Department of Energy
Review Committee Report

on the
Review of

NuMI OFF-AXIS NEUTRINO APPEARANCE (NOνA) EXPERIMENT

October 2007

EXECUTIVE SUMMARY

On October 23-25, 2007, a Department of Energy (DOE) Review Committee conducted a review at Argonne National Laboratory (ANL) of the NuMI Off-Axis ν_e Appearance Experiment (NOνA) Project, a Fermi National Accelerator Laboratory (Fermilab) project. By the request of Dr. Robin Staffin, Associate Director for the Office of High Energy Physics (OHEP), the Review Committee was chaired by Daniel Lehman, Director of the Office of Project Assessment. The purpose of the review was to assess the readiness of the project to establish technical, cost schedule and management baselines, which are needed for Critical Decision (CD) 2, Approve Performance Baseline. In addition, OHEP is planning to seek CD-3a, Approve Limited Construction so that NOνA may begin long-lead procurements and a limited set of other construction activities that are needed to maintain the proposed schedule with adequate contingency. The Committee reviewed the necessity of and project's readiness to carry out these activities.

The Committee was asked to verify that the design of the project adequately addressed the technical requirements, that the estimated cost and schedule were reasonable, and that there was a team capable of managing the project to a successful completion. The Review Committee was comprised of 24 technical and management experts from DOE national laboratories, DOE headquarters, and U.S. universities.

The NOνA project proposes to upgrade the Fermilab Proton Source and the existing NuMI beamline and construct two new detectors optimized to detect electron neutrino interactions in order to observe the oscillation of muon neutrinos into the electron neutrinos and measure the parameters of that oscillation. One detector (222 tons) would be located on the Fermilab site and one (15,000 tons) would be approximately 800 kilometers away at a northern Minnesota site.

Overall, the Committee judged that the project is ready for CD-2, with a recommended increase in flexibility, either in scope or in cost. Several long-lead procurements and selected construction activities are also considered ready for CD-3a.

The Committee was impressed with the technical design progress. Designs are satisfactory to meet the physics goals, and procurement and fabrication plans are appropriate.

The Committee was concerned that cost contingency may be barely adequate and that there was no scope contingency with a 15 kiloton (kt) required deliverable. The concern was that assumptions regarding confidence levels on the price of crude oil and certain escalation rates may not be suitably conservative to guarantee the 15 kt goal. The Committee recommended that the Project Execution Plan be modified to reflect clear definition of the technical goal versus the minimum technical baseline scope (e.g., 15 kt vs. 13 kt of detector), to provide sufficient scope contingency to guarantee higher confidence in delivery.

Conventional construction scope for the Near Detector was added recently and the concept is well understood. Details and cost need to be developed, but the assigned contingency is adequate. The Far Detector site preparation and road construction package meets technical performance requirements and is ready for execution. Title I design for the Far Detector building is well developed.

The cost baseline of $260 million is generally supported by detailed, well thought-out, and documented cost and contingency estimates. The project successfully matched its cost obligations profile to the DOE OHEP funding profile, but the funding profile requires that critical procurements be delayed.

The project did an excellent job developing the resource-loaded schedule. The Far Detector building is the critical path, and schedule is considered optimistic in some instances regarding receipt of materials. There is no impact to the project if the Tevatron operates for a full year beyond what is planned. The Committee recommended that the approximate eight months of schedule contingency with respect to CD-4 be re-evaluated.

ES&H programs supporting the NOνA project are effective and properly staffed, with Integrated Safety Management principles being effectively implemented into the project.

The project team is experienced, with most of the tools in place to successfully manage the project, including configuration control, engineering and other documents control, change control, Earned Value Management System, supporting databases, and Fermilab engineering document management systems. Draft or signed Memoranda of Understanding (MOUs) exist with the University of Minnesota (for implementing the Cooperative Agreement) and ANL addressing work scope, responsibilities, safety and interface issues. Additional, similar MOUs, Statements of Work, and Work Authorizations are being drafted to implement with the other NOνA institutions. There were no action items resulting from the review.

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1. INTRODUCTION

The Neutrinos at the Main Injector (NuMI) Off-Axis Electron Neutrino Appearance (NOνA) Experiment is planned to study the as of yet unobserved oscillation of muon neutrinos to electron neutrinos with the goal of illuminating the order of the hierarchy of neutrino masses and understanding the likelihood that CP violation occurs in the neutrino sector. The Department of Energy (DOE), Director of the Office of Science (SC), Raymond L. Orbach, approved Critical Decision (CD) 0, Approve Mission Need, for Electron Neutrino Appearance (EνA) on November 25, 2005 and CD-1, Approve Alternative Selection and Cost Range on May 11, 2007. The NOνA proposal utilizes the world's most intense neutrino beam, the NuMI neutrino beam at Fermi National Accelerator Laboratory (Fermilab) and will create a new large (approximately
15 kiloton) neutrino detector that is optimized for the detection of electron neutrinos.

The Office of High Energy Physics (OHEP) requested that the Office of Project Assessment conduct a review of the project in preparation for CD-2, Approve Performance Baseline. The review, chaired by Mr. Daniel Lehman, was conducted on October 23-25, 2007. The purpose of the review was to verify that the project is ready to establish technical, cost, and schedule baselines that would have high probability of being met.

The NOνA project consists of upgrades to the Fermilab proton source and NuMI beamline, a Near Detector on the Fermilab site, a Far Detector located 810 km away in Northern Minnesota, and a detector hall for that detector.

Accelerator and NuMI Upgrades: Fermilab is in the process of installing upgrades to the proton source (Linac, Booster, and Main Injector) to provide 320 kW of proton beam power on the NuMI neutrino production target. The NOνA project assumes the successful completion of those upgrades. The NOνA project will then incorporate change to the complex to allow the use of the Recycler as a proton storage ring to improve the throughput from the Booster to the Main Injector, as well as improvement to the Main Injector radio frequency (RF) system and the NuMI target to handle the power. In addition, the NuMI magnet focusing system will be adjusted to produce a higher energy beam.

NOνA Far Detector: The NOνA Far Detector is optimized for detecting low-energy (approximately 2 GeV) electron showers while rejecting background events. High-signal efficiency and good background rejection require frequent sampling in materials with low atomic

number.

The Far Detector will be an approximately 15,000-ton tracking calorimeter, measuring 16 by 16 meters and nearly 80-meters long. It is constructed from alternating vertical and horizontal cells of liquid scintillator (LS) contained in rigid plastic extrusion modules. A wavelength-shifting fiber is inserted into each LS cell and terminates on a pixel of a 32-pixel Avalanche Photo Diode (APD) chip. The APD is followed by front-end electronics that amplify, multiplex, digitize, and zero suppress signals before passing them to the data acquisition system.

NOνA Near Detector: The NOνA Near Detector will operate on the Fermilab site at a distance of about 1 km from the NuMI target in a new hall off the existing NuMI access tunnel. The primary purposes of the Near Detector are to measure the flux of muon neutrinos produced and to determine backgrounds to ν_e identification that will appear in the Far Detector. The NOνA Near and Far Detectors are nearly identical. The only significant differences are the size, the clock speed of the electronics, and the requirement that the Near Detector be mobile.

Far Detector Hall: The NOνA project requires construction of a detector hall in Northern Minnesota to house the NOνA Far Detector. The building will also include adequate space and infrastructure to facilitate construction and operation of the Far Detector. Most of the Far Detector hall will sit below grade. The exposed sides and top of the hall will be shielded from the electromagnetic component of cosmic rays.

2. TECHNICAL

2.1 Commodities: PVC Plastic, Wavelength-Shifting Fiber, and Liquid Scintillator

2.1.1 Findings

The Committee noted that these items, which here are termed "commodities" because they are to be obtained in very large quantities from industry, and are the key components that will form the heart of the NOνA neutrino detector. The liquid scintillator (LS) is a mixture of several components, mineral oil (MO), pseudocumene (PC), and two wavelength-shifting (WLS) fluors that will be dissolved in the PC.

The Committee commended the "commodities group" on their impressive work since the April 2006 DOE review, and on their attention to technical details. The designs for the extruded PVC cells, the WLS fibers, and the LS are satisfactory to meet the stated physics goals. The design of the detector area in the building at Ash River is good, with inclusion of secondary containment to prevent ES&H problems that could arise from potential LS leaks. The structural analysis is sound with appropriate engineering reviews. And the plan for the Integration Prototype Near Detector (IPND) is excellent. The quality assurance (QA) procedures are very thorough and well planned. In general, the project planning and execution are good, and the schedule is reasonable. The Committee noted, for example, that the expected long-lead time for the WLS production was included in the schedule.

The Basis of Estimates (BOEs) from some of the NOνA groups are unclear and too fragmented. They often lack readily available, important supporting material, such as MSDSs and QA procedures.

In general, the basic cost estimates for the commodities seem reasonable, especially for the early fiscal years. The Committee noted the fact that the vulnerability due to fluctuations in the market-driven cost of oil was considered in detail. The contingency rate of approximately 27 percent is not unreasonable. The yearly escalation rate of approximately 2.2 percent seems to be low but it may be acceptable if the cost and schedule risks were properly considered. However, there was some concern that unanticipated risks in costs and schedule may occur in FY 2011-2012, because it is planned that major commodity procurements equal to about one-third of the Total Project Cost (TPC) will not be made until four to five years from now (when 85 percent of the

PVC extrusions, 60 percent of the WLS fiber, and 80 percent of the LS will be obtained). In other words, the schedule is so long that the contingency and escalation rates for those out-years may be insufficient. The Committee also noted that the cap of $260 million imposed by DOE for the TPC may be insufficient to build and completely fill the planned 15-k detector.

2.1.2 Comments

The Committee commended the commodities group on the decision to use an experienced commercial toll blender, instead of creating a facility at Fermilab to mix the LS components. However, the location of the toll blender (in the Chicago area or in Minnesota) is a key logistical issue, with regard to the proposed schedule for long-distance shipments of the LS to Ash River.

The Committee judged that requiring beneficial occupancy of the Ash River detector building before acquiring the commodities creates a serious bottleneck. The resulting shipping schedule is very tight—what the Committee called "just in time shipping". Any problems or mishaps could create a domino effect to delay the schedule.

2.1.3 Recommendation

1. Consider decoupling the production of the commodities from the construction and occupancy of the Ash River detector building.

2. If this is done the project should: a) reevaluate the budget profile and production schedule to mitigate the cost/schedule risks from planned significant procurements in FY 2011-FY 2012 and possibly start these procurements earlier in the schedule, and b) obtain increased storage capacity for the fabricated PVC extrusions and for the completed detector modules.

3. Coordinate the procurement of the PVC modules, and of the PC, MO, and fluors that will fill these modules, so as to maximize (within the existing budget) the number of completed detector modules. Having excess empty PVC cells, or excess LS without the PVC cells to be filled, is a waste of resources.

4. Improve the uniformity of NOνA written documents, such as the BOE's, to elucidate the traceability of decisions and actions.
5. Resolve the noted inconsistency in what different collaboration groups are quoting for the required number of photoelectrons (PEs); some say 20 PEs, others quote 30.

6. Once these recommendations are addressed, the NOνA Commodities effort will be ready for CD-2 and CD-3a approval.

2.2 PVC Extrusion Module and Near/Far Detector Assembly

2.2.1 Findings

Module Production

The Module Production team made good progress since CD-1 in better defining the module construction process. A two-adhesive system for module assembly and sealing, developed in an extensive simulation and test program, cleanly satisfies both structural and contamination requirements for the module production.

The PVC module factory in Minneapolis (integrated production is 13,000 extrusion modules) is expected to produce 30 modules per day over a period of two years. Module production includes installation of WLS fiber in each cell, a manifold that routes the fiber to a joint for readout, and an end plate with mechanical fitments specialized for the two adhesive seal. The factory is planned to occupy a 60,000-square-foot facility that has good shipping capabilities and floor space for module production, along with buffer space for a one week supply of raw extrusions and a two-week supply of finished modules.

All steps of module production were thought through carefully, and time and motion studies for the steps with the largest uncertainties (approximately 70 percent) were completed. Tooling for the production was developed. The primary source of manpower will be the University of Minnesota student labor, identified as a flexible workforce. The factory will be active 12 hours a day. Safety oversight is handled by University of Minnesota, following OSHA and DOE requirements as detailed in the Memorandum of Understanding (MOU).

QA focuses on the two items: leak-tightness of the finished modules and light output of the fiber. Extensive tests were performed to establish the minimum acceptable leak rate. Test apparatus and procedures were developed to perform the leak checks during production. Light output of the fiber is key to performance of the finished detector. Tests were developed to measure transmission through the fibers to determine if the fiber was damaged during the construction process. Test data will be recorded in a common database accessible at all stages of construction. It is anticipated that both of these tests will be performed on receipt of the modules

at the Far Detector site to detect damage resulting from transport.

Near/Far Detector Assembly

The Near/Far Detector Assembly team made good progress since CD-1 in sharpening details of the assembly process. The scope of work includes completion of finite element analysis (FEA) work (in particular, validation of Far Detector (FD) structural stability over the 20-year detector design lifetime); incorporation of ES&H risk mitigation into the assembly process; design validation with full-size prototypes; preparation of infrastructure at both the Near/Far sites; design, fabrication, and installation of assembly fixtures; assembly of PVC modules into 31 planes to form a block; installation of the 33 blocks of the FD at the Ash River site; assembly of the 222-ton Near Detector (ND) in its cavern at Fermilab; filling of the modules with scintillator loaded oil to form the approximately 15kt FD; QA; detector outfitting with readout electronics and readout infrastructure; and commissioning of the detectors.

The FEA effort focused on bond performance and structural stability. The design team verified that a five-times safety factor for shear stress results for the chosen adhesive over all but a limited region, and that even if failure occurs in that region, the structural integrity of the block is not affected. Performance of a block section mock-up that used this adhesive matched FEA model expectations well.

Large scale prototyping, yet to be performed, includes a full-scale assembly prototype (FSAP) and full-height engineering prototype (FHEP); culmination of this program is the IPND, where many issues of the outfitting can be addressed in a prototype that will become part of the ND.

The commencement of the FD assembly is driven by the beneficial occupancy date of the FD Hall and the availability of the block pivoter, detector modules, and adequate work force. PVC modules will be received from the University of Minnesota factory and quality controlled (QC). Each block will be assembled approximately thirty feet off the floor on a flat table, the block pivoter, by coating the PVC modules with adhesive and laying them into alternating "horizontal" and "vertical" planes that form the block. Once the block is complete, the block pivoter swings into a vertical position, and translates the block into position at the working face of the NOνA detector at the far end of the hall. As the blocks are completed, they are filled with LS. The electronics readout boards are installed, along with cooling manifolds and cabling.

Block assembly time-and-motion studies were completed to choreograph block assembly. Current plans are to perform the assembly in two shifts of ten people, including two crew bosses. One crew of four applies adhesive, while another crew of four places the modules

on the block. Crane speed was factored into timing estimates. The block assembly process is driven by the 20-minute pot-life of the adhesive. The team is building a prototype dispenser to prove out the procedure and timing. The schedule incorporates approximately two hours of unassigned time per shift for the crews to primarily allow for inefficiencies. An additional crew installs the electronics modules, cooling water system, and cabling, while another crew fills the modules with scintillator fluid. All outfitting components are pre-assembled and tested, including cable harnesses, pipe and hose runs, and cable trays. There are two access bridges running on a common rail, to provide access for both crews to the tops of the blocks, as well as catwalks for access to the side of the block where the manifolds protrude. In addition, there will be an independent physicist crew that will commission the outfitted blocks.

The team anticipates that there will be a manpower ramp-up period during which new technicians are trained and efficiency is only 50 percent. This was folded into the assembly schedule. The complete assembly of the FD is scheduled to take roughly 2.5 years. There are eight months of contingency in the overall project schedule.

The block pivoter is acknowledged by all to be the key piece of assembly hardware. This is both because it is the single location through which all modules must flow, and because it is a very large and heavy fixture that has difficult design requirements. This combination results in a high technical risk for the development and operation of the fixture. The team plans to assemble the pivot table at Fermilab by welding, verify operation, plasma-cut it apart, ship to the Far Site, and re-weld it together. This is thought to be less expensive than bolting. The plan is to prototype the pivot table welding procedures by building a prototype for the FSAP.

2.2.2 Comments

Module Production

The Committee commended the team for the outstanding work completed since the April 2006 DOE review. This portion of the project appears to satisfy the EIR Lines of Inquiry. Technical progress was good. The elegant two glue solution, with specialized mechanical fitments, maintains scintillator and oil purity while providing a strong structural seal against leaks at the manifold and end plate.

The project team developed a credible cost and schedule for module production based on the time and motion studies that were performed for the majority of tasks associated with PVC module production. Value engineering considerations led to the consolidation of module production into a single factory, reducing costs and schedule risks, in particular, those associated

with additional shipping steps. Floor space in the factory is adequate for module production along with a small buffer space for extrusions and completed modules. Module production will be near the critical path due to the just-in-time paradigm of the module assembly process. Consequently, the Committee encouraged the team to investigate cost effective ways to provide extra buffer space, whether via an expanded factory footprint or via emergency space rental, to reduce risk.

Contingency appears to be adequate for the module production task. Although the labor contingency might appear light, effort can be readily expanded at modest cost via an increase in the low wage student labor force. The Committee noted that the 12-hourday schedule supplements the touch labor identified in the time and motion studies with a 33 percent buffer that is meant to cover inefficiencies, and includes down-time between choreographed tasks, machine maintenance, cleaning, kit preparation, and inventory control.

Critical path and risk analyses were performed and adequate performance measurement yardsticks developed.

The Committee recognized the mature state of the extensive module production QA program and applauded the use of a common database across all production steps.

The Committee noted that a number of design reviews were held; more are scheduled. However, it is important that the production readiness review include outside reviewers.

Plans for mitigation of safety issues were developed, in particular to deal with PVC glue vapors. The module production team is encouraged to investigate a curtain system to enhance worker safety. A safety review that includes external experts should be held well in advance of the beginning of production.

Near/Far Detector Assembly

The Committee commended the team for the outstanding work they have done since the April 2006 DOE review. This portion of the project appears to satisfy the EIR Lines of Inquiry.

Technical progress was good. In particular, the Committee is impressed with the FEA of the PVC block, as well as the detailed experimental verification of the performance of the PVC extrusions and glue.

At the time of the April 2006 DOE review, the ND was located in the access tunnel to the

MINOS near hall. The baseline now includes a separate cavern for the ND. This reduces the complexity of the infrastructure and installation, though likely increases the cost, as well as adds the risk associated with excavating the cavern.

The cost, with contingency, was estimated. Some individual items have perhaps overly conservative cost estimates and large contingencies; others are somewhat optimistic and have marginal contingencies. However, the roll-up of all these assembly costs and the overall contingency are adequate to the task at hand. The WBS is quite well developed. However, the Committee noted that access to back-up information for the Basis of Estimate was quite awkward.

Considerable progress was made in adapting to changes in block assembly that were required by the value engineering based reduction in size of the FD building. Though there is a conceptual design skeleton that has much flesh on it, there remains some schedule risk associated with resolving details of the block assembly procedure.

Safety received consideration in the development of the block assembly procedures. The Committee judged that keeping tight coupling of safety engineering in the design process/planning of assembly activities is crucial. It also suggests that in the early days of two shift operation, it would be beneficial if safety engineer oversight was present during the operations of both shifts.

The assembly group and the electronics group worked through details of electronics and cooling fit-up and installation. Progress in integration has improved lately. However, integration continues to be a concern. Better communication and focus are needed, in particular on the part of the electronics team. The integration activity remains a threat to the timely completion of detector assembly and checkout.

A number of design reviews were conducted. A substantially larger number remain to be done. The Committee encouraged more formality for the key reviews, with membership to include external reviewers. Costs associated with these reviews are perhaps best captured in the management WBS element.

The block pivoter, because of its central role in FD assembly, is an item that presents large associated risks. Clear performance, operations and servicing criteria must be established early on as part of the design development process. Analysis is needed to address lateral loading and acceleration. A list should be developed of all single failure points, along with their failure mechanisms, the way in which the failure is accommodated (stress analysis for overload conditions), inspection methods for preventative maintenance, and plans for servicing the

components. This includes key welds on brackets holding the pivots. This is similar to what is required for lifting fixtures, and is consistent with the spirit of the requirement, to ensure that all key hardware components be identified and checked for safety over the life of the fixture. Because the block pivoter involves stored energy, lock-out-tag-out requirements apply, requiring that operating and servicing procedures be approved prior to operations. Assembly personnel will work on top of the block pivoter during block assembly at approximately 30 feet off the ground; the working surface of the block will be more than four feet off the block pivoter table as the final layers are added onto the block stack. Fall protection, safe-standing locations while loads are transferred overhead via vacuum lifting fixtures, and egress issues should be thought through as part of the design. The project should consider incorporation of moveable platforms onto the block pivoter to ameliorate safety concerns. The Committee is concerned that the proposed block pivoter assembly via welding will make it very difficult to achieve the required flatness both on assembly at Fermilab, and then on re-assembly at the Ash River site. The cost to move from conceptual design through final design of the block pivoter seems inadequate. The conceptual design should be vetted soon, before more extensive engineering effort is invested. Finally, the Committee noted that potential risks would likely be reduced by prototyping and construction of the block pivoter earlier than called for in the project plan.

2.2.3 Recommendations

1. Ready for CD-2 and CD-3a approval.

2. Conduct a conceptual design review of the block pivoter that includes external reviewers before December 31, 2007.

3. Advance the funding for the block pivoter to allow earlier prototyping and construction.

4. Appoint before December 31, 2007 an Integration Coordinator to improve communication and progress in intersystem interface issues.

2.3 Electronics and Data Acquisition

2.3.1 Findings

The instrumentation of the NOνA detector includes an electronics system (WBS 1.6/2.6) and a data acquisition (DAQ) system (WBS 1.7/2.7).

The total estimated cost of Electronics R&D (WBS 1.6) and Electronics Production (WBS 2.6) is $12.8 million (six percent of the TPC). The estimated cost of DAQ system R&D (WBS 1.7) and DAQ System (WBS 2.7) is $4.4 million (two percent of the TPC). The contingency assigned to Electronics Production is 33 percent. The contingency assigned to the DAQ System is 28 percent. No contingency was applied to R&D preceding the IPND. The contingency assigned to Electronics R&D is six percent. The contingency assigned to DAQ System R&D is less than one percent. Installation activity and costs of electronics and DAQ are included in WBS 2.8/2.9, and were not reviewed by the Committee.

A resource-loaded schedule exists. It shows all activities at least ten to twelve months off the critical path. The schedule is paced by the availability of funding. Without funding profile limitations, completion would be approximately two years off the critical path.

The electronics and DAQ systems, subsystems, and components have not yet undergone design review. Design reviews following future prototype testing are planned.

Electronics (WBS 1.6/2.6)

The electronics system for NOνA consists of approximately 12,000 avalanche photodiode (APD) modules and front-end boards (FEBs) for the FD and approximately 500 APD modules and FEBs for the ND. Each APD module includes a 32-pixel APD photodetector with thermoelectric cooler and housing. Each FEB includes a low-noise amplifier-shaper ASIC, a high-speed custom analog-to-digital converter (ADC), and an FPGA for data movement and control. The electronics system also includes a low-voltage and high-voltage power distribution system and a liquid chiller system for the thermoelectric coolers.

The APDs used as photodetectors are high cost, sole source (Hamamatsu Photonics), semi-custom devices. APD procurement is the largest single cost item in WBS 2.6/2.7, with a base cost of $5.6 million. A small number (20) of final NOνA-specific devices were delivered and measured with gratifying performance results. Costing for the APDs is, however, very preliminary, and Hamamatsu is unable to do more than suggest a probable range of prices without final NOνA specifications. Measurements of the prototype APDs, especially in conjunction with the "vertical test", should allow finalization of specifications for the NOνA devices in calendar year 2007. There does not appear to be a schedule risk associated with this device.

A prototype of the FEB, with a preliminary prototype of the front end ASIC, demonstrated performance close to what is likely to be required for NOνA. An agreed upon set of requirements

was not shown and will depend to some extent on APD performance and on the light output of the fiber and scintillator. The custom ADC chips were obtained from production for CMS; however, they have not yet been packaged.

A detailed design was put forward for low-voltage and high-voltage power distribution from commercial supplies to the FEBs (and from FEBs to APD modules). A very detailed design was put forward for the distribution and control of cooling water for the APD thermoelectric coolers.

CD-3a approval for two procurements is proposed: 1) packaging of existing custom ADC chips for the FEBs, and 2) production of custom application-specific integrated circuits for signal amplification and shaping for the FEBs.

Data Acquisition System (WBS 1.7/2.7)

The major deliverables of the DAQ system are the Data Concentrator Modules, the timing system, and DAQ/control computing and software. The 198 Data Concentrator Modules each collect data from up to 64 FEBs and transmit data by Gigabit Ethernet to 136 buffer PCs for the far detector. The timing system distributes a common clock to all FEBs in order to synchronize events. Hardware and software to control and monitor high- and low-voltage power distribution, cooling, and the detector are included in WBS 2.7.

2.3.2 Comments

The system and subsystem technical designs of the electronics and DAQ systems will address performance requirements. The technical design of these systems has advanced beyond the requirements for CD-2 approval.

The collaboration does not use design reviews to actively advance and improve the details of a design during the design process. Comprehensive design reviews starting from requirements, system design, and interface specifications, and encompassing all subsystem and component specifications, designs, and prototype results, would be beneficial to future development work. Reviewers should include experienced individuals from outside the project, as well as individuals from within the project familiar with the detector elements and mechanical structures that interface with the electronics.

The “vertical test”, which will test the electronics and DAQ chain from particle detection

through analog signal processing and digitization, is essential to demonstrating adequate signal-to-noise ratio and to finalizing APD and FEB specifications. The IPND will be valuable for integration testing.

The combined cost of these systems is a relatively small fraction of the TPC (less than ten percent). The overall cost estimate is appropriate. Opportunity exists for additional value engineering that could somewhat reduce costs. Some contingency assignments are optimistic. The project management decision to assign no contingency to the design and prototyping R&D activities adds cost risk. Contingency of 30 percent on these R&D activities could require an addition $700K.

While the upper level costs in the budget and contingency tables appear reasonable, the BOE supporting documents examined by the Committee were of uneven quality, sometimes inconsistent with the WBS tables, sometimes not providing adequate detail for large cost items, and sometimes detailed but obsolete. The BOE for these systems needs to be improved in preparation for the EIR. At minimum, the BOE documents for all major cost items should be reviewed and brought to a uniform high quality. Wherever possible, multiple quotations should be sought.

The schedule is appropriate for CD-2. It allows completion with adequate contingency despite being limited by funding profile. Technical expertise and experience of the team developing the electronics and DAQ systems are matched to the technical design.

Completion within budget and on schedule will require proactive management following CD-2. It will also require additional attention to details and coordination of systems, project, and integration engineering, including with respect to interfaces to other Level 2 WBS activities.

While many of the electronics designs listed are backed up by Design Requirement documents, there do not appear to be simple, concise, and accessible documentation of requirements. Tables of requirements and specifications for the APDs, ASICS, ADCs, FEBs, and other components would help NOνA to determine if the present designs are adequate and to understand if further value engineering is possible. Specifications should be based upon and traceable to physics and engineering requirements.

Electronics (WBS 1.6/2.6)

The APD cost estimate is necessarily uncertain at this time, as evaluation tests and

specifications are not yet complete. The cost estimate and contingency are appropriate. Cost uncertainty will persist until a firm quotation is obtained just prior to procurement, which is scheduled for October 2009. Uncertainty in the exchange rate contributes some additional cost exposure. The sole source of APDs (Hamamatsu) has a long history of supplying high performance devices to the research community at fair prices, and the NOνA project's cost model and assigned contingency for the APDs are plausible and reasonable.

The prototype design of the APD housing, FEB, and power and cooling systems were presented and appear to be in an advanced state of development, fully adequate for CD-2 approval.

The cost and schedule estimates for the FEB seem reasonable.

Packaging of FEB ADC chips in the near term, in order to reduce the risk of performance degradation, is recommended. A choice of vendors should be possible, and multiple vendors should be investigated in order to obtain the best price.

The development of the FEB ASIC is still underway, and the chip is not yet ready for production fabrication. The final prototype must first be developed and tested, and the vertical test must be completed. The required fabrication process for this integrated circuit is very unlikely to be discontinued in FY 2008.

The design of the low-voltage power distribution system is a non-trivial task given the immense size of the detector; nevertheless, the design seems adequate and reasonable. The cost and schedule information presented was detailed and plausible. The design anticipates use of the remote sense capability of the Weiner bulk power supplies. Use of remote sensing is somewhat risky in terms of possible oscillations in a large distributed system and seems unnecessary given the final regulation step planned for the FEBs.

The liquid cooling system consists of a very large number of identical or nearly identical manifolds delivered from an assembler directly to the far detector site. At the moment, there is no plan for leak testing prior to installation on the detector. It would probably be wise to examine the relative costs of leak checking prior to installation vs. rework *in situ* or removal and reinstallation costs should a leak be found after installation.

The NOνA detector is, in some ways, a very simple repetitive structure. However, the detector is very large, the electronics are distributed across an immense surface area on the top and one vertical side, and access to the electronics is not always simple.

It was not clear that possible concerns of the NOνA installation and integration tasks had been fed into the detailed design of the front end electronics housing and of the power and cooling distribution systems. A closer coupling of WBS 2.6 and 2.8/2.9 activities during the upcoming final design phase would likely be valuable.

In summary, WBS 1.6/2.6 is ready for CD-2 and CD-3a approval.

Data Acquisition System (WBS 1.7/2.7)

The design of the DAQ system for the most part uses conventional techniques and methodology, and the design is being performed by an experienced group. The unusual feature of the DAQ system is buffering of many seconds of zero-suppressed events that are read out continuously and assembled in buffer PCs in which software selects events for recording. This design simplifies the timing and triggering requirements at the expense of additional commodity computing hardware (processors and network switches), and the trade-off is reasonable.

The performance of the timing system will far exceed performance requirements. Cost savings is possible if a simpler design concept were adopted.

DAQ software staffing is now marginally adequate for timely completion. Installation of DAQ electronics, high- and low-voltage power, and cooling are not part of the scope of WBS 2.7, but are part of WBS 2.8/2.9. Information about installation was not presented.

In summary, WBS 1.7/2.7 is ready for CD-2 approval.

2.3.3 Recommendations

1. Improve BOE in preparation for EIR.
2. Perform timely design reviews.
3. Produce a concise and coherent set of electronics specifications.

2.4 Accelerator and Beamlines

2.4.1 Findings

The accelerator portion of this project provides the capability of increasing the beam power onto the NuMI target. There is an ongoing program at Fermilab, known as the Proton Plan, which will incrementally increase the beam power on the NuMI target. Since the CD-1 review, a significant portion, but not all, of the Proton Plan scope was brought into the NOνA project. Within NOνA this is known as the "Accelerator and NuMI Upgrades" (ANU). The accelerator portion involves changes to the Recycler and Main Injector that will increase the power to 700 kW, essentially through the following:

- The accumulation of booster batches, presently done on the Main Injector front porch, will be done in the recycler ring while the Main Injector is ramping. This reduces the cycle time by .7 sec.
- The Main Injector ramp rate will be increased by the addition of one power supply and two RF systems. This reduces the Main Injector cycle time by approximate .17 sec. These upgrades, and previous bullet items, reduce the cycle time from 2.2 to 1.33 sec.
- All booster batches will be sent to the NuMI target (presently two are sent to anti-proton target).

The technical equipment to support these changes is primarily in the first bullet; the recycler needs to be modified to accommodate particles rotating in the opposite direction than at present and therefore existing transfer lines need to be removed, and new transfer lines will be built and installed. The transfer line from the booster, which presently injects beam into the Main Injector will be extended into the Recycler, and new RF systems that support slip stacking will be designed, built, and installed in the Recycler. There will be an upgrade to recycler instrumentation to accommodate the higher charge and different bunch structure. The majority of the cost and activity associated with these changes involves new kickers and installation work.

The NuMI or Beamlines portion of the ANU work scope involves:

- Relocation of the NuMI second horn to the medium energy configuration
- New higher power (700 kW) target
- Upgrades to accommodate higher power
- Upgrades to accommodate shorter cycle time

The cost of the work in these WBS elements is $52.3 million including contingency (34 percent). The schedule is based around two shutdowns: October 2010 – December 2011 for accelerator upgrades, and April-June 2012 for NuMI beamline upgrades.

The target is one of the few new designs in this WBS element. The target is being designed by Institute of High Energy Physics (IHEP) in Protvino, Russia, the laboratory that designed the present target (see drill down #8 below).

2.4.2 Comments

The Committee concurred that this work scope can be done in the budget and schedule presented. The management and technical staff that is in place is experienced and well prepared to carry out the project. The ANU work scope satisfies the performance requirements of the NOνA project, although the Committee noted that the ultimate deliverable of 700kW on target does partially depend on off-project elements (e.g., the proton plan).

The project is prepared to proceed with the long-lead procurements in this WBS and has provided adequate justification for the procurements. The procurements that were identified are related to components for which there are existing designs (or minor modifications). The need for the early procurements is related to the available effort profile, and the need to get certain tasks done early.

The Committee noted that initially the highest rated risk items were the ceramic beam chambers needed for the kickers. The project has essentially mitigated this risk by purchasing twice the number needed to account for quality and fabrication problems. The next highest risk item is insufficient manpower, particularly the short-term need for mechanical engineers. The Committee encouraged project management to continue their ongoing discussions with the Accelerator Division to address this concern.

The overall level of contingency throughout this WBS is reasonable. Items that require R&D have justifiably higher contingency as a result of not having the design frozen.

In evaluating the credibility of the cost and schedule estimates, the Committee utilized

provided reports from two director's reviews done earlier this year. In these reviews, a total of seven drill down exercises were performed.

- Drill down #1: RR Injection and Gap Clearing Kicker (WBS x.0.1.2.1)
- Drill down #2: RR30 Remove Electron Cooling/Rebuild Section the FODO Lattice
- Drill down #3: 53 MHz System for the RR (WBS 2.0.1.1.2)
- Drill down #4: RR BPM Cable and Board Procurement/Installation (WBS 2.0.1.3.1)
- Drill down #5: 53 MHz System (WBS 2.0.1.1.2)
- Drill down #6: RR Injection and Gap Clearing Kickers (WBS 1.0.2.1.1)
- Drill down #7: NuMI Target Hall Infrastructure (WBS 1.0.1.2/2.0.3.3)

The Committee reviewed these, noting that they included a range of tasks. These drill down exercises revealed that it was straightforward to follow the costs, and that the cost and schedule estimates are credible. The Committee then performed two further drill down exercises during the course of this review, documented below.

Drill Down #8—NuMI Target Hall Technical Components (WBS 1.0.3.2/2.0.3.2)—Engineering and Design, and Construction.

Documents reviewed included: 1) the NOνA schedule, budget and contingency documents, 2) the BOE document for selected items, and 3) discussions with project engineers. The Target Hall technical components consist of the following items:

- **Medium Energy Target**. This is a new design. The most demanding technical element is the window, with beryllium and graphite possible options. The design, contracted out to IHEP (who built the existing low-energy NuMI target) is not finalized. Basis for target estimate is the existing low-energy target. Sufficient contingency was allocated (>60 percent) both for R&D and Construction to accommodate a more expensive target design if needed.

- **Target Carrier**. This is the frame that holds the target. Basis for cost estimate is the existing target carrier. The one for NOνA will not need longitudinal motion, so it is in principle technically easier. A large contingency was nevertheless included to allow for additional manpower if needed in the design.

- **Baffle**. Low cost items, BOE also the one for the existing NuMI target.

- **Hadron Monitor**. Detector at the end of the line—important for commissioning, aligning, and monitoring the NuMI beam line. The new detector for NuMI is a modification of the aging, existing detector. The plan is to add this to the NuMI beam abort system, which needs additional capability and electronics. The BOE is

the present detector, built by the University of Texas at Austin, who will build the new one too.

Conclusions on the drill down exercise on the NuMI Target Hall Technical components:

- Reviewed budget and BOE documents.
- The component with the highest risk is the new medium-energy target (especially the window). However sufficient, previous experience on the existing target exists and sufficient contingency was allocated to insure time and resources for the new design.
- Target carrier, baffle, and hadron monitor designs are modifications of existing NuMI designs and appear relatively straightforward. Again, enough contingency is allocated.
- Appropriate design review and milestones are planned.
- The balance of components in the project scope and outside (i.e., horns and spares) appears reasonable.

Drill Down #9—Beam Lines (WBS 2.0.1.1.1)—Transfer, Abort, and RR 30 Straight

Review of the methodology of BOE costs for the various tasks within this work package revealed a consistent approach in line with other WBS areas. Individual tasks are well defined and detailed enough to capture duration and costs. The duration of each task is estimated primarily on past experience with resource type (e.g., engineer, technician, craft, etc.) being allocated, which in turn yields a cost for the task. BOEs are allocated unique numbers and these are easily identified within the resource-loaded schedule. All tasks reviewed within this WBS were consistent with the BOE numbers leading directly to the construction, budget, and contingency schedules.

Further discussion regarding management of union craft labor for installation purposes (e.g., electricians, pipe-fitters, etc.) revealed that the project has a sound plan in place to supervise and monitor hours worked. This is managed using work authorization forms and weekly sign-off of time sheets for all craft labor.

2.4.3 Recommendations

1. This WBS is ready for approval of CD-2 and CD-3a.

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3. SITES and BUILDINGS

3.1 Findings

The Title I estimate for the FD Site and Building is $54.8 million, including 22 percent contingency. This includes the costs for design by an Architect/Engineer (AE), construction costs, University of Minnesota fee and the fee of the Construction Manager (CM).

A Value Engineering study by Fermilab was performed for the FD design that resulted in a cost reduction of $1.8 million, which was incorporated into the baseline.

Three independent estimates were prepared for the FD construction and the baseline estimate was developed with Monte Carlo techniques.

A site investigation of the FD Site was conducted. This included performing site borings to determine the overburden and assess the competency of the rock.

The conventional scope for the ND (WBS 2.8) was recently added. The concept is well understood, but the details and costs need to be developed.

3.2 Comments

The FD site preparation package meets the technical performance requirements and with minor revisions is ready for execution.

The project should be commended for evaluating the sub-surface to determine the suitability of the building location.

Project documentation supports the project schedule.

The Title I design for the FD Building is well developed.

3.3 Recommendation

1. Incorporate the conventional portion of WBS 2.8 into WBS 2.1.

2. Develop a document to support the MOU between Fermilab and the University of Minnesota that clearly defines roles and responsibilities between all parties involved in the design and construction of the FD Site and Building.

3. Reassess contingency for the FD Site and Building (WBS 2.1) assigning risks at the lowest level of the WBS.

4. The University of Minnesota should provide their requirements for operation and maintenance of the FD facility and those requirements should be incorporated into the Title II design.

5. Proceed with the design of the ND conventional work as soon as practical.

6. Proceed with plans to have an independent assessment performed of the means and methods for constructing the FD Building. That review should also investigate methods to compress the construction schedule, since the building is on the project's critical path.

7. Conventional Facilities for the FD Site and Building is ready for CD-2 and CD-3a.

4. ENVIRONMENTAL, SAFETY and HEALTH

4.1 Findings

The Environment, Safety, and Health (ES&H) programs are effective and properly staffed. The staff is highly experienced and provides appropriate support to the project.

The ES&H aspects of the project are being properly addressed. The appropriate Hazard Analyses have been completed, and scope, schedule, and costs necessary for safety were incorporated into the respective baseline. All required permits have been identified, and plans are underway to acquire the appropriate permit(s) to support construction at the Ash River site. NEPA documentation is undergoing final review and should be completed in time to support the project. The State of Minnesota Environmental Assessment Worksheet was prepared and submitted, and approval is anticipated by mid-November 2007.

Integrated Safety Management (ISM) principles are effectively incorporated into the project.

4.2 Comments

Staffing levels and areas of expertise are appropriate for this stage of the project; the ES&H program will provide appropriate and timely support.

ES&H staff were properly involved in initial phases of work planning, and have excellent knowledge of the plans. Of note, the appropriate hazard analyses were completed, and the respective safety documentation is sufficient for this stage of the project. For the Accelerator and NuMI Upgrades, the appropriate radiation safety calculations were performed and these serve as the foundation for regulatory permitting decisions and ultimate commissioning.

The project spans two national laboratories, numerous educational institutions, and two States. Two MOUs, one finalized between ANL and Fermilab, and one draft between the University of Minnesota and Fermilab were examined. In these MOUs, ES&H responsibilities and jurisdictions are clearly identified. These MOUs should serve as models for additional MOUs with remaining institutions.

Project support documents are extensive and well-written, and efforts to update and

maintain the documents are planned.

4.3 Recommendations

1. ES&H interfaces between all parties need to be formalized, and this is currently planned through the MOU process.

2. DOE/CH, the Fermi Site Office, and Fermilab/NOνA parties, in coordination with the University of Minnesota, need to provide all necessary and sustained effort required to ensure that the NEPA process is successfully completed. NOνA can then address any comments on the EA that may arise during the state/public comment period in Illinois, and move successfully on to the next stage.

3. The University of Minnesota should submit application(s) for Aquatic Resource Alteration Permits (ARAP) as soon as practical to support construction of the Ash River access road in spring 2008.

5. COST ESTIMATE

5.1 Findings and Comments

The cost baseline is supported by detailed, well planned cost estimates. The project clearly identified resources by type, organization, and function, making it easy to apply appropriate burdens and determining staffing requirements. The massive amount of documentation supporting the project estimate may be daunting to the EIR.

It is clear that the project put significant effort into developing a sound BOE and contingency and should be commended.

The performance baseline utilizes three sets of escalation: one for labor (4.8 percent per year), one for construction (variable), and one for all other procurements (approximately two percent per year). The funding profile requires that the project delay critical procurements.

5.2 Recommendations

1. The project should plan on providing personnel to assist the EIR team and guide them in following and finding documentation.

2. Re-evaluate the appropriateness of the procurement escalation rate used, particularly for the three major cost drivers (LS, PVC extrusions, and WLS fiber) that are now using the two percent factor.

3. The project should pursue obtaining a reduced overhead rate for those purchase orders that will not be received and handled at Fermilab.

4. The project cost estimate will be ready for CD-2 and CD-3a once increased flexibility, either in scope or in cost, is obtained.

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6. SCHEDULE and FUNDING

6.1 Findings and Comments

The project schedule contains 5,970 activities and 7,284 relationships. Most activities are resource-loaded. Milestones are not resource-loaded. Some logic ties are absent (e.g., LOE activities) and some are incorrect (e.g., receipt of MO not tied to appropriate QA and fabrication activities).

Four random BOEs were selected to validate traceability (2.6.2.1.7.1-3, 2.5.3.1.1, 2.4.5.3.1.1, 2.1.1.4). Documentation errors that have no significant impact on the project cost were found in two of the four.

The project did an excellent job in developing and resource-loading the schedule. The schedule is optimistic in that it assumes that receipt of the materials associated with these phase-funded contracts occurs in October of the next fiscal year. The schedule contingency is approximately eight months, which is approximately 12.5 percent of the total project's duration.

6.2 Recommendations

1. All schedule logic should be verified to ensure that ALL activities are logically tied and that the ties are correct before the EIR.

2. Change the delivery activities to allow appropriate time for the contracts to be modified and the vendors to receive funding before delivery can begin.

3. Re-evaluate schedule contingency once recommendations 1 and 2 were incorporated into the project schedule.

4. Investigate acceleration of activities to minimize project risk.

5. The project schedule will be ready for CD-2 and CD-3a once these recommendations are implemented.

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7. MANAGEMENT

7.1 Findings

An overview was given of the progress made since the April 2006 DOE review and in preparation for the upcoming CD-2 and CD-3a and EIR reviews. The changes made to reduce the TPC to under $260 million were covered, and the project status in preparing for the 16 EIR Lines of Inquiry was shown.

The Project Execution Plan (PEP) was updated in October for CD-2 and reviewed by the Program Office but has not been finalized. The Project Management Plan (PMP) was also updated. The Technical Design Report and other project management documents are largely complete, and were updated for a 15kt baseline detector.

A single page master schedule with critical path was shown for the overall project. Schedule contingency is at eight months. Formal change control is planned, and is ready to be used upon establishing baseline.

Monthly reports are being carried out in narrative reform, and will include earned value upon establishing baseline.

Draft MOU and Statements of Work (SOW) were available to the committee. The Cooperative Agreement with the University of Minnesota is in place and a draft MOU is ready to be signed.

In addition to the Acquisition Strategy, the project developed an Acquisition Plan for each major procurement that includes: procurement description, identification of suppliers and/or market survey, evaluation criteria, procurement schedule and milestones, and cost estimates.

The project is using the regular Fermilab procurement staff with a nearly dedicated expediter assigned to the project.

Project office staffing is projected to include nine FTEs in FY 2008, and continue at nine FTEs in FY 2009-FY 2012, before ramping down substantially in FY 2013. The project office is fully staffed including all WBS Level 3 managers. The project manager, the deputy project manager, associate project manager, and head project scheduler are all full time and fully

engaged and competent. The Federal Project Director (FPD) is currently 80 percent assigned to the project, with balance of time toward final completion of another project this year, and is assisted by a part-time deputy. The FPD is Level 2 certified. The project relies heavily on operations staff to supplement project staff. The Laboratory Director assigned a representative who can resolve staffing issues between the current accelerator staff and project staff.

Current overall project staffing is now 66.5 FTEs, which is near the average projected requirement for FY 2008 and FY 2009. Staffing may be an issue as resource requirements increase over time after FY 2010.

A database group is in place for maintaining databases and applications for the project. Schema is developed from Level 2 manager's requirements, such as inventory, fabrication, simulation, and testing data. The database can be used to support quality control.

Configuration control, including project document control, engineering document control, and change control, utilize a combination of the EVMS and costing system (Open and Cobra), the NOνA DocDB, the Change Control Database (MS Access), and existing Fermilab engineering document management systems. The methods of configuration control are aligned with the PEP and PMP. Change Requests Forms and Document Change Notices were defined and will be used to manage and communicate changes. Configuration control is ready to implement upon approval of the baseline.

7.2 Comments

The project should be commended for their continued progress towards baselining the NOνA project. The project team is a good one, and they have nearly all the tools in place to successfully manage the project. The project team did an excellent job of answering the reviewer's questions.

The PEP and PMP should be modified to reflect clear definition of technical goal versus minimum technical baseline scope (13kt vs. 15kt). Details of current design should be in the Technical Design Report or similar documentation instead of the PEP. The draft PMP should also allow the potential for a future management reserve to be established.

The FPD is highly capable and engaged. The project would benefit from having his full-time assignment. For a project of this size, Level 3 certification is required and should be accomplished in a timely manner.

Given the recent history of a continuing resolution and tight funding for FY 2009 the project should review the budget vs. allocation on a monthly basis to ensure that the project is not impacted by a continuing resolution.

Estimation and management of contingency: consider implementing a contingency management plan that identifies how the contingency will be controlled by the FPD and the project.

The project should ensure that the key personnel interfaces and authorities between work conducted by the University of Minnesota and Fermilab are clearly defined in terms of personnel responsibilities and scope to be delivered. Thus, project planning depends on the drafted MOU between Fermilab and the University of Minnesota, especially with regards to safety and contingency utilization, where these issues should be addressed.

It is important to finalize the MOUs and SOWs and have them approved by all parties. Understanding resources (planned on by the project and committed by the collaborating institutions) will avoid misunderstandings and put planning on more solid ground.

The migration to WelcomRisk is good and was completed. However, it is difficult to easily trace the quantitative relationship of risk analysis to contingency determination.

There is no impact to the project should the Tevatron operate for up to one year.

The technical goal of 15kt was estimated to be achievable with a cost of $260 million at a 95 percent confidence level for the statistical analysis of the price of crude oil and a 2.2 percent escalation on M&S. These assumptions may not be suitably conservative to guarantee achieving the 15kt goal. It would be valuable to analyze the affect of increasing confidence level and escalation rates on baseline cost and evaluate versus establishing a baseline minimum required technical scope slightly less than the currently established technical goal of 15kt to allow for scope contingency.

7.3 Recommendations

1. Complete and approve the MOU between Fermilab and the University of Minnesota to supplement the Cooperative Agreement prior to CD-2. Include configuration management for the FD Building in the MOU to ensure configuration management is in place for conventional facilities while the project completes equipment installation and transitions into operations.

2. Finalize all MOUs and SOWs for all institutions prior to CD-2.

3. Review and update both PEP and PMP prior to the EIR, including proposing CD-3 and CD-4 approvals be delegated to the Associate Director for the Office of High Energy Physics.

4. Scrub all CD-2 related documentation for self-consistency before the EIR.

5. Because schedule contingency is tight, evaluate amount of schedule contingency before the EIR.

6. Combine management reserve and contingency at this stage of the project.

7. Verify that a reasonable cost contingency and escalation is being applied to address commodity pricing risks.

8. Approve CD-2 and CD-3a for the NOνA project after addressing these recommendations.

APPENDIX A

CHARGE MEMORANDUM

memorandum

DATE: September 5, 2007

REPLY TO
ATTN OF: Office of Science

SUBJECT: Request to Conduct a Baseline Readiness Review of the NOνA Project.

TO: Mr. Daniel Lehman, Director, Office of Project Assessment, SC-1.3

The Department of Energy (DOE) Office of High Energy Physics (OHEP) requests that a baseline readiness review for the NUMI Off-Axis Neutrino Appearance (NOνA) Project be conducted on October 23-25, 2007 at Fermi National Accelerator Laboratory. The purpose of this review is to assess the readiness of the project to establish technical cost schedule and management baselines, which are needed for Critical Decision 2 (Approval of Performance Baseline).

The Acquisition Strategy calls for the far detector enclosure to be built by the University of Minnesota under a financial assistance agreement. The cost of the enclosure will be captured as part of the Other Project Costs and therefore part of the Total Project Costs. The project and the university are developing strategies to ensure proper integration of the university's efforts into the overall project.

In addition, OHEP is planning to seek CD-3a (Approve Limited Construction) so that NOνA may begin long-lead procurements and a limited set of other construction activities that are needed to maintain the proposed schedule with adequate contingency. Please review the necessity of and project's readiness to carry out these activities.

The NOνA project will build two neutrino detectors, an enclosure for one of the detectors, and will fabricate and install upgrades to the Fermilab proton source and the NuMI facility to enhance the intensity of the neutrino beam used by the detectors.

In performance of a general assessment of progress, current status, and the identification of potential issues, the committee should address the following specific items:

1. Technical Scope: Review the technical scope in order to assure that the proposed design and associated implementation approach satisfies the performance requirements.
2. Cost Estimates: Is the cost estimate consistent with the plan to deliver the technical scope with the stated performance?
3. Does the project satisfy all 16 lines-of-inquiry (Appendix A)?
4. Management: Evaluate the management structure as to its adequacy to deliver the proposed technical scope within specifications, budget, and schedule.
5. Limited construction: Are the requested long-lead procurements and other construction activities scheduled for FY 2008 necessary to achieve the stated schedule? Have Fermilab and the project done the necessary preparations to execute these activities during FY 2008?

6. Are ES&H issues being properly addressed given the project's current stage of development?

Michael Procario is the program manager for the NOνA Project in this office and will serve as the OHEP contact person for the review.

We appreciate your assistance in this matter. As you know, these reviews play an important role in our program. I look forward to receiving your Committee's report.

You are asked to submit a formal report to OHEP with 30 days of the review.

/signed/

Robin Staffin
Associate Director
Office of High Energy Physics

APPENDIX B

REVIEW PARTICIPANTS

REVIEW COMMITTEE PARTICIPANTS

Department of Energy Review of the
NuMI Off-Axis Neutrino Appearance (NOvA) Experiment
October 23-25, 2007

Daniel R. Lehman, DOE, Chairperson

SC1
Commodities: PVC/Fiber/ Scintillator

* Richard Hahn, BNL
Jim Proudfoot, ANL
Bill Louis, LANL

SC2
PVC Extrusion Module & Near/Far Detector Assembly

* Bill Wisniewski, SLAC
Dick Loveless, U. of Wisconsin
Jim Krebs, SLAC
Martin Nordby, SLAC

SC3
Electronics and Data Acquisition

* Andy Lankford, UC Irvine
John Haggerty, BNL
Rick Van Berg, Penn

SC4
Accelerator and Beamlines

* Rod Gerig, ANL
Fulvia Pilat, BNL
Graeme Murdoch, ORNL

SC5
Sites and Buildings

* Jim Lawson, ORNL
Ove Dyling, BNL
David Saenz, SLAC

SC6
ES&H

* Steve Trotter, ORNL

SC7
Cost, Schedule, and Funding

* Barb Thibideau, ORNL
Steve Tkaczyk, DOE/SC

SC8
Management

* Derrick Mancini, ANL
David Dale, BNL
Scott Mallette, DOE/TJSO
Gail Penny, DOE/BHSO

Observers

Mike Procario, SC-25
Pepin Carolan, DOE/FSO
Steve Webster, DOE/FSO

LEGEND

SC Subcommittee
* Chairperson
Count: 24 (excluding observers)

APPENDIX C

REVIEW AGENDA

Department of Energy Review of the
NOνA Experiment at Fermilab

AGENDA

Tuesday. October 23, 2007—ANL Bldg Number 362, Auditorium

8:00 am	DOE Executive Session—**Bldg 360, Rm A-224**.....D. Lehman
9:00 am	Plenary Session—**Bldg 362, Auditorium**
9:00 am	Welcome ..... H. Weerts
9.05 am	Fermilab Overview .....P. Oddone
9:10 am	Scientific Performance Requirements.....G. Feldman
9:25 am	Project Overview ..... J. Cooper
10:15 am	**Break** —Bldg 362, outside Auditorium
10:40 am	Project Cost Drivers..... R. Ray
11:05 am	Accelerator & NuMI Upgrades..... N. Grossman
11:30 am	Site and Building ..... S. Dixon
11:45 am	Scintillator.....S. Mufson
12:00 pm	**Lunch—Bldg 362, Rm E-148**
1:00 pm	Fiber .....C. Bromberg
1:10 pm	PVC Extrusions.....R. Talaga
1:25 pm	Extrusion Modules.....K. Heller
1:50 pm	Near/Far Detector Assembly .....D.Ayres
2:15 pm	Electronics and DAQ .....L. Mualem
2:30 pm	Cost and Schedule Methodology .....W. Freeman
2:50 pm	Working within the TPC Guidance..... J. Cooper
3:00 pm	**Break** – Bldg 362, outside Auditoium

3:30 pm Subcommittee Breakout Sessions

- SC1 Commodities: Scintillator, Fiber, and PVC— Bldg 362, Rm F-240
- SC2 Extrusion Module Production & Near and Far Detector Assembly— Bldg 362, Rm F-108
- SC3 Electronics and DAQ—Bldg 362, Rm E-356
- SC4 Accelerator and Beamlines— Bldg 362, Rm E-188
- SC5 Site and Building— Bldg 362, Rm B-116
- SC6 ES&H— Bldg 362, Rm C-141
- SC7 Cost, Schedule and Funding— Bldg 362, Rm F-253

4:30 pm	DOE Executive Session—**Bldg 360, Rm A-224**.....D. Lehman
6:00 pm	Adjourn

Wednesday. October 24, 2007

8:00 am Subcommittee Breakout Sessions

- SC1 Commodities: Scintillator, Fiber, and PVC— Bldg 362, Rm F-240
- SC2 Extrusion Module Production & Near and Far Detector Assembly— Bldg 362, Rm F-108
- SC3 Electronics and DAQ— Bldg 362, Rm E-356
- SC4 Accelerator and Beamlines— Bldg 362, Rm E-188
- SC5 Site and Building— Bldg 362, Rm B-116
- SC6 ES&H— Bldg 362, Rm C-141
- SC7 Cost, Schedule and Funding— Bldg 362, Rm F-253
- SC8 Management— Bldg 360, Rm A-224

10:00 am **Break – Bldg 362, Rm E-148**

10:15 am Subcommittee Breakout Sessions

- Continued in same rooms as 8:00 am Sessions

12:30 pm **Lunch – Bldg 362, Rm E-148**

1:30 pm Three Options – D. Lehman to choose Wednesday morning:

1. Full Committee Session with NOνA Management
2. Tour of NOνA work, Building 366, Full Committee plus Level 2 Managers (30minutes total)..... D. Ayres
3. Continued Breakout Sessions

2:30 pm Subcommittee Working Session

3:00 pm DOE Full Committee Executive Session—**Bldg 360, Rm A-224** .....D. Lehman

6:00 pm Adjourn

Thursday, October 25, 2007

8:00 am Subcommittee Working Session

10:00 am DOE Full Committee Executive Session Dry Run— .....D. Lehman
Bldg 360, Rm A-224

12:00 pm Working Lunch

2:00 pm DOE Summary and Closeout—**Bldg 362, Auditorium**.....D. Lehman

3:00 pm Adjourn

APPENDIX D

COST TABLE

Cost

	WBS	Items	NOvA 's Cost Estimate AY $M									
			Estimated Cost (with indirects)			Contingency Estimate			Contingency %			Total
			M&S	Labor[1]	Total	M&S	Labor[1]	Total	M&S	Labor[1]	Total	Cost
TEC	2.0	Accelerator & NuMI Upgrades	$ 10.1	$ 18.6	$ 28.7	$ 3.5	$ 6.2	$ 9.7	35%	33%	34%	$ 38.4
	2.1	Far Detector Site and Building	$ -	$ 2.2	$ 2.2	$ -	$ 0.3	$ 0.3	0%	14%	14%	$ 2.5
	2.2	Liquid Scintillator	$ 19.3	$ 0.4	$ 19.6	$ 5.3	$ 0.2	$ 5.5	27%	54%	28%	$ 25.1
	2.3	Wave-Length-Shifting Fiber	$ 9.6	$ 0.9	$ 10.5	$ 2.7	$ 0.1	$ 2.8	28%	10%	27%	$ 13.3
	2.4	PVC Extrusions	$ 24.9	$ 1.7	$ 26.6	$ 6.8	$ 0.6	$ 7.4	27%	35%	28%	$ 34.0
	2.5	PVC Modules	$ 6.3	$ 3.8	$ 10.1	$ 1.5	$ 1.3	$ 2.7	23%	33%	27%	$ 12.9
	2.6	Electronics Production	$ 11.4	$ 0.9	$ 12.3	$ 3.7	$ 0.3	$ 4.1	33%	35%	33%	$ 16.3
	2.7	Data Acquisition System	$ 1.7	$ 1.8	$ 3.5	$ 0.5	$ 0.5	$ 1.0	27%	29%	28%	$ 4.5
	2.8	Near Detector Assembly	$ 3.7	$ 0.5	$ 4.2	$ 3.4	$ 0.3	$ 3.8	94%	57%	90%	$ 7.9
	2.9	Far Detector Assembly	$ 5.7	$ 5.7	$ 11.4	$ 3.7	$ 3.8	$ 7.5	65%	66%	66%	$ 18.9
	2.10	Project Management	$ 0.5	$ 4.1	$ 4.6	$ 0.1	$ 1.0	$ 1.2	25%	25%	25%	$ 5.8
		Management Reserve	$ 0.6		$ 0.6							$ 0.6
		Subtotal Construction	**$ 93.7**	**$ 40.7**	**$ 134.4**	**$ 31.2**	**$ 14.7**	**$ 45.8**	**33%**	**36%**	**34%**	**$ 180.2**
OPC		**R&D - Accelerator**	$ 2.0	$ 7.2	$ 9.2	$ 0.6	$ 2.5	$ 3.0	29%	34%	33%	$ 12.2
		R&D - Detector	$ 5.2	$ 4.8	$ 10.1	$ 0.4	$ 0.5	$ 0.9	8%	10%	9%	$ 11.0
		Cooperative Agreement	$ 45.0	$ -	$ 45.0	$ 9.9	$ -	$ 9.9	22%	0%	22%	$ 54.8
		Operating	$ 0.2	$ 1.0	$ 1.2	$ 0.1	$ 0.4	$ 0.5	34%	42%	41%	$ 1.7
		Total OPC:	**$ 52.4**	**$ 13.1**	**$ 65.5**	**$ 10.9**	**$ 3.4**	**$ 14.3**	**21%**	**26%**	**22%**	**$ 79.8**
		TPC:	**$ 146.1**	**$ 53.8**	**$ 199.8**	**$ 42.1**	**$ 18.1**	**$ 60.2**	**29%**	**34%**	**30%**	**$ 260.0**

Notes:

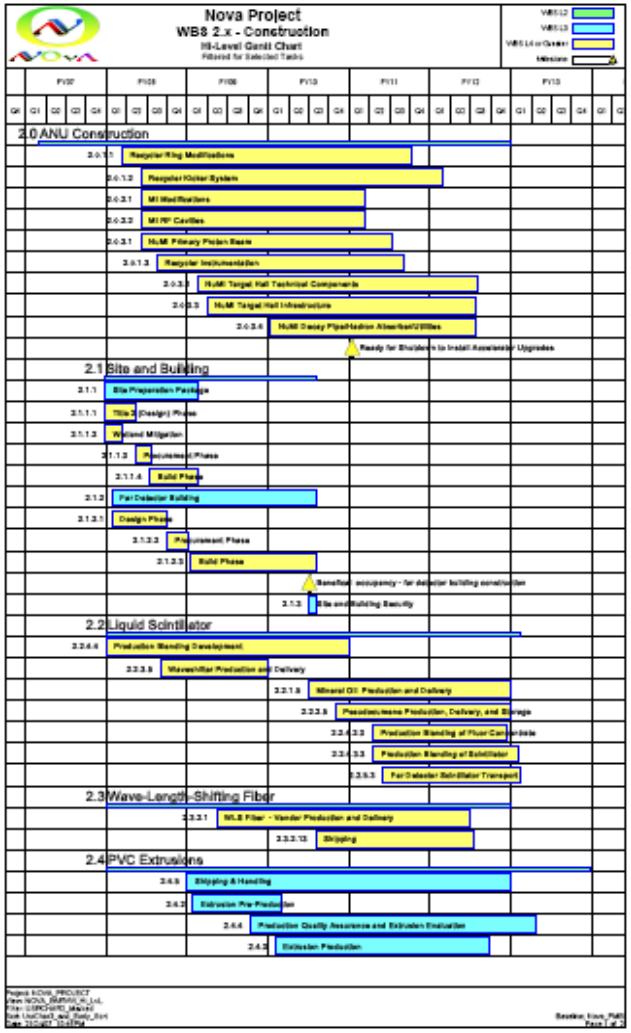
[1] Labor costs presented here include all project labor from Fermilab, other DOE facilities and Universities.

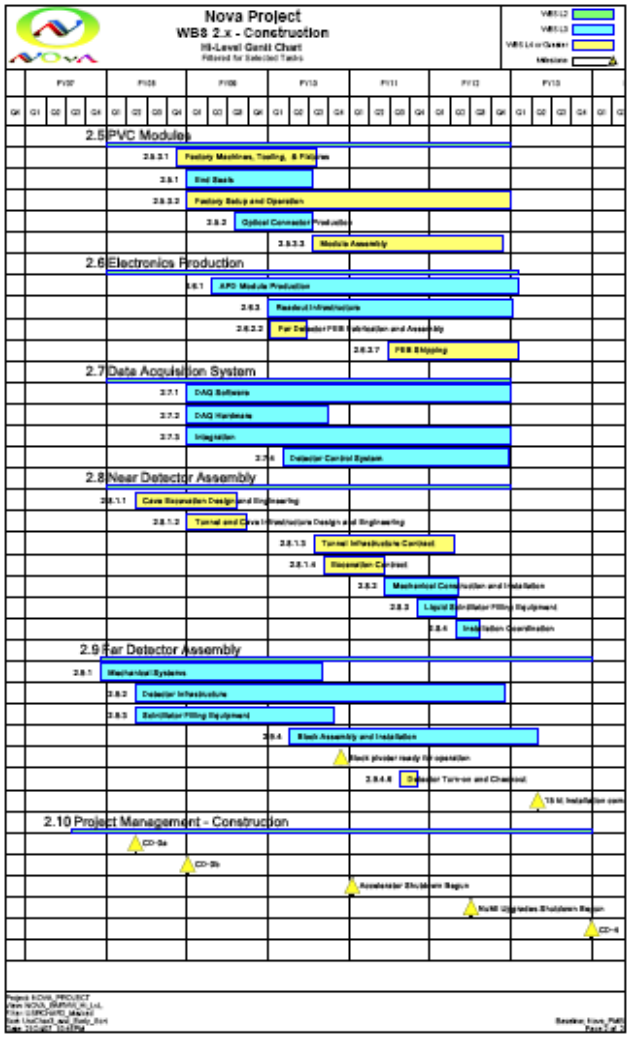
- Costs from Open Plan escalated using Cobra
- TPC matches the $ 260 M guidance
  - Contingency overall is 30%
  - Small Management Reserve of $ 616 K
  - [TEC – (Accel., Bldg, Near Detector, Proj. Management, Reserve)] / 15 kt implies ~ $ 8 – 9 M per kt.

APPENDIX E

SCHEDULE TABLE

Schedule on a page





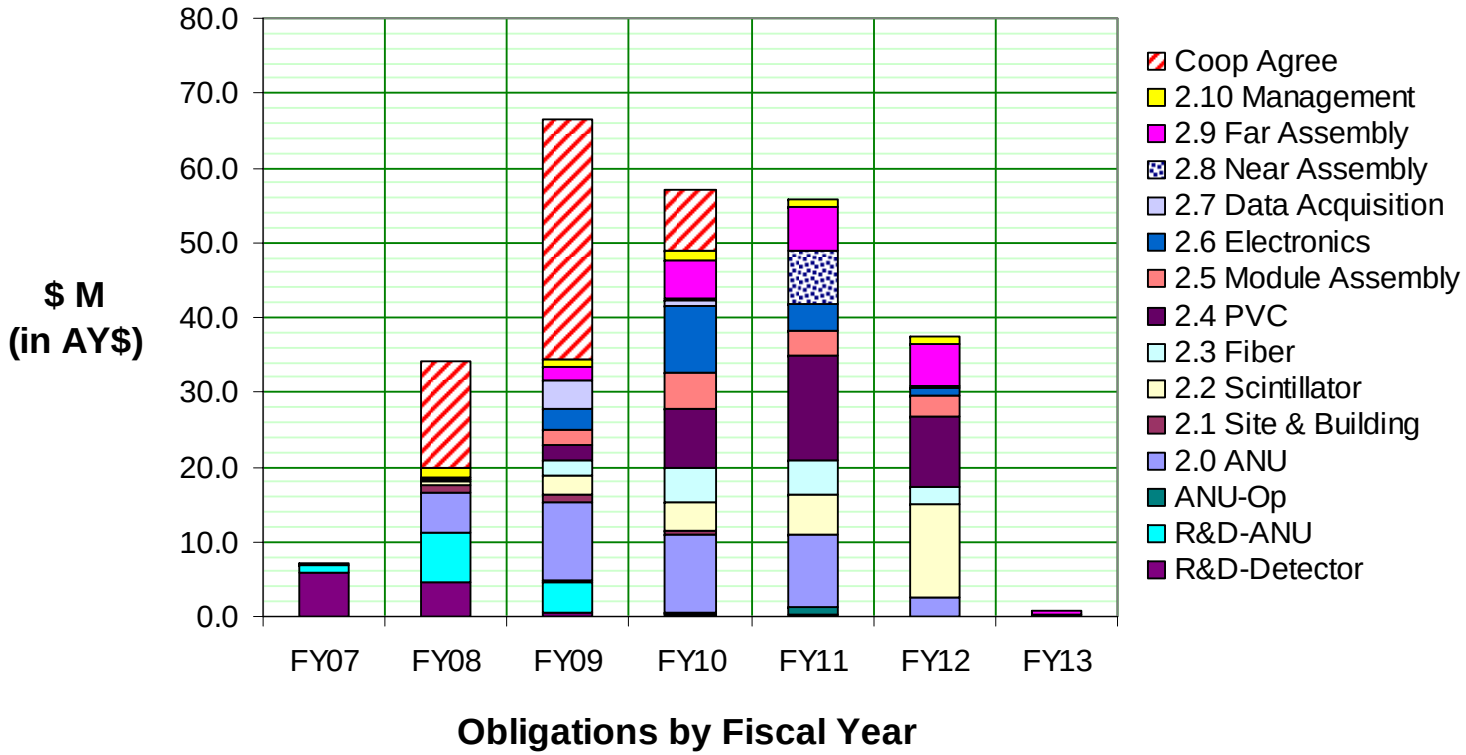
APPENDIX F

FUNDING CHART

Obligation Profile

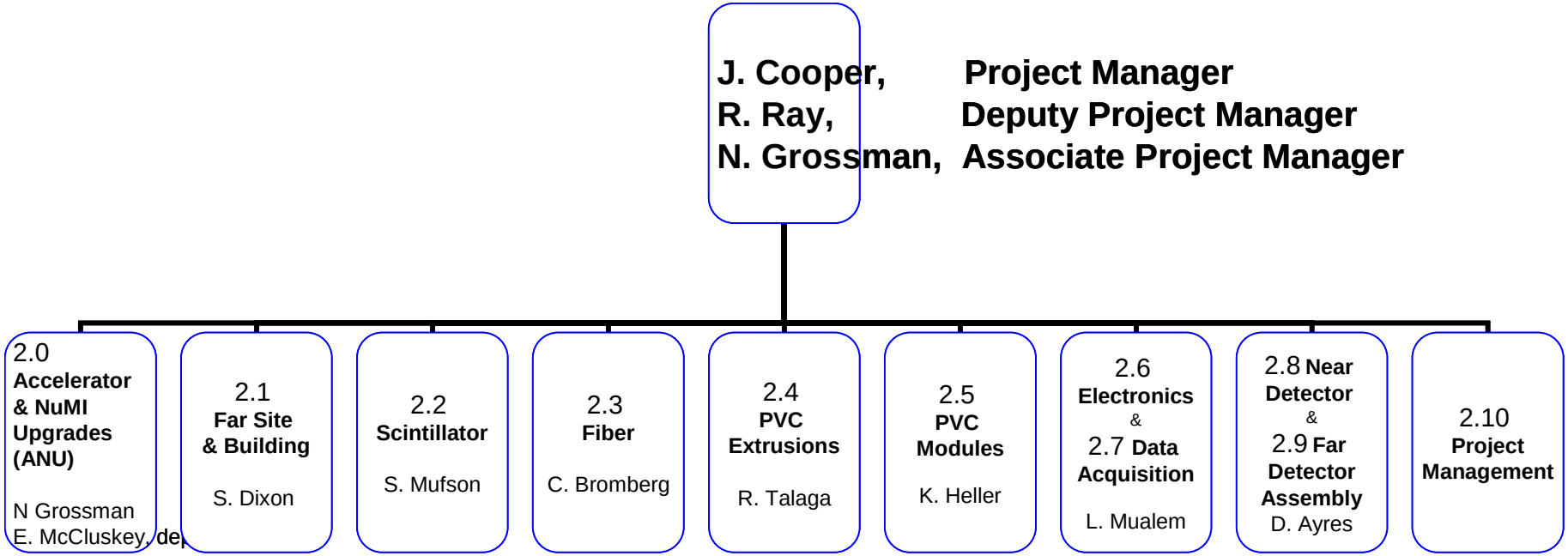
- DOE funding profile in red
  - Obligations in stacked histogram from Open Plan escalated using Cobra
  - Obligations never exceed obligation authority, though close in FY09

	Totals by YR	Funding Profile	Delta	Integrated Delta from profile
FY07	7.22	7.97	0.75	0.75
FY08	34.12	36.05	1.93	2.67
FY09	66.47	65.00	-1.47	1.21
FY10	57.03	73.22	16.19	17.40
FY11	55.85	46.00	-9.85	7.55
FY12	37.52	31.76	-5.76	1.79
FY13	0.85	0.00	-0.85	0.94
	259.06	260.00	0.94	



APPENDIX G

MANAGEMENT CHART



Project Office Staff:

Dave Pushka, Mechanical Project Engineer
John Oliver, Electronics Project Engineer
Anna Pla-Dalmau, Project Chemist
Suzanne Pasek, Project Financial Officer
Bill Freeman, Project Scheduler
Ken Doman, ANU scheduler
Harry Ferguson, Assistant Project Scheduler

Keith Schuh, ES&H Detector, EA, pSAD
Mike Andrews, ES&H for Accelerator side
Alan Wehmann, websites / document databases
Nancy Grossman, QA oversight
Elaine McCluskey, Configuration Control
Bob Bernstein, Expediter & Document Coord.
Jon Paley, databases

APPENDIX H

EIR
LINES of INQUIRY

EIR Lines of Inquiry for the
NOνA Upgrade

1. Resource Loaded Schedule—Satisfactory

Laboratory Response: The project has a resource-loaded schedule (RLS) documented and in use. The project has 443 DOE documents. The project believes that the cost and schedule assumptions are reasonable. The project completion is well defined. The total cost is consistent with the total funding cap of $260 million.

Committee Response: The project schedule contains 5,970 activities and 7,284 relationships. All activities are resource loaded. Milestones are not resource loaded. With a few exceptions (e.g. receipt of mineral oil not tied to appropriate QA and fabrication activities), all the schedule activities are logically tied. LOE activities will be logically tied but not to CD-4 (so as not to be the critical path). The project's early finish date assumes that the project is funded consistent with the funding profile. The basis of estimate information is very detailed and varies in terms of level and amount of detail between the various WBS elements. These documents identify the various labor resources (and their required hours) as well as material procurements. These resources are then assigned to the schedule activities. There are some inconsistencies between the various documents that need to be fixed before the EIR.

2. Key Project Cost and Schedule Assumptions—Satisfactory

Laboratory Response: The project believes that its assumptions for each WBS is reasonable. Cost contingency rules are in place and have been applied. There is approximately eight months of contingency between final work and CD-4. The project completion date includes everything required for CD-4.

Committee Response: The schedule is funding limited and therefore, procurements are phased. The schedule is optimistic in that it assumes that receipt of the materials associated with these phase-funded contracts occurs in October of the fiscal year. The activity durations appear to be reasonable. The schedule contingency is approximately 8 months which is approximately 12.5% of the total project's duration. However, the schedule is success-based which suggests that 3 months additional schedule float would significantly increase the probability of achieving the project's CD-4 date. The project has approximately 23% contingency (60/260M). Since the project uses very low M&S escalation rates (FY08=2.2, FY09-FY11=2.1 and FY12=2.2), it is most likely that some of the $60M will be called upon to mitigate escalation increases. The project should review their application of these escalation rates, particularly with respect to the fact that, in 7 out of the last 10 years, the escalation rate has been greater than 2.2%. The current (October 2007) escalation rate is 2.7%.

3. Critical Path—Satisfactory

Laboratory Response: The critical path is understood and the schedule reflects reasonable schedule durations.

Committee Response: The project's critical path (in terms of 12 days float) goes through manifold parts to fabrication of PVC modules for blocks 1 and 2 through installation of the detector. The project's next closest path involves construction of the building, pivoter completion, detector assy and installation. There is another "close to critical path" that starts at site prep. This latter path is the one the project most believes. At this point, there is really no difference between 12 days float, 18 days float and 30 days float and the latter is the most credible path for the project to monitor closely.

4. Funding Profile—Satisfactory

Laboratory Response: The funding profile is consistent with the RLS.

Committee Response: The project funding profile supports execution of the work as described in the resource loaded schedule. The funding profile also supports the allocation of contingency in each year. The current plan shows $17M carryover in FY10. The project should to see if it is possible to accelerate some activities and mitigate risk.

5. Work Breakdown Structure (WBS)—Satisfactory

Laboratory Response: The WBS incorporates all project work. The WBS breakdown is reasonable. The RLS and WBS are consistent by design.

Committee Response: The Work Breakdown Structure incorporates all project work, and represents a reasonable breakdown of the project work scope. The resource loaded schedule is consistent with Work Breakdown Structure for the project work scope.

6. Risk Management—Satisfactory

Laboratory Response: Risks have been identified and properly classified (see project PMP, Risk Management Plan, Risk Registry, and detailed documentation of high risks). Mitigation was built into this project from the beginning. The contingency reflects risk (see NOνA contingency rules).

Committee Response: Risks have been identified and properly classified as high, medium, and low. Appropriate risk mitigation has been incorporated into the baseline. Contingency is barely adequate. The project would benefit from increased schedule and cost contingency. There is no scope contingency with a 15kt required deliverable for the detector. Values associated with risks for contingency analysis are difficult to trace. No risk owners identified.

7. Basis of Design—Satisfactory

Laboratory Response: The Technical Design Review (TDR) gives the overview of the project's preliminary design and is consistent with the Scientific Design Criteria and Design Requirements. The TDR covers safety structures, systems, and components as part of the design description.

Committee Response: Preliminary design is adequate for this stage of the project.

8. Design Review—Satisfactory

Laboratory Response: The project has documented, completed Design Reviews, the results of which have been incorporated into the current design. More Design Reviews are planned and are in the RLS. The NOνA PMP discusses the ongoing Engineering Review Process.

Committee Response: The results of preliminary design reviews have been incorporated into the performance baseline. The Director's review provided feedback to the preliminary designs and TDR. Adequate design review has been conducted for most technical elements needed for this stage of the project, with future reviews planned and identified in the schedule. Review is needed for 2.6 Electronics & 2.7 Data Acquisition.

9. System Functions and Requirements—Satisfactory

Laboratory Response: The Scientific Design Criteria, which forms the Mission Need for the scientific enterprise, is documented in the Technical Design Requirements. Safety and external requirements are documented in the Hazard Analysis and the draft Environmental Assessment.

Committee Response: Functions and requirements are reflected in the baseline. System requirements are derived from and consistent with Mission Need. Project would benefit with better integration across Level 2 activities.

10. Hazards Analysis—Satisfactory

Laboratory Response: The project has an updated Hazard Analysis, and preliminary Safety Analysis Document, and a draft Environmental Assessment.

Committee Response: The appropriate Hazard Analyses have been completed, and scope, schedule, and costs necessary for safety have been incorporated into the respective baseline.

11. Value Management/Engineering (VM/VE)—Satisfactory

Laboratory Response: The project has done extensive VM/VE and the Technical Design Requirements describe the additional VM/VE efforts. The Project Management Plan discusses the VM process.

Committee Response: Value engineering has been performed and incorported into the baseline. Value engineering is ongoing, and is generally good, although the 2.6 Electronics & 2.7 Data Aquisitions can benefit with continued VE.

12. Project Controls/EVMS—Satisfactory

Laboratory Response: A NOνA specific implementation for EVMS exists. Performance Measurement Techniques are in place within the RLS for every task. The Level 2 managers are the Cost Account Managers. Change Control procedures are documented in our Configuration Management and change Control Plan.

Committee Response: The FNAL EVMS system description document is augmented by NOνA's Implementation of Fermilab's Earned Value Management System which describes the project's specific procedures. The project has not yet implemented the EVMS in terms of reporting BCWP, ACWP, BCWS and the associated variances.

13. Project Execution Plan (PEP)—Satisfactory

Laboratory Response: The PEP is a DOE document, which has been checked for consistency with other project documents.

Committee Response: The PEP with the PMP reflects and supports they way the project is managed and is consistent with other project documents. The PEP should be updated to appropriately identify the baseline technical scope.

14. Start-Up Test Plan—Satisfactory

Laboratory Response: The Start-Up Test Plan includes the: R&D Integration Prototype; Ash River Building; Recycler and Main Injector; Near Detector Cavern; Near Detector; Far Detector; NuMI Beamline; and the connection of each part of the plan to the CD-4 deliverable is noted. Costs are included in the plan.

Committee Response: Start-up test plans are appropriately defined and are sufficiently described to be included in cost estimates and schedule durations. We note that 2.0 ANU has testing with beam (commissioning) occuring later and outside the scope of the project.

15. Acquisition Strategy (AS)—Satisfactory

Laboratory Response: The AS was signed by Raymond Orbach in April 2007. The plan is appropriate and being followed. The Cooperative Agreement strategy was part of this approved plan. Inclusion of the Accelerator and NuMI Upgrades was included as part of the AS.

Committee Response: The Acquisition Strategy is consistent with the way the project is being executed. The current strategy represents a best value to the government.

16. Integrated Project Team (IPT)—Satisfactory

Laboratory Response: The Integrated Project Team was formed by Pepin Carolan, FPD, and meet every week (minutes are documented). The IPT has the ability to add expertise when appropriate.

Committee Response: The integrated project team appears to be suited to support the project. The project management staffing is at an appropriate level with all of the appropriate disciplines included in the IPT. A charter has been prepared and is an appendix to the PEP.