Office of High Energy Physics
Office of Science

CD-1, Approve Alternative Selection and Cost Range for the NUMI Off-Axis ν_e Appearance (NOνA) Project

A. Purpose

The purpose of this paper is to document the review by the Office of Science Energy Systems Acquisition Advisory Board-equivalent for the Critical Decision "Approve Alternative Selection and Cost Range (CD-1)" for the NuMI Off-axis neutrino (ν) Appearance (NOνA) Project.

The CD-0 Mission Need for the Electron Neutrino Appearance (EνA) experiment was approved by the Director of the Office of Science, Raymond L. Orbach, on November 22, 2005. The proposed NOνA experiment has been selected to meet that mission need and the project will thus be referred to as NOνA. The NOνA Project will include accelerator and detector facilities and components at the Fermi National Accelerator Laboratory (Fermilab) site, as well as a detector facility located 810 km northwest from Fermilab in Northern Minnesota (Ash River).

B. Mission Need

The mission of the High Energy Physics (HEP) program is to explore and to discover the laws of nature as they apply to the basic constituents of matter and the forces between them. The core of the mission centers on investigations of elementary particles and their interactions. Among the currently known elementary particles, the least well understood is the neutrino. The NOνA experiment will enable study of the pattern of neutrino masses and the details of neutrino mixing by using the Neutrinos at the Main Injector (NuMI) facility at Fermilab to provide an intense flux of neutrinos to a large new detector in Northern Minnesota. The only existing DOE facility capable of producing the neutrino beam required to study the pattern of neutrino masses and the details of neutrino mixing is the NuMI facility. If the version of neutrino mixing that is being sought is determined to exist, then it should ultimately be possible to determine the ordering of the neutrino masses and measure Charge-Parity (CP) violation in neutrino oscillations. There are theoretical models that use CP violation by neutrinos to understand why the Universe is composed solely of matter, rather than equal amounts of matter and antimatter.

A coordinated neutrino program developed from an American Physical Society study and a joint HEPAP/NSAC Advisory subpanel review includes the NOνA Detector. The National Academy of Sciences "EPP2010" report recommended a diverse HEP program using a variety of tools to attack the exciting opportunities in elementary particle physics, including a staged internationally coordinated program in neutrino physics. One of those opportunities, the observation of muon neutrino beam, can be met by this project with a new detector optimized to detect electron neutrinos, namely the NOνA Detector.

C. Project Preliminary Scope Baseline

The NOνA project consists of a near detector located at the Fermilab site, a far detector located in Northern Minnesota, a detector enclosure for the far detector, and accelerator and NuMI beamline upgrades needed to increase the beam power and provide the intense flux of neutrinos to the NOνA far detector. These elements are described further below.

Accelerator and NuMI Upgrades: The Fermilab Recycler will be converted from an anti-proton to a proton storage ring and pre-injector to the Main Injector, the Main Injector cycle time will be reduced, and the NuMI neutrino line will be upgraded to handle a substantial increase in beam power (up to 700 kW) and modified to operate in the medium energy neutrino configuration.

NOνA Far Detector: The NOνA far detector is optimized for detecting low-energy (~2 GeV) electron showers while rejecting background events. The far detector is conceived to be up to a 20 kiloton tracking calorimeter, ~16 m by 16 m by ~100 m long. It will be constructed from alternating vertical and horizontal cells of liquid scintillator contained in rigid polyvinyl chloride (PVC) extrusion modules. A Wavelength Shifting (WLS) fiber is inserted into each liquid scintillator 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 suppresses signals before passing them on to the data acquisition system.

NOνA Near Detector: The NOνA near detector will operate on the Fermilab site at a distance of about 1 kilometer from the NuMI target in the existing NuMI access tunnel. The purpose of the near detector is to measure the flux of muon neutrinos from the beam, to measure the backgrounds to electron-neutrino identification that will appear in the far detector, and to measure the initial electron neutrino content of the beam. The NOνA near and far detectors are nearly identical. The significant differences are the size (near detector is only 200 tons) and the clock speed of the electronics.

NOνA Far Detector Enclosure: The NOνA Project requires construction of a detector enclosure in Northern Minnesota to house the NOνA far detector. The enclosure will also include adequate space and infrastructure to facilitate construction and operation of the far detector. The enclosure should provide shielding against the photon component of cosmic rays.

The sensitivity of NOνA depends on the product of the number of protons on target and the mass of the far detector. It also depends on time. A longer data run is equivalent to mass or protons in improving the sensitivity of the experiment. The accelerator and NuMI facility upgrades to increase beam power will provide a high intensity proton beam that more than doubles the present protons on target. This combination of protons on target and detector mass makes NOνA the most sensitive experiment for meeting the physics objectives. The NOνA Project scope as defined above thus provides the capability to optimize both of these inputs (protons on target and detector mass) providing the most sensitive experiment for the cost, to meet the mission need.

D. Project Preliminary Cost and Schedule Baseline

The Office of Project Assessment was charged by the Office of High Energy Physics to conduct a review to validate NOνA conceptual design and cost range for CD-1 on April 4-6, 2006.

The project and documentation were reviewed and judged to be ready for CD-1. The Conceptual Design Report was judged to be complete and comprehensive and the cost and schedule ranges appropriate. Subsequent to this review, there have been a few key developments that now enable the NOνA project to reach CD-1 approval:

- a key item needed to support CD-1 is the acceptance of a proposal and selection of a recipient of a cooperative agreement, which finalizes the alternative selection and the acquisition strategy for construction of the far detector building.

- to achieve reduced NOνA detector cost within the proposed scope range, and to incorporate other refinements to the preliminary cost and schedule, the detector cost range has been revised and scaled to provide a best estimate for up to a 20 kiloton detector.

- given the importance of the planned increase in neutrino intensity to support the physics goals of NOνA and in order to ensure appropriate project management oversight and integration, this collection of accelerator and NUMI upgrades and improvements has been added to the scope of the NOνA project.

Incorporating these developments, the preliminary cost range at CD-1 for the NOνA project is $244M to $293M, for a 20 kiloton detector. The cost range also includes additional contingency for the accelerator and NUMI upgrades, since the current basis of estimate for those is at an earlier stage relative to the detector. The currently planned preliminary funding profile, which will allow the completion of the project by fiscal year 2013, is given in Table 1 below. NOνA estimates that an 18 kiloton detector can be built within the constraints of the profile in Table 1. It is anticipated that the best case earned contingency scenario would allow a modest upscope to a 20 kiloton detector, which would fill the far detector building. The final scope for CD-2 will depend on the updated CD-2 cost and schedule, which is being developed in accordance with the funding profile and guidance, and the Total Project Cost (TPC) expectation of $260M. The CD-2 baseline will incorporate the results of several on-going cost reduction and value engineering studies.

Table 1. NOνA Project Preliminary Funding Profile

	FY 2007	**FY 2008**	**FY 2009**	**FY 2010**	**FY 2011**	**FY 2012**	**FY2013**	**Total**
TEC *	1.0	13.0	42.8	60.9	45.7	28.1	0.7	192.2
OPC +	9.3	23.0	27.2	8.1	0.3	0	0	67.8
TPC	10.3	36	70	69	46	28.1	0.7	260

* includes all MIE funded equipment, detector and accelerator construction/fabrication costs
\+ includes operating funded project R&D, far detector building, and operating activities

The following list is a preliminary schedule of critical decision milestones for the NOνA project.

Preliminary Critical Decision Schedule	Planned Fiscal Year
CD-0 Approve Mission Need	1Q2006 (A)
CD-1 Approve Alternative Selection and Cost Range	2Q2007
Accept cooperative agreement proposal	2Q2007
CD-2/3A Approve Performance Baseline/3A Start	4Q2007
Award cooperative agreement	4Q2007
CD-3B Approve Start of Construction	2Q2008
CD-4 Project Closeout	4Q2013

A phased CD-3A/3B is planned. CD-3A is to approve start of construction for site preparation at the far detector site (upgrade access road, building excavation) and start of some initial procurements needed to support detector fabrication. An earlier start to the road construction will enable a gain in the schedule for construction of the far detector building. For the accelerator and NuMI upgrades, CD-3A enables procurement and initial construction or fabrication of new and refurbished accelerator components, and procurements for the NuMI target upgrades. CD-3B approves construction start for the total project, including the far detector building.

Although the project is expected to be complete at the end of FY12, if the project is able to realize contingency savings, then additional mass will be added to the detector, requiring additional time to complete. There is also uncertainty related to possible programmatic developments outside of the NOνA Project in the schedule for Fermilab shutdowns needed for NOνA accelerator work. Considering these possibilities, a conservative estimated CD-4 closeout date was selected to cover a possible schedule extension into FY13.

The DOE CD-1 prerequisites have each been met for the NOνA Project. The key project documents required for CD-1 (i.e. Acquisition Strategy, Preliminary Project Execution Plan, Conceptual Design Report, Integrated Project Team charter, Environmental and Preliminary Hazard assessments) have all been revised by the IPT to include the updated project scope (i.e. the accelerator and NUMI upgrades).

E. Acquisition Strategy

An Acquisition Strategy (AS) approved by the Acquisition Executive and reviewed by the DOE Science Office of Project Assessment (OPA) is a prerequisite for CD-1. The NOνA AS has been reviewed by OPA and approved by the DOE Acquisition Executive. Briefly, the AS describes why Fermi Research Alliance (FRA) has been chosen to lead the project based on their existing scientific and engineering expertise, the need to deeply involve the collaborating physicists to participate in the design and construction, and to simplify the interfaces among the collaboration, the project and the rest of the lab.

FRA will serve as the prime contractor for work involving fabrication of the near and far detectors as well as the upgrades to the accelerator and NuMI facilities. Thus, Fermilab will have primary responsibility for oversight of all contracts required to execute this part of the project. These contracts are expected to include the purchase of components from vendors as well as contracts with university groups to fabricate some of the detector subsystems. The IPT reviewed and evaluated the feasible acquisition alternatives, taking into account Fermilab's extensive in-house capabilities and the capabilities of institutions participating in the scientific research collaboration. The primary source of materials for these projects will be commercial vendors vying for purchase orders under competitive conditions. Several components will be provided by universities.

It is anticipated that Fermilab will issue fixed-price contracts or fixed-price contracts with economic adjustment for work to be performed whenever possible. The NOνA Project has prepared a detailed procurement plan for the small number of critical procurements. i.e. those with larger overall cost /risk or limited commercial sources, that comprise ~half of the NOνA detector cost. For each of these

items, the procurement plan addresses cost estimates, constraints, contract types and evaluation methodologies, to provide a well-thought out basis for decisions and planning.

As discussed in the Acquisition Strategy, the DOE received an unsolicited proposal from the University of Minnesota for a cooperative agreement to conduct research on neutrino oscillations as part of the NOνA collaboration. As part of the research program the University has proposed to construct the far detector enclosure on university owned land, to operate the building on this site, to be responsible for security and ES&H on the site, and to participate in the calibrations, data-taking, and maintenance of the NOνA detector and the subsequent data analysis.

The cooperative agreement will be awarded and administered by the Contracting Officer from the Chicago Office. The award is supported by a DOE approved Determination of Noncompetitive Financial Assistance (DNFA), which establishes that a non-competitive award is in the public interest. The DNFA supports the Acquisition Strategy, and approval of both of these documents is in parallel with this ESAAB, to support its recommendation on CD-1. This financial assistance award for the cooperative agreement includes the portion of the NOνA TPC that covers construction of the detector enclosure. Upon DOE acceptance of the Cooperative Agreement proposal and prior to CD-2, negotiation is planned between Fermilab/NOνA Project and the awardee (University of Minnesota) to define authorities among the parties, and agree upon means to ensure adequate communications, work authorizations and flow, and project controls and reporting to cover design, construction and oversight activities.

F. Environmental Strategy

All NOνA Project work will be covered by an Environmental Assessment (EA) under the National Environmental Policy Act (NEPA). An EA has been prepared to evaluate the potential environmental impacts associated with the full NOνA Project, including proposed construction or upgrade and operation of facilities for NOνA at Fermilab and its far detector facility located in Ash River, Minnesota. The EA incorporates an extensive radiological assessment of increasing the power of the NuMI beam line. In addition, this subject has been addressed with local leaders and officials as part of Fermilab's public outreach efforts. Fermilab has considerable experience in this area and maintains a good working relationship with the surrounding communities. The EA has been submitted to DOE for approval and has been through an initial DOE review.

The state of Minnesota allows for a discretionary Environmental Assessment Worksheet (EAW) to be completed to determine if a further environmental assessment will be required for the Minnesota portion of the project. Fermilab has engaged a consultant to characterize the environment of the preferred site for the far detector, and to evaluate potential environmental impacts of the proposed project, and has developed a draft EAW document. The University of Minnesota may utilize this information to prepare a discretionary EAW for State review, according the State of Minnesota environmental review process. If the University does so, the EA may incorporate the EAW by reference. If the University does not prepare a voluntary EAW, the information will be incorporated into the EA directly. The University of Minnesota is in the process of establishing itself as a Responsible Government Unit (RGU) to complete the EAW process. A complete draft of an EAW was included in the initial DOE review of the EA. This type of joint assessment process allowed by NEPA was completed successfully by DOE and a Minnesota RGU for the MINOS neutrino experiment project involving the University of Minnesota.

The EA draft is being finalized based on the initial DOE review, and in preparation for submittal to the States (Illinois, Wisconsin and Minnesota) and for a public comment period. These actions will be coordinated as necessary with the University of Minnesota, acting as the RGU for the EAW portion of the EA covering the work in Minnesota. State and public comments will be reviewed and a complete EA incorporating final revisions is anticipated in early Summer 2007. The NEPA process and the final decision document is expected to be completed in late Summer 2007 to support a CD-2 approval.

G. Risk Management

NOνA Project Environment Safety & Health (ESH) risks have been identified in the NOνA preliminary hazard and environmental assessment documentation. These are addressed via institutional line management ESH programs, such as Fermilab's Integrated Safety Management and Environmental Protection programs. Fermilab, the University of Minnesota and the collaborating institutes have a history of performing similar accelerator, detector and civil construction in a safe and environmentally sound manner. In addition, safety assessment documentation specific to the NOνA project will be finalized and approved prior to sustained operations.

The NOνA Project has developed a Risk Management Plan. The IPT expects the project to manage risk as a line responsibility. Risks are identified by WBS Level 2 managers and ranked within their projects based on probability of occurrence and impact/consequence. NOνA Project management reviews the results and classifies the risks as high, medium, or low based on a "Risk Classification Matrix." Included in this process are high level risks and risks that might be shared among several subprojects. Risk Mitigation/Abatement Plans are developed for all risks rated as either high or moderate and successful implementation will be tracked by the project management team.

To address cost risk associated with special commodities, the NOνA Procurement Plan includes a special risk-based contingency analysis for those items impacted by fluctuations in key commodities (e.g. crude oil, which affects detector mineral oil and PVC resin costs). Overall, use of fixed-price subcontracts and competition will be maximized to reduce cost risk. Incentive subcontracts, such as fixed-price with incentive, will be considered when a reasonably firm basis for pricing does not exist or the nature of the requirement is such that the subcontractor's assumption of a degree of cost risk will provide a positive profit incentive for effective cost and/or schedule control and performance.

Technology and engineering risk is low. The project has been designed to minimize technical and engineering risk by exploiting previous experience and proven technologies to the greatest extent possible, minimizing exposure to single vendor failures, or making deliberately conservative design choices. Items with higher technical risk have a prototype phase and carry higher contingency.

The NOνA Project Manager and project team will manage the cost and schedule risk. Contingencies have been built into the estimates for each part of the project, and schedule float is incorporated in the project plan. The project schedule and plans presented at the time of CD-1 are dependent upon the project funding profile identified in the CD-1 documentation. Project plans and milestones will need to be adjusted accordingly if the funding profile is changed.

Submitted by:

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Recommendations

The undersigned "Do Recommend" (Yes) or "Do Not Recommend" (No) approval of CD-1, Approve Alternative Selection and Cost Range, for the NOνA Project at Fermilab and Ash River, MN as noted below.

_____ Yes____ No____
ESAAB Secretariat, Office of Project Assessment Date

_____ Yes____ No____
Representative, Non-Proponent SC Program Office Date

_____ Yes____ No____
Representative, Budget and Planning Date

_____ Yes____ No____
Representative, Environmental, Safety and Health Division Date

_____ Yes____ No____
Representative, Security Mgmt. Team Date

_____ Yes____ No____
Representative, Laboratory Infrastructure Division Date

_____ Yes____ No____
Representative, Grants and Contracts Division Date

Approval

Based on the information presented above and at this review, Critical Decision-1, Approve Alternative Selection and Cost Range for the NOνA Project at Fermilab and Ash River, MN, is approved. Therefore, the Fermi Site Office is authorized to begin the project Execution Phase of the NOνA Project.

_____ _____
Raymond L. Orbach Date
Director
Office of Science