the project. The Draft Risk Management Plan uses a familiar and understood methodology. The risk discussions in the CDR are generally rather short, and not in the format used in the Draft RMP. Given the short time the reviewers had with the documentation it is possible that the subproject risk documents were missed by the reviewers.

Section 9: Cost and Schedule:

Findings:
The NoVA Project Team presented cost and schedule information in the plenary sessions on 2/28/06 and the breakout sessions on 2/28/06 and 2/29/06. The single point Total Project Cost (TPC) with contingency is estimated to be $249 million (FY06 dollars) the project duration is anticipated to be 50 months. The TPC range is estimated between $213M and $263M with contingency (FY06 dollars) and the project schedule ranges is estimated between 41 and 57 months without schedule contingency.

The Project team should be commended for their proactive approach to understanding the costs and potential risks of the commodities and civil construction which are considered the cost drivers of the NoVA project. The large procurements of scintillator, WLS fiber, and PVC appear to be defensible and are based on the vendor quotations and proposals that have been received. The NoVA project should also be commended for their early involvement of procurement personnel in the understanding of these large procurements. The Deputy Project Manager explained that the contingencies for the cost drivers have been painstakingly established by combining both project and procurement risks utilizing a monte-carlo analysis as requested in DOE 413.3. The Project Manager recognized that efforts thus far have been focused on estimating the cost drivers. It was recognized that near future efforts will include more detailed work on estimating the remaining smaller project elements including R&D.

The NoVA Project Manager noted that the labor costs associated with this project appear to be lower than normal for HEP projects. The latest estimate suggests labor cost accounts for only 11% of the TPC. The Project Management team explained this was because of the relatively expensive M&S commodities (PVC, Fiber and scintillator) and the civil construction which comprise approximately 61% of the TPC.

NOvA has developed a schedule that contains both R&D and Construction activates. WBS 1 R&D branch includes 9 level 2 WBS elements and WBS 2 Construction branch has 10 level 2 WBS elements. A WBS dictionary does exist for many of the activities. Milestones for WBS 2 were presented.

Comments:
- To eliminate any potential confusion a note should be added to NOvA's materials/presentations that the labor dollars shown includes labor from Fermilab and all other institutions.
- NOvA needs to tag those activates that will be funded by PED Funds so they can be properly tracked and report on.

Recommendations:
1. Update the Basis of Estimate documents to include labor estimates and justification.
2. Coordinate the cost information between the Resource Loaded Schedule (RLS) the BOE. Many inconsistencies were noted between the RLS and BOE.

3. Review the contingency assigned to the civil construction (WBS 2.1) to ensure it is adequate based on the latest understanding of the method of construction subcontract delivery.
4. Review the need for contingency on Project Management (WBS 2.10). There is currently no contingency applied.
5. Review the need for labor on Wavelength shifting fiber (WBS 2.3). There is currently no labor costs associated with this section. Some examples include engineering effort in supporting the preparations for the procurement, labor for vendor visit/inspections.
6. Develop life cycle costs of the current design including, R&D, Design, Construction, Maintenance, Operations and Decommissioning. We understand that work is ongoing regarding life cycle cost estimates, but the information was not developed at a level that could be presented at this review.
7. NOvA's Project Management recognized that they have not yet accounted for project management related activities in all level 2 WBS. Review and include as necessary the need for project management related labor for all level 2 WBS.
8. NOvA should work hard with the Directorate and DOE to establish a draft obligation profile prior to the CD-1 review.
9. NOvA has not defined how to establish and implement schedule contingency. During the breakout session the NOvA scheduler said that imbedding contingency throughout the schedule is not the preferred method. Relating schedule contingency to the appropriate milestones is preferred. The review team agrees that having schedule float related with the milestones is the better method. NOvA needs to define and document their process and then implement it in their schedule.
10. The DOE's Expectations for a Successful CD-1 Review is to verify "There is a plan to complete the R&D needed for the design and resources to implement the plan have been identified." The design work is included in NOvA's R&D schedule (WBS 1) which has not been fully developed to a level that the review team could conclude that the duration is credible and that the required resources are available. NOvA needs to complete the R&D schedule prior to the DOE CD-1 review and show that the resources needed are available to the project.

Note: Comments and recommendations regarding cost and schedule may also be included in other sections of this report.

Cost Questions:

- Does the conceptual design report and supporting documentation adequately justify the stated cost range and project duration?
  Yes, while there are a few remaining project costs to be included into the resource loaded schedule the cost drivers and their associated risks appear to be well known. The anticipated TPC range was stated by the NoVA project Manager to be between $213 million and $263 million. As of the date of the review the anticipated TPC was not included in the CDR. The presented project schedule

ranges is estimated between 41 and 57 months without schedule contingency which appears to adequately justified.

- Has the project developed a life-cycle cost estimate that includes costs for research and development, construction, operations and decommissioning?
  No, NoVA project Management told the Review committee that this work is ongoing and will be included in chapter 21 of the CDR.
- Do the cost estimates for each WBS (or cost) element have a sound documented basis and are they reasonable?
  The cost drivers (commodities and civil construction) appear to be very well documented in the NoVA basis of estimate. Large procurements are based on vendor quotations or proposals. The civil construction estimate is based on Means construction data and FESS experience. It was noted that some labor resource loading and R&D costs do not appear to have a documented basis of estimate.
- Has the project established a realistic cost estimate for the work associated with performing Preliminary Design, Final Design and Value Management activities to request an appropriate level of PED (Project Engineering and Design) Funds?
  At the time of the review the costs for R&D were not fully identified. An estimate for Title II engineering does exist for the civil construction, however, at this time the availability and uses of PED funds are not fully understood by NoVA Project Management.

<u>Schedule Questions:</u>

- Does the Project's Work Breakdown Structure (WBS) define the total scope of the project as a product-oriented family tree composed of hardware, software, services, data, facilities and other components?
  Yes, a product-oriented WBS was presented.
- Is a schedule developed and resource loaded?
  The R&D schedule (WBS 1) has activities loaded with some resources loaded but the schedule is not developed beyond that state. The construction schedule (WBS 2) has been developed and mostly resources loaded. (Not all PM resources have been loaded for the level 2 subprojects.)
- Are the activity durations reasonable for the assumed resources?
  Yes, the durations appear reasonable for resources identified for the construction schedule WBS 2.
- Is the schedule duration feasible for the resources assigned to accomplish the tasks?
  The schedule duration appear feasible for the resources assigned to accomplish the WBS 2 Construction schedule. The R&D schedule could not be assessed at this time.
- Does the schedule contain appropriate levels of milestones, sufficient quantity of milestones for tracking progress and do they appear to be achievable?
  The Construction schedule (WBS 2) to appear to have an appropriate level and suitable quantity of milestones appropriate for the maturity of the schedule. Milestones have been identified for the R&D schedule (WBS 1) but could not

confirm if they are achievable based on the current stage of schedule development.

- Does the schedule include activities for design reviews, which include assessment of the designs readiness for procuring prototypes and preproduction materials?
  Yes, the schedule does include some activities for design reviews. As the project further develops the schedule they will assure that the appropriate number of reviews have been identified.
- Has the activities associated with the Preliminary Design, Final Design and Value Management activities been appropriated identified in the schedule so they can be properly tracked if PED funds are used?
  No, these activities have not been identified in the schedule at this time to allow the work and PED expenditure to be tracked, but the project has planed to tags these actives so they can be tracked.

Executive Summary for NOvA Director's CD-1 Review

Technical

A collaboration of about 150 scientists has proposed a NuMI Off-Axis electron neutrino Appearance (NOvA) experiment. The NOvA detector is a totally active tracking calorimeter detector using a liquid scintillator designed for the detection of electron neutrinos appearing off-axis 810 km distant from the NuMI muon neutrino source. In a five year run with 6.5E20 protons per year on the NuMI target a unique feature of the NOvA experiment is the ability to resolve the neutrino mass ordering for a significant portion of the parameter space for neutrino oscillations.

A Draft Conceptual Design Report (CDR) has been prepared for the NOvA detector. The CDR sets forth the science requirements for the experiment, describes the detector design, and shows the detector performance specifications meet the science requirements. The CDR closely follows the guidelines for such a document set forth in DOE Order 413.3 Program and Project Management for the Acquisition of Capital Assets. The collaboration has prepared 38 technical requirements documents for the detector. The CDR contains the Work Breakdown Structure (WBS) and WBS dictionary at level 3.

Significant R&D and design progress has been made since the July 2005 Preliminary Director's Review of NOvA. R&D highlights include scintillator performance measurements and prototype ASICs for the front end electronics while design advances have been made in the far detector structural design and assembly, erection/installation plans for the PVC module blocks. The current conceptual design plus some additional R&D provides a good basis for starting and completing the Preliminary Design that will form the basis for proposing technical, cost, and schedule baselines.

Cost Range

A detailed cost estimate has been prepared resulting in of a total project cost (TPC) "cost range" in then-year $ with contingency (at about 40%) of $232M to $288M. Surprisingly for this early stage of a project the data supporting this range is comprised of quotes for about 2/3 of the total. The contingency analysis is based on a standard approach augmented by an additional risk-based contingency using a Monte Carlo process to include special effects such sensitivity to crude oil fluctuations, other commodity price fluctuations, and currency fluctuations, based on historical data.

The basis of estimate (BOE) is in FY06$ and includes appropriate adders for General and Administrative overheads for both materials and supplies (M&S) and labor (using Fermilab or specific university rates as appropriate). The cost range is reasonable.

Schedule Range

A detailed schedule has been prepared that has been resource loaded. The resulting schedule duration range is 3.4 to 4.8 years. Assuming a start in the fall of 2007 leads to

beginning initial operations with a 5 kiloton detector late in 2010 and a CD-4 approval late in 2012. The wavelength shifting fiber and the building are critical path items in the schedule. The committee believes that the project can be accomplished within this time frame.

A quite flat funding profile peaking at about $62M per year is needed for the as spent point estimate TPC of $273M to deliver on this schedule.

Management

A nearly fully staffed Project Office is in place and level 2 and 3 (L2/L3) managers are identified. It was this team that has conducted the R&D; produced the CDR, cost estimate, schedule, management and other associated documents.

The four required CD-1 management documents (CDR, Preliminary Project Execution Plan, Preliminary Project Management Plan, and Preliminary Hazards Analysis Report) are in the advanced draft stage. In addition, the NOvA project team has prepared Risk Management Plan, Configuration Management Plan, and Value Management studies.

The major efforts to be completed prior to the DOE Lehman CD-1 Review for NOvA are to determine and document the R&D Plan, complete the CDR, and make the supporting documentation (resource loaded schedule, basis of estimate, and presentations [including breakouts]) more consistent.

10.0 Charge Questions

Technical

10.1 Are the requirements that form the basis for the design and engineering phase of the project clearly documented?

The relation between design and engineering requirements (energy resolution, evenr tate, background rejection etc.) and the design (technology, location) is well documented by simulation studies. The explanation of the relation between the design and engineering requirements and the high level goals (precision on physics variables) could be made more clear for non-experts.

10.2 Does the conceptual design satisfy the performance requirements?

Yes

10.3 Has a Conceptual Design Report (CDR) been developed that includes a clear and concise description of the alternatives analyzed, the basis for the alternative selected, how the alternative meets the approved mission need?

Yes, in fact far more exploration of alternatives than is the norm in HEP.

10.5 Has the Project identified specific standards which include codes, standards, regulations, and needed discipline (electrical, mechanical, nuclear, fire, radiation control, etc.) requirements to procure, fabricate, construct, inspect, and test the components, subsystems, and systems?

The project has identified some specific codes and standards to be used during the life of the project (example: life safety codes noted). Disciplines necessary during project development and execution are also identified (e.g.: expertise of Project Mechanical Engineer for liquid scintillator mixing and quality control).

10.6 Can the conceptual design be built? The committee sees no show stoppers in the detector design that would inhibit it from being fabricated and assembled as presented. **Does the design meet the technical specifications?** Yes, it is believed that the design as presented will meet the technical specifications of the CDR. **Is it a reasonable design?** Yes. This is the design that is needed to accomplish what the NOvA project has specified.

10.21 Are ES&H aspects being properly addressed and are future plans sufficient given the projects current stage of development?

ES&H aspects of the project are in various stages for different parts of the project. Some areas have identified specific hazards and outlined mitigations. Other aspects are noted, but solutions not yet developed. Overall, for a project at CD-1, the project's ES&H concerns are reasonably well addressed, and it appears ES&H is integrated into all aspects of the project