Acquisition Strategy for the NOνA Project

Project ID SC-25-06-1

at

Fermi National Accelerator Laboratory

Lead Program Office:
Office of High Energy Physics
Office of Science

Total Project Cost Range:
$244 - $293 million

March, 2007

Concurrences:

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Undersecretary of Science
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Critical Decision (CD)-0 Approval

The CD-0 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 NuMI Off-axis neutrino (ν) Appearance (NOνA) experiment has been selected to meet that mission need, utilizing the neutrino beam from the Neutrinos at the Main Injector (NUMI) facility at the Fermi National Accelerator Laboratory (Fermilab) site. The primary requirement to meet this mission need is a product of the proton intensity and mass of the far detector. The Mission Need statement described an alternative with a large detector and no upgrades to the NuMI beam. The currently preferred alternative combines a smaller detector with an upgraded NuMI beam.

Since the upgraded NuMI beam could support other uses besides NOνA, it was not originally considered relevant to the NOνA project. Given the importance of the planned increase in NUMI neutrino intensity to support the physics goals of NOνA, the importance of NOνA to the U.S. neutrino program, and in order to ensure appropriate project management, oversight and integration, this planned collection of accelerator and NUMI upgrades and improvements has been added to the scope of the project. The project will be referred to as NOνA hence forth.

1. Desired Outcome and Requirements Definition

Summary Project Description and Scope

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 study the pattern of neutrino masses and the details of neutrino mixing by using the accelerator complex and NuMI facility at Fermilab to provide an intense flux of neutrinos to a large new detector in northern Minnesota. If the version of neutrino mixing that is being sought is determined to exist, then we should ultimately be able 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.

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 modifications and upgrades needed to increase the beam power and provide the intense flux of neutrinos to the NOνA detectors. The project provides for engineering design, materials, supplies and resources needed to support fabrication, construction and installation of these items. The following further describes the project requirements and scope:

Accelerator and NuMI Upgrades- The Fermilab Recycler (an existing storage ring that stores antiprotons and supplies them to the Tevatron) 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 and modified to operate in the medium energy neutrino configuration for the NOνA experiment. To accomplish this, the NOνA project scope consists of new kicker systems for clean beam injection and abort; new Recycler injection and extraction lines; additional radio-frequency (RF) stations for the Main Injector and Recycler; NUMI beamline power supply and quadrupole upgrades; and NUMI target system design and cooling modifications. The scope includes associated re-configuration, removal, relocation, refurbishment and installation activities for the components involved.

NOνA Far Detector- The NOνA far detector is optimized for detecting low-energy (~2 GeV) electron showers while rejecting background events. The scope of the far detector is conceived to be an approximately 20 kiloton tracking calorimeter, approximately 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. The NOνA Project scope includes fabrication of the necessary tooling, installation and commissioning of the far detector.

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, the backgrounds to electron-neutrino identification that will appear in the far detector, and the initial electron neutrino content in the beam. The NOνA near and far detectors are nearly identical, and the scope of the near detector consists of the same technology, materials and type of modules described above, except the modules are shorter to accommodate restrictions of the NUMI underground tunnel and access shaft. The other significant differences are the overall size (near detector is only ~one or two hundered tons) and the clock speed of the electronics. The NOνA Project scope includes fabrication of the necessary tooling, installation and commissioning of the near detector.

NOνA Far Detector Enclosure- The NOνA Project scope includes design and 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.

Performance Parameters Required to Obtain Desired Outcome

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 at Fermilab. The sensitivity of NOνA depends on the product of the number of protons on target and the mass of the far detector, as well as the length of the data run. The accelerator complex and NuMI facility will be upgraded to provide a high intensity proton beam nearly double the present proton intensity. The mass of the NOνA far detector is planned to be up to ~20 kilotons. Although the Conceptual Design Report describes a 25 kiloton far detector, because of the highly modular nature of the detector design the total number of modules can be determined at the time the project performance baseline is established (CD-2), based on the better understood cost estimate and required physics reach. This combination of protons on target and detector mass makes NOνA the most sensitive experiment for all of the physics objectives listed above.

To meet the scientific and technical objectives for the NOνA experiment a significant neutrino flux must be provided along with a far detector of sufficient size and capability. The following performance parameters must be achieved:

- The Fermilab accelerator complex must be upgraded:
    - The Recycler must be converted from an anti-proton to a proton storage ring with proton injection and extraction systems connecting to the Booster and Main Injector, and allowing the Recycler to serve as a proton pre-injector to the Main Injector.
    - The Main Injector cycle time must be reduced, to enable increased proton beam power to the NUMI neutrino line.
    - The NUMI neutrino beamline must be upgraded to handle a substantial increase in beam power up to 700 kW and modified to the medium energy neutrino beam configuration.
- The NOνA Far Detector must be capable of observing the oscillation of muon type neutrinos to electron type neutrinos by observing the interaction of the electron type neutrinos in the active detector and identifying the associated electron. Efficient observation of electron type neutrinos while rejecting backgrounds from other processes is the key performance parameter for the NOνA far detector.

- The NOνA Near Detector is a smaller version of the NOνA far detector. Its performance parameters are similar to those of the far detector, but it must operate at higher rates because of its proximity to the NuMI production target.

- The NOνA far detector enclosure is an approximately 36,000 square foot space for the NOνA far detector, an assembly area, mechanical/electrical spaces and office space for a small operations crew. It should be as far as possible from Fermilab but still within the United States. Key performance parameters include maintaining the temperature and humidity conditions, providing the power necessary to operate the far detector. Other performance parameters include providing cosmic background shielding as needed, effective containment of materials (i.e. in the event of liquid scintillator spill), and code compliant life safety and fire protection systems.

2. Cost and Schedule Range

Total Project Cost Range

The NOνA Project has not yet been baselined, but the pre-baseline total project cost (TPC) for accelerator and NuMI upgrades, a 20 kiloton NOνA far detector, the smaller near detector, and the enclosure to house the far detector is expected to be in the range $244 million to $293 million in then-year dollars.

Funding Profile

NOνA is an MIE, which is the dominant funding type and is included under TEC in the table below. The currently planned preliminary funding profile, which will allow the completion of the project by fiscal year 2013, is given in Table 1 below.

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

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 CD-2 scope, cost and schedule baseline is being developed in accordance with this funding profile and guidance, and the Total Project Cost (TPC) expectation of $260M. The Project is actively working on completing the baseline cost estimate for CD-2, including incorporating results of on-going cost reduction and value engineering efforts and engineering studies.

Key Milestones and Events

Table 2 shows the key preliminary milestones.

Table 2. *NOν*A Project Key Milestones, (A) = Actual

Description	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[1]	4Q2007
CD-3B Approve Start of Construction	2Q2008
CD-4 Project Closeout	4Q2013

[1] See acquisition alternatives in section 4 for details.

Overall, the project and documentation have been reviewed and judged to be ready for CD-1. The Conceptual Design Report is complete and comprehensive and the cost and schedule ranges are appropriate. A key item needed to support CD-1 is the acceptance of a proposal and selection of a recipient of a DOE Cooperative Agreement, which represents an important component to finalize the alternative selection and the acquisition strategy.

CD-2 represents the completion of preliminary design and establishment of the project performance baseline. Preparation for CD-2 will be reviewed along with the preparation for a CD-3A. For the detector, CD-3A is to approve construction of a site access road that is needed to support the start of far detector construction (CD-3B). An earlier start to the road construction will enable a gain in the schedule. In addition, CD-3A is to approve start of procurements for key detector materials such as fiber and Avalanche Photo Diodes as well as start procurement and initial construction or fabrication of new and refurbished accelerator components, and procurements for the NuMI target upgrades.

If the project is able to realize contingency savings, then additional mass will be added to the far detector, requiring additional time to complete. On the other hand, the schedule range for the accelerator and NUMI portion of the project depends on the timing and duration of the Fermilab shutdown periods, which can be either delayed or shortened by programmatic developments outside of the NOνA Project. Considering these possibilities, a conservative estimated CD-4 date was selected to cover this schedule range.

Operations & Life Cycle

The far detector operations costs are estimated from the experience of the MINOS experiment which is also a high energy physics experiment located in northern Minnesota. The actual operating time for NOνA will depend on the mass of the far detector and the number of protons on target as well as the currently unknown magnitude of the parameters that drive the physics processes NOνA is designed to measure. The major operations costs will be for a small crew (~5 FTE) of technicians to maintain the far detector, the cost for power to the far detector, telecommunications, and maintenance of the enclosure. The total cost for operating the far detector is $1-1.25 million a year. The near detector is significantly smaller with much smaller power requirements and is located on the Fermilab site so a dedicated crew of technicians is not necessary. It is estimated that less than one FTE of technical labor will be needed for the near detector. The cost to operate the near detector is estimated to be ~five percent of that needed for the far detector.

Operating costs for running the accelerator and NuMI Facility when the upgrades are complete will be very similar to those for running these facilities in the past. When this work is completed, the Fermilab Collider program is planned to be shut down. The combination of operating the upgraded neutrino program and not operating the Collider program is projected to result in an overall operating cost decrease for the accelerator and

NuMI Facility of approximately 30-40%. This range is very preliminary and will require further revision and refinement as Fermilab's overall programmatic planning proceeds.

A conceptual decontamination and decommissioning (D&D) plan has been developed for the NOνA far detector. The basic plan is to remove the NOνA far detector from the site building, and convey the empty building to the University of Minnesota (as discussed in section 4 under acquisition alternatives). It is anticipated that the final cost of far detector decommissioning will be less than $10 million. Based on present regulations much of the material should be able to be recycled (e.g. electronics and scintillator oil); alternative uses for the materials (e.g. retained for use by a future experiment) could significantly offset or diminish decommissioning cost. D&D cost was also a criterion for comparison of the far detector and site alternatives, but none of the NOνA alternative sites and technologies hold a D&D cost advantage relative to the preferred alternative.

The near detector D&D considerations are similar to those of the far detector except that the volumes of material involved are two orders of magnitude lower, and costs involved will accordingly be much lower. The near detector will also be located in the existing Fermilab MINOS near detector facility, and its D&D will be planned and coordinated within the overall Fermilab NUMI and MINOS D&D plan.

The primary and most challenging consideration for D&D of the NUMI facility following cessation of operations will be addressing the production of radioactivity in the beamline components and its environs. This is further discussed in the NOνA Environmental Assessment. The eventual D&D approach will be one that assures compliance with applicable radiological requirements. D&D will include monitoring, analysis and removal activities (e.g. removal of activated components, or pumping out activated water), with a duration that will be dependent on the criteria and goals established to meet the applicable requirements. Further studies have already been outlined, to be undertaken by Fermilab to properly define a D&D plan. Selection of the D&D approach will require detailed planning, including cost, safety, environmental, and schedule considerations. It also will depend on the future of Fermilab and the future of neutrino research.

For both accelerator and detector facilities, options will be evaluated and narrowed to the decommissioning method of choice as the end of the NOνA experiment approaches, and associated cost and schedule will be reviewed and refined accordingly.

The benefits of fundamental physics research are increases in our knowledge of the universe and it workings, however it is not possible to assign a monetary value to this, so a cost benefit analysis against the overall total project, operations and life-cycle cost has not been carried out.

3. Major Applicable Conditions

Environmental, Regulatory and Political Sensitivities

As is discussed further in section 4. under Acquisition Alternatives, DOE has received an unsolicited proposal from the University of Minnesota for a cooperative agreement, which includes a proposal to construct the far detector enclosure on University owned land in Ash River, MN. This proposal is a key element of this Acquisition Strategy and supports the proposed action and the preferred alternative site selection for CD-1.

All work done at Fermilab and the far detector site will be in accordance with federal, state, and local regulations and guidelines. All work done at collaborating universities will be in accordance with university, state and local regulations and guidelines.

One Federal requirement is the National Environmental Policy Act (NEPA). An Environmental Assessment (EA) is being 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 to be located in Ash River, Minnesota. The EA incorporates an extensive radiological assessment of increasing the power of the NuMI beam line.

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. Although not required, the University of Minnesota may utilize this information to prepare a discretionary Environmental Assessment Worksheet (EAW) for State review. 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. The Minnesota Pollution Control Board has concluded that the liquid scintillator to be used by NOνA is not considered hazardous material, with the result that it is not required to be addressed in an EAW.

A preliminary draft EA has been prepared by Fermilab. It is in the process of being revised to address DOE comments. In addition, this subject has been discussed with local leaders and officials as part of Fermilab's public outreach program. Fermilab has considerable outreach experience and maintains an excellent rapport with neighboring communities. No significant environmental, regulatory or political sensitivities have been identified.

Safety is integrated into all aspects of project work performed at Fermilab in accordance with Fermilab's DOE-approved Integrated Safety Management (ISM) program. Likewise, Argonne National Laboratory, which is performing some NOνA project work (detector R&D and development and testing of gluing/epoxy operations and lifting fixtures), also operates under a DOE-approved ISM program..

Analysis is underway to document any safety hazards/concerns associated with NOνA near and far detector fabrication and these will be addressed in a Preliminary Safety Assessment Document covering NOνA detector fabrication, installation and operations.

Updates to the existing Fermilab Accelerator Division (AD) Safety Assessment Document (SAD) and the NuMI/MINOS SAD will be prepared and approved prior to commissioning the accelerator and NuMI Beamline systems upgraded in the NOνA Project. Prior to sustained operations, the Safety Assessment Documents for the accelerator and NUMI beamline, and NOνA detector operations will be finalized by Fermilab and concurred on as required by the site office.

The Minnesota Occupational Safety and Health program is administered by the Minnesota Department of Labor and Industry (DLI). Construction work at the far detector site would be subject to DLI regulation. In addition, permits are expected to be required from the U.S. Army Corps of Engineers, the Minnesota Pollution Control Agency, the Minnesota Department of Health, the Minnesota Department of Natural Resources, and St. Louis County commissions. The DOE cooperative agreement for construction of the Far Detector building would include provisions requiring the awardee to obtain these permits, to provide full-time on-site oversight of construction activities, and making the awardee accountable for any ES&H issues that may arise.

Others

There are no significant other sensitivities.

4. Risk and Alternatives (Technical, Location, and Acquisition Approach)

Technical Alternatives

For the Accelerator and NuMI Upgrades portion of the NOνA project, several technical alternatives were considered to the preferred method of using the Fermilab Recycler as a proton accumulator/injector with slip stacking injection to obtain higher proton intensities. The alternatives fell into three categories: increase the intensity of the proton source (i.e. the Booster); use of other machines or configurations (i.e. a new Proton Driver or the existing Accumulator); and other stacking techniques for optimizing beam injection and capture. Based on studies and operations experience, compared to using the Recycler, these other alternatives presented specific technical limitations or unproven technologies, or were found to be cost-prohibitive. Trying to stack more batches in Main Injector without using the Recycler in order to increase the beam power is a losing proposition because of the extra time it takes to inject the new batches. A new machine, such as a new Booster or an 8 GeV linac/Proton Driver, which would cost hundreds of millions of dollars, is clearly cost prohibitive.

After the conclusion of the Fermilab Collider program, the Recycler becomes available for use as a proton accumulator and represents an economical and opportune way to meet the needs of NOνA, using an accelerator method (slip stacking) already proven in other accelerator operations.

For NOνA detector design, a number of technical alternatives to the preferred liquid scintillator detector were considered. These were water Cherenkov detectors, liquid argon time-projection chambers (LaTPC), and sampling calorimeters with low atomic weight materials. Water Cherenkov detectors are a poor match to the neutrinos produced by the NuMI beam. The LaTPC is a promising new technology, but it has never been demonstrated on the scale required for NOνA. The sampling calorimeters were studied in some detail, but their performance was found to be inadequate. A more detailed discussion of these alternatives is included in the NOνA Conceptual Design Report. The preferred alternative results in the best physics sensitivity per unit cost and presents the fewest technical, schedule and cost risks.

Location Alternatives

The location alternatives are limited by the location and the direction of the recently completed NuMI beamline at Fermilab. The NuMI beamline, completed in 2005, is the only existing facility in the world capable of providing a significant flux of neutrinos to a long baseline detector sufficient to study the pattern of neutrino masses and the details of neutrino mixing.

In order to capitalize on this investment and to meet the scientific requirements of the NOνA experiment, the location of the far detector must be sited along the NuMI beamline. where the neutrino beam exits the earth's surface. An optimal site for the NOνA far detector is in northern Minnesota near the Canadian border. The area is rural and sparsely populated which will have an impact on the acquisition alternatives.

Acquisition Alternatives

Detectors

The cost drivers for this project are the detectors, which are unique scientific devices. It is highly desirable to closely coordinate the fabrication of those devices with the scientific collaboration that will utilize them. The collaboration has the expertise in detector technology to optimize the design. Information collected during the prototyping of the components is fed to the collaboration, which can estimate impacts on the ultimate detector performance, allowing value engineering judgments to be made. Data collected from individual detector components during the fabrication is used by the collaboration to develop simulations needed for the eventual data analysis.

Given these considerations, it is more efficient to rely on Fermi Research Alliance (FRA), LLC, the operating contractor of Fermilab, to act as the prime contractor for the fabrication of the NOνA detectors rather than have DOE issue a contract for fabrication by a third party. The Fermilab Contractor, FRA, will be able to build on an existing strong and successful relationship with the neutrino research community and its leadership, which includes many Fermilab scientists and engineers. Therefore, this arrangement best ensures the necessary close cooperation and coordination between the NOνA scientific collaboration and a highly competent and experienced team of project managers, engineers and procurement staff managed by Fermilab as part of an integrated project team.

Far Detector Enclosure

Although the enclosure to house the far detector has a special requirement to shield the far detector from cosmic rays, it is a conventional civil engineering project and, therefore, allows a broad range of acquisition alternatives.

The NOνA Integrated Project Team (IPT) considered the following options:

1. A financial assistance award, most likely a cooperative agreement, to the University of Minnesota,
2. DOE prime contracting, or
3. Subcontracting via the Fermilab operating contractor.

The DOE has received an unsolicited proposal from the University of Minnesota for a cooperative agreement to conduct research on neutrino oscillations as part of the NOvA collaboration. As part of the research program the University proposes to construct the far detector enclosure on University owned land, to operate the building, to be responsible for security and ES&H, and to participate in the calibration, data-taking, maintenance of the NOvA far detector and the subsequent data analysis.

As indicated in its proposal, the University of Minnesota has selected an optimal site for the far detector in Ash River, MN after considering both primary and alternate sites. The Ash River site meets the selection criteria, which include being: 12 km off-axis to NUMI/MINOS; in the United States; as far as possible from Fermilab; and accessible for both vehicles and utilities. The University of Minnesota currently operates the Soudan Underground Laboratory (SUL) and successfully managed the construction of the SUL cavern that now houses the MINOS detector; and so, it has relevant and unique experience in the construction and operation of modern physics facilities in remote locations far from the technical infrastructure of a national laboratory or a major research university.

This financial assistance award would include both a portion of the NOνA TPC (construction of the far detector enclosure) and subsequent research activities. The DOE OHEP, supported by the DOE NOνA project staff at the Fermi Site Office, will provide oversight for both the cooperative agreement and the far detector fabrication funded as a Major Item of Equipment (MIE) and any interactions between the two efforts. The first option above is the IPT's recommended option.

In the last two options, DOE would need to acquire the rights to the land through either purchase or a long-term lease. The IPT consulted with the real property department of the Chicago Office. The estimate was that the purchase of the land would take about one to two years to go through the processes of sole source justification or competitive solicitation, environmental assessments, surveys, and appraisal, as well as approvals by other Federal Agencies. This potential delay would be detrimental to the scientific mission.

In addition, if DOE owns the land, then DOE would provide oversight for procurements, security, and compliance with environment, safety, and health (ES&H) requirements. If Fermilab were to subcontract the construction of the enclosure, then Fermi Site Office (FSO) would be responsible for the oversight, requiring two additional full-time equivalents during the construction phase and one during the operational phase. If DOE manages the contract to build the enclosure directly, all of the same DOE manpower requirements would apply and approximately five additional FTE's would be needed to manage the contract, which would include a safety professional, a field construction coordinator, a construction manager, a project engineer, and someone to manage the technical drawings. With the University of Minnesota award, management and operating efficiencies are expected due to its previous experience managing and operating physics research facilities in northern Minnesota.

Furthermore, if DOE owns the land and the building; the facility will need to be shutdown and the enclosure demolished once the operations of NOνA cease as there is little likelihood that DOE will have any further use for the facility. In the case of the recommended option, DOE would remove the far detector and the University of Minnesota could consider making further scientific or other use of the building to best exploit the investment, if desired, prior to disposition.

Accelerator and NuMI Upgrades

The existing accelerator and beamline complex at Fermilab will be upgraded to provide a larger neutrino flux for the NOνA detectors. This equipment was designed, fabricated, and installed by scientific and engineering experts in this field. The upgrades to this equipment are best suited to be designed and installed by these same experts, both due to the knowledge of the staff and the integration of the upgrades with ongoing accelerator operations. Prototyping will be done utilizing some existing Fermilab equipment.

Given these considerations, it is more efficient to rely on Fermi Research Alliance (FRA), LLC, the operating contractor of Fermilab, to act as the prime contractor for the fabrication of the accelerator and beamline upgrades, rather than have DOE serve in that capacity or contract out to a third party. This arrangement best ensures the necessary close cooperation and coordination between accelerator operations and a highly competent and experienced team of project managers, engineers and procurement staff managed by Fermilab as part of an integrated project team.

Project Risk Analysis

Cost Range

Every effort to minimize cost risks shall be made based on acquisition planning and project management efforts to define a clear performance work scope and by establishing a clearly defined process for all changes. Detailed cost estimates of each of the major procurements for the NOνA Project have been made from vendor quotes and experience with earlier and similar procurements. As a result, these cost estimates will serve as the benchmarks as these projects evolve and will be utilized to estimate project procurement costs and to understand and explain any variances.

Cost risks are considered medium at this early stage of the project. There are three large purchases that are cost drivers for NOνA: PVC extrusions, liquid scintillator and wavelength shifting fiber. Small price increases in these items could have significant overall cost implications due to the large quantities involved. The cost of PVC and liquid scintillator are loosely tied to the cost of crude oil, which is obviously subject to fluctuations. Quotes which are indexed to the cost of oil have been obtained and will be used to estimate the potential impact of fluctuations in the cost of crude oil in the project's contingency analysis. Accelerator and NuMI upgrades work mainly consists of improvements and modifications to existing designs. Items with greater risk have a prototyping phase and carry larger contingency.

Schedule Range

To the extent feasible, procurements will be accomplished by fixed-price contracts or fixed-price contracts with economic adjustment and awarded on the basis of competitive bids. Incremental awards to multiple subcontractors to assure total quantity or delivery will be performed to reduce schedule risk.

Overall schedule risk is considered low. The largest schedule risk is a delay in beginning construction on the far detector enclosure. The far detector enclosure is on the project's critical path and must be complete before assembly of the far detector can begin. The construction of the enclosure itself poses no particular risks. However, the schedule depends on the successful implementation of the cooperative agreement. The DOE has received an unsolicited proposal from the University of Minnesota to construct and operate the far detector enclosure on University owned land. It should be noted that a group of physicists from the University of Minnesota has been participating in the construction, operation and research program of the ongoing MINOS experiment and has also been participating in the research and development of the NOνA concept. The University built the cavern for the MINOS far detector under the existing HEP grant and has successfully managed the Soudan laboratory under a contract from Fermilab over the last few years.

A parallel critical path exists through the Accelerator and NuMI Upgrades portion of the project. This critical path is through the new kicker systems required for the new injection and extraction lines to the Recycler. The kicker schedule requires installation during the shutdown following termination of the Tevatron Collider program. It is during this shutdown that all the accelerator work is presently planned to be performed. Delays in this shutdown would delay installation of the Accelerator and NuMI upgrades. Several items must be removed from the accelerator, modified and re-installed during this shutdown and drive the length of the shutdown.

The project will establish appropriate schedule contingency at CD-2 to address schedule risk.

Funding Range and Budget Management

Overall funding risk is low. All funding is planned to be from the High Energy Physics program. There is no plan for the University of Minnesota to directly contribute to the funding of the project.

Technology and Engineering

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, and minimizing exposure to single vendor failures. Technically risky elements have been minimized by making deliberately conservative design choices. These include ceramic beam tubes, target design, liquid scintillator, wavelength shifting fiber and commercial off-the-shelf electronics, such as programmable logic devices, digital signal processors, and network switches. Items with higher technical risk have a prototype phase and carry higher contingency.

Interfaces and Integration Requirements

The risk associated with the interfaces and integration requirements is like that for similar projects, which Fermilab has successfully managed through the use of Integrated Project Teams (IPT) and Project Management Groups (PMG) to effectively coordinate interfaces among DOE, laboratory management, project management and the experimental collaboration, to effectively oversee the overall project integration activities.

The technical components produced by the project will be installed according to a detailed integration plan. Development of this plan has already begun. This plan will be used early on to understand and address potential risks with component integration and installation during the near detector installation. This experience will be used to better understand and address potential future integration risk associated with the installation of the far detector, when much larger volumes of components must flow to the far detector site on a regular and reliable schedule. A model has already been constructed to work out the details of the parts flow, parts storage and installation. The installation of the MINOS far detector presented a similar situation and was handled successfully, and that experience will be referenced and utilized wherever relevant.

An important interface for this project would be the coordination between the University of Minnesota (as recipient of the cooperative agreement) and Fermilab, which will serve as the overall project integrator. To ensure effective communication, the award of the cooperative agreement will require the University of Minnesota to implement an integration plan that addresses how the activities performed under the cooperative agreement will be integrated with the total project. The proposal describes how the cooperative agreement fits into the NOvA Project Management structure, and a further

Memorandum of Understanding, management plan or equivalent document is planned prior to CD-2.

Because an accelerator shutdown is required to reconfigure components for NOvA operations, interfaces with ongoing Fermilab accelerator and NuMI operations present a potential risk. Tevatron operations must terminate before the accelerator upgrades portion can be installed and tested. Other experiments use the NuMI facility so coordination is required with program planning for shutdowns and changes in beam configuration within this facility. This type of coordination and planning is part of general operations at Fermilab where the accelerator complex is normally shared by several experiments. Communication and coordination with laboratory management regarding NOvA requirements for shutdowns will occur through PMG meetings and with the Accelerator Division.

Safeguards and Security

The NOνA Project will create no new security issues during design, fabrication, and operations. The facility will be a low-hazard, non-nuclear facility. Security on the Fermilab site will be covered under Fermilab's existing DOE-approved program. Fermilab has experienced no major incidents in the past. Access to Fermilab is controlled to ensure worker and public safety and property protection. Access to the far detector site will be similarly controlled by the University of Minnesota (as recipient of the financial assistance agreement) which will be responsible for safeguards and security at the far detector site in Minnesota. None of the work at Fermilab or for the NOvA Project is classified. The risk of safeguards and security issues is, therefore, small.

Location and Site Conditions

The accelerator and NuMI upgrades, as well as the NOνA near detector, will be located in existing Fermilab enclosures. There are no known site related risks. The far detector will be located in a remote area in northern Minnesota. The location and capacity of the electric utilities in the area are well known and will have to be extended to the site. The cost and feasibility of the required expansion of the capacity have been discussed with the local utility company. The cost estimate to provide the required capacity is well understood and, therefore, the overall risk is considered low. An existing logging road must be upgraded for truck traffic during construction as a part of the project. Required permits from the U.S. Army Corp of Engineers, county or state will be obtained. None of the impacted areas is designated as a Protected Water or Wetland by the Minnesota Department of Natural Resources.

Legal and Regulatory

There are no known legal or regulatory issues that could impact the project construction. The project will be in full compliance with all applicable federal, state, and local requirements.

The NOνA far detector enclosure and far detector will be built along the NuMI beamline in northern Minnesota. The MINOS far detector and its detector cavern were also built in northern Minnesota so Fermilab has some relevant experience in dealing with the local regulatory agencies. Several permits are anticipated to be needed for this construction (e.g., discharge permit, local building permit), and those will be obtained by the University of Minnesota which is responsible for the construction management.

Fermilab has a Lifetime Operating/National Emissions Standards for Hazardous Air Pollutants (NESHAP) Permit from the Illinois Environmental Protection Agency (IEPA) that regulates onsite air emissions, including radionuclide emissions from beamline ventilation stacks associated with accelerator and NUMI operations upgraded by this project. Total releases are reported annually to the IEPA and the U.S. Environmental Protection Agency (EPA) in accordance with conditions of the relevant NESHAP permit. Based on the conceptual design report, conservative estimates of total radioactive air emissions due to planned accelerator and NUMI upgrades demonstrate that no revisions are required to the laboratory's permits or monitoring methodologies.

Fermilab holds several NPDES (National Pollution Discharge Elimination System) permits that regulate the discharge of liquid effluent to surface water and other bodies, and these permits are maintained or modified as needed based on Fermilab's operations. Water on the Fermilab site associated with accelerator and NUMI operations upgraded by this project is discharged in accordance with DOE requirements concerning discharges to surface waters at DOE facilities, and covered by existing permits and currently approved outfalls.

No additional environmental permits or permit modifications, beyond those existing, are required for the Fermilab site due to the NOνA project.

Environment, Safety and Health

ES&H risk is anticipated to be very low on this project. An Environmental Assessment (EA) is being finalized for this project as required by NEPA. Fermilab has a fully developed Environmental Management System. Environmental monitoring is part of that system and consists of two elements: effluent monitoring and environmental surveillance. Surface water monitoring includes outfall, sump, ditch, sanitary discharge, storm water, sediment, pesticide, and off-site monitoring.

NOνA Project activities are carried out at or under the supervision of national laboratories and institutions and are subject to the ES&H policies and procedures of those specific laboratories or institutions. Safety considerations for work to be conducted at the Fermilab or ANL site will be addressed according to each lab's existing Integrated Safety Management Program. Work at the far detector site in Minnesota will be done in accordance with all state and local guidelines and regulated by OSHA. ES&H considerations for this project will be similar to those encountered on the existing MINOS detector. DOE and Fermilab have a history of performing similar accelerator, detector, and conventional construction in a safe manner. In addition, a Safety

Assessment Document specific to the NOνA detectors will be produced prior to sustained operations, as well as updates to the existing Safety Assessment Documents for the Accelerator and NuMI Facilities.

Stakeholder Issues

No significant stakeholder issues have been encountered during the project initiation and definition phases. The NOνA Collaboration is a primary stakeholder of this project, and other important stakeholders are the public and communities surrounding Fermilab and the northern Minnesota site, Fermilab, the University of Minnestoa, the States of Illinois and Minnesota, and the U.S. DOE.

The Project and the Collaboration are tightly knit and members of the collaboration are intensively involved in the design and construction of the project. Together, the Project and the Collaboration have engaged in extensive stakeholder outreach since 2003 with Minnesota stakeholders, Fermilab and DOE, as documented in Chapter 21 of the NOνA Conceptual Design Report. The MINOS detector in the Soudan mine in Minnesota has had the strong support of local and regional businesses, local government, and congressional members. Fermilab and the University of Minnesota have developed excellent relations with the local community in northern Minnesota. This outreach program will continue for NOνA. DOE, Fermilab, and the University of Minnesota will keep stakeholders updated on the progress toward completion of the NOνA Project.

Fermilab has built and maintains an open and trusting relationship with the surrounding communities and local leaders that includes a Community Task force on Public Participation, and many other means of public outreach. During the NEPA process, Fermilab has used such means to present results of the NOνA EA and to identify public information and input needs for the EA. Fermilab has also worked very successfully in the past with the Illinois Environmental Protection Agency, DOE and the local public to address such issues as low levels of tritium on-site from Fermilab accelerator operations. The strong experience and relationships established and outlined above, along with communications and outreach efforts in Illinois and Minnesota, will continue to be applied to the NOνA Project as needed to identify and address stakeholder concerns that may arise. The risk from stakeholder issues is, therefore, small.

5. Business and Acquisition Approach

As discussed in the acquisition alternatives section, 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.

For construction of the far detector enclosure, research, and subsequent operations of the facility, a financial assistance agreement is planned. DOE has prepared a Determination of Noncompetitive Financial Assistance, and award of a cooperative agreement is anticipated in response to the unsolicited proposal from the University of Minnesota. This determination will support that a non-competitive award is in the public interest. The cooperative agreement will be awarded and administered by the Contracting Officer from the Chicago Office.

Acquisition and Contract Types

Accelerator/NuMI Upgrades and Detector Fabrication. Fabrication and assembly of the accelerator and NuMI upgrades and the near and far detectors will require procurements of a wide variety of components. 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. Subsystems considered to be appropriate to be contracted out to various participating institutions are the PVC module assembly, portions of the front-end electronics, the data acquisition system and the replacement hadron monitor. In these cases, the scope required and procedures to be followed will be described in Memoranda of Understanding between Fermilab and the participating institution, and funding will be provided incrementally on a yearly basis.

Labor for accelerator, NuMI, and detector fabrication activities will come from both Fermilab and university staffs (also including a group from ANL working on the detector). Assembly of the far detector will take place in northern Minnesota using a mix of laboratory and university personnel. Universities will be selected based on their detector development experience, commitment to the physics goals of the project, and cost effectiveness.

Three major procurements have been identified as critical to the project because of their overall cost or because of limited commercial sources. These are the procurement for the liquid scintillator, the procurement for the PVC extrusions, and the procurement for the wavelength shifting fiber. In the case of the wavelength shifting fiber, there are limited sources, but the sources have historically been reliable and have produced detector components for previous major experiments (e.g. MINOS, ATLAS). Risks associated with these procurements are considered to be small. It is anticipated that Fermilab will issue fixed-price contracts or fixed-price contracts with economic adjustment for work to be performed whenever possible. NOνA has prepared a detailed procurement plan for the critical procurements.

Far Detector Enclosure. An unsolicited proposal has been received from the University of Minnesota to build the far detector enclosure with financial assistance as part of the university's program of neutrino research. In order to allow the crucial coordination with the DOE project, a cooperative agreement would be the financial assistance instrument. The agreement will include the acquisition of a site for the far detector, the design and construction of the enclosure to house the far detector, as well as participation in the design, construction, and operation of the far detector, and collaboration on the research performed with the detector. Facility operations and research at the facility, while funded as part of the cooperative agreement, are not within the project scope. The University of Minnesota as the award recipient will be responsible for procuring the materials and labor necessary for construction and operation.

Incentive Approach/Linkage to Performance Metrics

For the accelerator/NuMI and detector fabrication scope to be performed by Fermilab, existing contract incentives will remain in place and apply to this project. Specifically, for example, the 2006 Performance Evaluation and Measurement Plan for Fermilab's contract included the following metric: "*Provide for Efficient and Effective Design, Fabrication, Construction and Operations of Research Facilities*". Performance on the NOνA project was a factor in the Fermilab contractor's rating on this element. Similar measures are in place for the new Fermilab contractor, FRA.

Specific incentives are not planned for the financial assistance agreement to construct and operate the far detector enclosure. However, the University of Minnesota, as the financial assistance recipient, will be expected to work in close collaboration with Fermilab and the NOνA project to ensure good integration of schedule and performance requirements between the far detector and facility.

Competition

All actions will be competitive procurements unless specifically authorized by the project manager(s) and will be in accordance with the DOE-approved procurement policies and procedures.

6. Management Structure and Approach

IPT Structure

The NOνA Integrated Project Team (IPT) is a multi-disciplinary team, consisting of personnel from DOE, Fermilab and other institutions responsible for execution of the project. The IPT is led by the NOνA Federal Project Director (FPD), a DOE Fermi Site Office (FSO) employee, who has the authority for day-to-day implementation and direction of the project. The FPD is supported by the NOνA Project Manager and works closely with the DOE NOνA Program Manager from the DOE Office of High Energy Physics, who provides programmatic guidance and direction. The NOνA Project Manager has the primary responsibility of completing the project within the approved scope, budget and schedule and ensuring that the project's technical goals support the planned physics program.

To acquire the multi-disciplinary support necessary, the FPD and IPT utilize support from FSO, the DOE Office of Science Chicago Integrated Support Center (CH), Fermilab, and the institutions participating in the project. The areas of support include environment, safety & health (ES&H), legal, business (e.g. procurement, budget and funding administration, accounting), project management (e.g. project controls and reporting), quality assurance and technical (e.g. in the area of particle physics accelerator and detector R&D, fabrication and construction).

FSO support includes a warranted contracting officer, support in business management (e.g. local procurement expertise), coordination of ES&H team support as needed (e.g. NEPA, safety assessment and operational awareness), and management oversight and support of the FSO NOνA project team. CH support includes ES&H, financial, procurement and legal areas.

The specific technical and managerial expertise to design, fabricate, construct, commission and operate the NOνA accelerator and NuMI upgrades, detectors and support infrastructure resides at the laboratories and universities participating in the NOνA collaboration. The NOνA Project Manager, a Fermilab employee, leads the project management team consisting of the level 2 managers and the NOνA Project Office at Fermilab. The NOνA Project Manager coordinates all necessary project support from Fermilab in the areas of business, procurement, legal, ES&H and other Fermilab Division/Section support as needed.

The NOνA Project Manager is the primary project interface with NOνA collaboration spokespersons and management, and the institutions providing project deliverables. This includes in particular the cooperative agreement awardee anticipated in this Acquisition Strategy for construction of the far detector enclosure in Minnesota, the University of Minnesota. This interface will be managed to ensure coordinated execution of authorities among the parties, and to maintain adequate communications, work authorizations and flow, and project controls and reporting to cover design, construction and oversight activities.

As the project progresses, membership of the IPT will change as needed to provide sufficient support in all project phases- initiation, definition, execution and transition/closeout. The following are key members and positions on the initial NOνA Integrated Project Team

- Michael P. Procario, DOE OHEP Program Manager
- Pepin Carolan, DOE Federal Project Director, IPT lead
- Stephen Webster, DOE Deputy Federal Project Director
- Dennis L. Wilson, FSO Business Manager**
- Jonathan P. Cooper, FSO ES&H Lead+
- Barbara Lewandowski, CH Procurement
- James Fuerstenberg, CH legal
- John Cooper, NOνA Project Manager ++

- Ron Ray, NOνA Deputy Project Manager
- Nancy Grossman, NOνA Associate Project Manager
- University of Minnesota DOE Cooperative Agreement Awardee/Principal Investigator

* *Warranted contracting officer within the Fermi Site Office; it is anticipated that an FSO business team vacancy will add FSO Procurement Specialist support when filled.
+ Will coordinate FSO ES&H team support as needed.
++ In addition to leading the project management team, coordinates necessary project support from Fermilab business, procurement, legal, ES&H and other Division/Section support as needed.

The IPT structure, responsibilities, interfaces and functioning is further discussed in the Preliminary Project Execution Plan, which also includes an IPT charter.

Approach to Performance Evaluation and Validation and Baseline Management

An Earned Value Management System (EVMS), which will meet the criteria of chapter 12 of Manual 413.3-1, will be implemented and maintained for this project. The basic Work Breakdown Structure has been established and can be found in the Preliminary Project Execution Plan (PEP). The resource-loaded schedule is being developed and inserted in the OpenPlan scheduling software. The OpenPlan and COBRA earned-value software will be used as tools to monitor project performance. The recipient of the cooperative agreement will prepare an integration plan and provide information to Fermilab in support of the EVMS described above.

The baseline change control process will be documented in the Project Execution Plan (PEP) as part of CD-2 preparation. The project baselines and control levels are defined in a hierarchical manner that provides change control authority at the appropriate level. The highest level of baseline management authority is the DOE Deputy Secretary. Depending on the DOE thresholds in place, Deputy Secretary approval may be needed for new performance baseline approval from deviations with cumulative changes of >6 months or >25% of cost beyond the approved performance baseline. Undersecretary of Science approval may be required if preceding thresholds are not exceeded, or Program Secretarial Officer (Acquisition Executive) approval, if delegated. For the NOνA Project, baseline management for routine project change control is under the authority of the Associate Director, OHEP, and is executed by the DOE NOνA Federal Project Director. Change control levels are defined for the Program, Project and contractor (Fermilab) as specified in the PEP and Project Management Plan.

The DOE NOνA Project Director will provide quarterly reports on the Project to OHEP and monthly updates to the Project Assessment and Reporting System. Monitoring of the Project will occur through established mechanisms among project participants. Reviews of the project status will be conducted by the Associate Director for High Energy Physics and DOE Science Office of Project Assessment approximately semiannually. Fermilab will provide formal monthly reports to the DOE NOνA Project Director. The requirements of the monthly reports will be included in the NOνA Project Management Plan.

Interdependencies and Interfaces

The NOνA Project will involve interfaces between Fermilab, the University of Minnesota as recipient of the cooperative agreement, other national laboratories, U.S. universities, foreign research institutions, and industry in the procurement and installation of the accelerator and detector elements. These interfaces are very similar to those of other detector projects undertaken by Fermilab in the past, e.g., the Run IIa and Run IIb CDF and D-Zero projects, Compact Muon Solenoid, MINOS, LHC Accelerator and NuMI.

Fermilab uses a Project Management Group (PMG) to handle the interface between the project and the rest of the lab. PMG membership includes the project manager, the deputy project manager, the affected division heads, and is chaired by the lab director or his designate. The purpose of the PMG is to provide oversight and enable efficient execution of the NOνA Project by fostering appropriate communication between the Fermilab divisions and sections, NOνA project management, and the DOE.