Quality Assurance Program for the NOνA Project V1.0

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NOνA Project Quality Assurance Program
Change Log

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List of Abbreviations

AD……..Accelerator Division
APD .....Avalanche Photo Diode
CDR .....Conceptual Design Report
ES&H.....Environment, Safety & Health
FESHM .....Fermilab Environment, Safety & Health Manual
FPD .....Federal Project Director
ISM .....Integrated Safety Management
MINERνA.....Main INjector ExpeRiment: ν-A
MINOS.....Main Injector Neutrino Oscillation Search
MOU .....Memorandum of Understanding
NOνA .....NuMI Off-axis ν (neutrino) Appearance
NuMI.....Neutrinos at the Main Injector
ORC .....Operational Readiness Clearance
PA .....Financial Project Accounting System
PEP.....Project Execution Plan
PMP .....Project Management Plan
PPD .....Particle Physics Division
QA.....Quality Assurance
QAP .....Quality Assurance Program
SOW.....Statement of Work
TDR .....Technical Design Report
WBS.....Work Breakdown Structure
WLS .....WaveLength Shifting

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Quality Assurance Program
for the
NOνA Project

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1 INTRODUCTION

This document defines the Quality Assurance Program (QAP) for the NuMI Off-axis ν (neutrino) Appearance (NOνA) project. This project is to be carried out by the Fermi National Accelerator Laboratory (Fermilab), supported by collaborating institutions working on the NOνA experiment, which is designated as Fermilab E929. This QAP sets forth the policies needed to accomplish the NOνA project goals with the required level of product quality provide reliability of performance and protect the safety and health of personnel, property and the environment.

This QAP is established in accordance with Department of Energy (DOE) Order 414.1C "Quality Assurance" and Fermilab Director's Policy Manual, Chapter 10, Quality Assurance. These are applicable to the NOνA Project and to all Fermilab Divisions and Sections.

This Quality Assurance is implemented through the policies set forth in the Project Execution Plan (PEP)[i] and Project Management Plan (PMP)[ii] for the NOνA project. This QAP is reviewed at least annually and revised with the approval of the NOνA Project Manager.

1.1 Scientific Objectives

The purpose of the project is to upgrade the beam power to the NuMI beam line, to construct the NOνA near and far detectors as well as the far detector hall and to install the detectors in a state ready to take data. The NuMI beamline will also be modified to run in the medium energy neutrino beam configuration. The far detector is constructed from PVC extrusions filled with liquid scintillator. Each of the extrusion cells contains a Wavelength Shifting (WLS) fiber to collect the scintillation light and route it to an Avalanche Photo Diode (APD) optical detector. The technology for the near detector is identical to the far detector but implemented on a much smaller scale. The NOνA detectors will permit the experimenters to search for the oscillation of ν_μ to ν_e neutrinos. Once this oscillation is discovered it can be exploited to determine the mass ordering of neutrinos and to search for CP violation in neutrinos. The NOνA far detector, sited 810 km from Fermilab, has the longest baseline of any experiment proposed in the near future. A long baseline is necessary to determine the mass-ordering and NOνA is uniquely positioned to make this determination.

1.2 Technical Objectives

The sensitivity of NOνA depends on the product of the proton beam power and the mass of the far detector. One of the goals of the NOνA Project is to increase the power of the NuMI beam to approximately 700 kW. A further upgrade beyond 1 MW is also expected but is not part of the current Project. Based on the number of protons expected on the NuMI target in a 6-year run, the mass of the NOνA detector has been set at 18kt. This combination of beam power and detector mass makes NOνA the most sensitive proposed experiment for all of the scientific objectives listed previously.

The NOνA detector must be capable of observing ν_μ to ν_e oscillations by observing the interaction of the ν_e in the active detector and identifying the associated electron. Electrons appear in the detector as "fuzzy" tracks due to the way the electromagnetic shower evolves in the low Z material from which the detector is constructed. The detector must further be able to distinguish electron tracks from muons and

π^0's that appear as background. An additional background results from electron neutrinos that are produced from the decays of pions and kaons near the NuMI target rather than from ν_μ to ν_e oscillations that take place over a long baseline. The NOνA near detector will be used to measure the off-axis ν_e content of the beam near the NuMI target and extrapolate that background to the far detector.

To meet the scientific and technical objectives for the NOνA experiment, the following goals must be achieved:

- The Fermilab accelerator complex must be upgraded:
    - The Recycler must be converted from an anti-proton to a proton storage ring for slip stacking with proton injection and extraction lines.
    - The Main Injector cycle time must be reduced.
    - The NuMI neutrino line must be upgraded to handle a substantial increase in beam power and modified to the medium energy neutrino beam configuration.
- The NOνA far detector hall must be constructed at an appropriate site in Northern Minnesota.
- The NOνA Far Detector must be constructed:
    - Plastic PVC extrusions must be manufactured to the appropriate size and shape. The inner walls of the extrusion cells must be highly reflective to maximize light collection. The extrusions will be sealed at both ends forming leak-tight containers that will hold liquid scintillator and WLS fiber.
    - The PVC extrusions must be glued together in alternating layers of vertical and horizontal extrusions into a strong, self-supporting honeycomb structure.
    - The light produced by the liquid scintillator and collected by the WLS fiber is directed onto a pixilated APD optical detector. The output from the APD must be amplified, digitized and zero-suppressed by the front-end electronics.
    - A data acquisition system must accumulate the data from the front-end electronics and log the appropriate data to permanent storage.

More detailed discussions of the technical goals can be found in the Conceptual Design Report (CDR)[iii] and the Technical Design Report (TDR)[iv].

1.3 NOνA Project Description

The purpose of the NOνA project is to fabricate the NOνA near and far detectors in a state ready to take data and to provide a detector hall for the far detector, as well as upgrade the Fermilab Recycler and Main Injector accelerators and the NuMI beamline to support NOνA. The detector will permit the experimenters to study neutrino oscillations, in particular, to search for the oscillation of muon-type neutrinos to electron-type neutrinos. If these oscillations can be observed then the experimenters may be able to determine the mass ordering of the neutrinos and to observe Charge Parity (CP) violation in the neutrino sector. Determination of the mass ordering is a unique contribution made possible by NOνA's very long baseline.

1.4 QAP Elements

This QAP is based upon the following principles. That quality is assured and maintained in an integrated, effective manner with management support in all aspects such as planning, organization, resources and control. Workers are responsible for achieving and maintaining quality with help through assessments and corrective action. Management and workers work together to minimize the impacts on ES&H, while maximizing reliability and performance.

The major elements of the NOνA QAP address the project's management, performance and assessment. The key QA management elements of the project are the QAP itself, the qualification and training of personnel, the quality improvement process and documentation. Performance elements include work processes, design, procurement and acceptance criteria. The assessment elements include assessments by project management and by independent sources. The implementation of each of these QA elements is described in the following sections.

2 MANAGEMENT

This section describes the implementation of QA in the management of the NOνA project. The Directorate approves HEP experiments and allocates funds to provide the facilities, personnel, and equipment required to achieve successful completion of this mission. The NOνA Project Office is responsible for ensuring the quality of the support mechanisms, all FNAL fabricated items and non-FNAL supplied items that may have an operational impact or an Environmental, Safety, and Health (ES&H) impact. The Project Manager must ensure that the Project structure and organization are appropriate for effectively carrying out this mission.

2.1 Quality Assurance Program

This Quality Assurance Program is approved by the NOνA Project Manager and is implemented through the policies set forth in the Project Execution Plan (PEP)[i] and Project Management Plan (PMP)[v] for the NOνA project. This QAP is reviewed at least annually by NOνA Project Management, and revised with the approval of the NOνA Project Manager.

2.1.1 Organization

The NOνA Project is composed of the Project Management Office and a supporting structure organized according to the Work Breakdown Structure (WBS) assigned to the Project and listed in the main body of the NOνA PMP. The Project Manager maintains an organization chart. General descriptions of the primary functions for the groups are also found in the Project Management Plan. Level 2 Managers set QA goals and objectives pertaining to their work environments and periodically assess progress toward them. Regular NOνA meetings (NOνA Technical Board, Integrated Project Team, Working Group, L2, and Engineering meetings etc.) and the resource-loaded schedule are the main tools for planning, scheduling and providing resources for work.

2.1.2 Roles, Responsibilities, and Authorities (RRA's) for Quality

RRA's for Quality flow down through the Project as outlined in the Fermilab Quality Assurance Policy, Section 10 of the *Director's Policy Manual.* The Project Manager assigns the QA/QC function to the appropriate manager for the NOνA Project. Stop Work Authority related to quality of work has been delegated to all management and supervisory personnel within the Project. They are authorized and expected to halt unsatisfactory work being performed by any of the individuals or organizations reporting to them. The relevant Division Head and Project Manager may specify other stop work authority outside of the normal management chain at their discretion.

2.2 Personnel Training and Qualification

2.2.1 Scope

The Project supports Fermilab efforts with respect to personnel training and qualification, and understands that maintaining a trained and qualified work force is instrumental in ensuring the quality of products and services provided by the Project. This section describes the responsibilities and requirements necessary to provide the Project with qualified personnel who possess the appropriate level of skill, experience, and academic qualifications to support the achievement of the Project mission and performance objectives.

The Project Manager requires that all Project personnel be trained and have the appropriate experience to ensure that they are capable of performing their assigned work in a safe and efficient manner. This training must reflect the fact that the Project's scope of work involves the collaborative effort of personnel who have widely divergent levels of education, skills, and experience. It is the responsibility of the Project Manager and/or Project Leaders to have adequate verification methods in place to assure that only properly trained, qualified, and certified personnel are involved in the design, manufacture, and installation of components.

The roles and responsibilities of the Technical Board, as well as the responsibility for assigning personnel to team positions, are described in the PMP. As head of the Technical Board, the NOνA Project Manager appoints Level 2 subsystem managers, who assume responsibility for all aspects, including QA, of these subsystems at Level 2 of the Work Breakdown Structure (WBS) as shown in the PEP.

Fermilab employees and NOνA collaborators working at Fermilab receive training in accordance with Fermilab policies.[vi] Personnel conducting work at collaborating institutions are trained in accordance with the policies of those institutions. Where special safety or technical training is necessary, this is specifically stated in a Memorandum of Understanding (MOU) between Fermilab and the institution.

2.2.2 Education and Qualifications

Line management will ensure that assigned personnel have the appropriate level of qualifications. Qualifications may be job related experience or skills; technical and/or professional society certifications; formal education; or any combination thereof.

The education that is required for obtaining a university/college degree (or other professional certification) constitutes qualification for working within the discipline in which the degree was granted. Equivalent work experience and technical activity in a related discipline may also constitute acceptable qualifications.

2.2.3 Specific Job Related Training

When it is determined that an employee needs specific job related training in order to effectively and efficiently carry out duties that are assigned, training will be made available to the employee. In-house training will be provided to ensure that an appropriate level of skills, knowledge, expertise, and experience are available to accomplish stated mission and objectives. Training may come from several sources such as mentoring, or be provided by physicists, engineers, supervisors, lead personnel, consulting firms, QA personnel, ES&H personnel, and/or other sources.

In order to ensure that training skills are maintained at an appropriate level, an Individual Training Needs Assessment (ITNA) is required for Fermilab employees on an annual basis or whenever a change in job assignment and/or job hazards occurs. The training needs assessment is be performed and reviewed with each Fermilab employee in conjunction with the Fermilab Employee Performance Review process. This shall include a review of employee training needs with respect to the work the employee is expected to perform or hazards to which the employee would be exposed during the normal performance of the assigned job. Fermilab Users will also require training depending on their activities. Examples include radioactive source training and crane and forklift training.

Managers are chosen for their technical and communication skills. The Project does not specify any further training or education for these personnel beyond what they initially bring to their positions. However, the Project Manager may also require further technical training for key personnel.

2.3 Quality Improvement

2.3.1 Scope

The NOνA Project Manager has the overall responsibility for effecting quality improvement throughout the project and is supported in this effort by the Technical Board. At the project level, the Technical Board takes steps to detect and prevent quality problems, identify the cause and correction of quality issues, and provide for improvement. At the subsystem level, these responsibilities devolve onto the Level 2 Managers. The Level 2 Managers are responsible for developing and documenting processes, making technical specifications for subsystem elements and carrying out QA procedures to ensure that products and procured items conform to these specifications.

As always, achieving quality is a line responsibility. The Project encourages personnel to eliminate problems and improve performance. Managers are encouraged to use statistical methods or other management tools to help make the decisions necessary to improve quality for their operations. These methods may serve as a basis for trending, for continuous quality improvement from lessons learned, or to help foster a positive attitude toward quality initiatives. Managers are also encouraged to document non-conformances and identify, analyze, resolve, and follow up on recurring problems.

The Project has a strong commitment to continuous quality improvement in all areas and activities for which it is responsible. All levels of personnel are encouraged to report performance problems and maintain a "no fault" attitude toward individuals identifying concerns. Stop Work Authority related to quality of work is described in Section 2.1.2. The objective is to identify a problem, to promptly report it to the appropriate level of management for corrective action, and for management to take the necessary corrective action commensurate with the programmatic significance or importance of the problem.

2.3.2 Identification/Reporting of Concerns and Non-conformances by Employees

A series of regular meetings have been established to allow employees to report and discuss performance problems. Project management has regularly scheduled weekly meetings to assess the progress of Project initiatives. Level 2 and 3 Managers present status reports at these meetings and free and open discussion of concerns is encouraged. Lessons learned are thus disseminated and are also utilized for additional feedback concerning quality improvements. Each Project group has its own methods for evaluating problems and performance. These include regular meetings and discussion by appropriate supervisory and technical personnel.

Within NOνA production facilities, a Traveler will accompany each component through the assembly process. These information packets are used to identify, report, correct, and trend non-conformance situations adverse to quality detector performance. The Travelers will contain whatever historical information accompanies the equipment, list the specified operating parameters, and provide a place for testing results to be entered. The test results and certifications will then be compared to the required specifications and a determination will be made as to the final use or disposition of the item. It should be noted that testing and verification for performance within proper operating parameters will occur multiple times throughout the construction process as was the case during past detector construction projects. This multi-tiered testing approach will ensure that improperly installed, faulty, or failed components are detected at the earliest possible opportunity and allow immediate remedial action to be taken without jeopardizing or negatively impacting detector operation.

2.3.3 Documentation and Reporting

Quality non-conformances identified during operations, inspections, and design reviews shall be documented as appropriate. For problems with Fermilab-procured items and services, the Business Services Section (BSS) Procurement Department should be provided with details regarding non-conformances as specified in Section 3.3.4, Verification of Acceptable Quality.

Quality non-conformances for products and services procured outside of the Fermilab system are to be reported to the Project Manager by the appropriate Level 2 Manager. Procured items that do not meet Project specifications must not be used. It is the responsibility of the organization that received the items to properly segregate the material and decide on its final disposition.

2.4 Documents and Records

2.4.1 Document Control

The Project determines which records require document control as part of the Configuration Management Program[vii]. These records are controlled for reasons of personnel safety as well as for legal and/or historical purposes. These and other documents are maintained in a document database, DocDB.[viii] DocDB was developed for the BTeV Project at Fermilab and is supported by the Fermilab Computing Division. This database is accessible via the World-Wide Web and is password-protected. Depending on their sensitivity, documents may or may not be accessible to the public and may even have restricted access within the project. Access to and support for NOνA DocDB is negotiated in an MOU between the NOνA Project and the Fermilab Computing Division.[ix] The Computing Division maintains the software, administers the computing platforms and performs backups of the database. Through this database, each project document is assigned a unique identification number and its versions are tracked by date and submitter, with a record of the changes made. Early versions and drafts remain accessible.

DocDB is also used to maintain records of various meetings within the project. The organizer of the meeting defines it as an event and the participants submit presentations, background documents and minutes. The database can provide links to previous meetings so that reference documentation is available on-line. Examples of meetings maintained in this way include the weekly NOνA general meeting and the Off-line Meeting as well as full meetings of the NOνA Collaboration, held approximately quarterly. Meetings of more specific interest, e.g., technical meetings on development of software or subsystems, are also documented in the database as appropriate. Such meetings, or series of meetings, are scheduled *ad hoc* by the appropriate subsystem manager.

DocDB will be used in the same way to organize project and ES&H reviews. Review presentations, reports and findings will be maintained, as well as the implementation status of review recommendations or corrective actions. Non-conformance documentation is covered in Section 2.3.3.

2.4.2 Records Retention and Disposition

Records produced within the Project must be retained. A disposition schedule must be created and maintained in accordance with Fermilab guidance. Examples are the Technical Design Report (TDRs), Project procedures, Basis of Estimate (BoE) documents, survey results, non-conformance reports, design drawings, QA Travelers, etc. Records that are not forwarded to Fermilab as part of component shipments are not subject to Fermilab requirements.

3 PERFORMANCE/CRITERIA

3.1 Work Processes

3.1.1 Work Process Control

The ultimate goal of work processes on the NOνA Project is to construct neutrino detector systems that will, in their final configuration, meet the technical and scientific objectives of the project. These objectives are specified in [i] and [ii]. Descriptions of the systems that will meet these objectives are described in the NOνA TDR. The Project Manager, with the support of the Technical Board, coordinates work on the project to ensure that the work is performed to these specifications. The specifications are prepared and, if necessary, revised by the Level 2 Managers. The Level 2 Managers, with support from the Technical Board, identify the appropriate technical and safety standards to be applied in the system and maintain a schedule and budget for producing it. With the advice of the NOνA Collaboration, which includes scientists and engineers who have experience in the production of detectors for high energy physics experiments, the Level 2 Managers select the appropriate components, tools, materials and configuration for their subsystems. The project includes an extensive research & development phase for the purpose of making appropriate tests, establishing controls, and ensuring proper calibration.

Work done at Fermilab is performed in accordance with Fermilab policies and procedures and in conformance with Fermilab's Integrated Safety Management (ISM) program.[x] To address ES&H issues specific to NOνA, the project has developed the NOνA ISM Plan.[xi] Work done at collaborating institutions is performed in accordance with the policies and procedures of those institutions, as well as the NOνA ISM Plan. All Level 2 work processes, including those performed off-site, are reviewed by the Technical Board to ensure that an appropriate level of safety and quality is achieved. As necessary, work processes are also reviewed by the NOνA ES&H Review Committee (see *Independent Assessments*).

Work performed by collaborating institutions is specified in a Memorandum of Understanding between the institution and Fermilab. This MOU is supplemented annually by a Statement of Work (SOW), which specifies the work to be done, resources to be provided by Fermilab and other sources, personnel to be provided by the institution, milestones for the work and deliverables for the project.

The Project Manager requires that each Level 2 and 3 Manager develop means for analyzing work processes to determine if the work is sufficiently complex or hazardous to be performed to written procedures. The responsibility for determining which work processes require procedures rests with the Department Head or Group Leader responsible for the activity.

The Project Manager requires that each Level 2 and 3 Manager strive to maintain an effective and efficient work force. The Project attempts to appropriately utilize personnel skills in the assignment of work responsibilities. Ensuring that the Project successfully meets its objectives is accomplished by assigning personnel to particular tasks that have the appropriate skills, experience, academic qualification, or professional certification to complete the work. The Project relies on line management to monitor activities to successful completion and to take necessary steps to incorporate added expertise and effort when indicated.

3.1.2 Maintaining Items to Prevent Damage, Loss or Deterioration

Items for the NOνA Project will be secured as appropriate, using the graded approach, based on cost, risk and schedule implications. They will be secured and stored in conditions appropriate to minimize damage, loss and deterioration.

3.1.3 Measuring and Test Equipment (MTE) Calibration

The necessity for calibration and control is dependent upon the application and criticality of the equipment. The Project Manager requires that each Level 2 and 3 Manager analyze their work process measuring and test equipment to determine the appropriate calibration requirements and develop an effective program for the necessary calibration activities. In cases where industry standards exist, these standards are applied and the test equipment is used and maintained in accordance with such standards. In cases where the acceptance criteria are based on the particular requirements of the NOνA experiment, industry standards may not exist and test procedures and equipment must be designed and fabricated specifically for these items.

3.2 Design

The technology of the NOνA Project is based upon designs that have been used successfully in previous similar experiments.[xii] The project includes a Research & Development phase aimed at optimizing these technologies in beamline components and detectors that will achieve the specific technical and scientific objectives of the NOνA experiment. The Level 2 Managers are scientists and engineers who are experienced in applying the engineering principles needed to produce beamline components and detectors. They are supported by the project mechanical and electrical engineers, who assist in developing and reviewing project designs.

3.2.1 Scope

Equipment designed by Project personnel follows federal codes; the *Fermilab Environment, Safety and Health Manual*; Laboratory standards; and accepted industry standards. Applicable engineering standards are cited in the Fermilab Engineering Standards Manual.[xiii] This includes technical instructions and national standards or other codes. Standards and guidelines related to safety are found in the Fermilab ES&H Manual (FESHM)[xiv]. All work is performed in accordance with Fermilab's "work-smart" standards[xv], which are mandated in Fermilab's contract with the DOE. Relevant personnel are required to incorporate sound engineering and scientific principles and appropriate technical standards into designs to ensure that they will perform as intended.

3.2.2 Design Interface

In some cases, the Project relies on organizations outside of Fermilab to generate complete design packages. Each collaborating institution agrees to the scope of work they will undertake for the Project by means of a Memorandum of Understanding (MoU) and specific Statement of Work (SOW). These documents are generated and kept on file by the Project Office and reviewed at appropriate times in order to keep them current. Interfaces between the subsystems include the exchange of drawings, diagrams and prototypes. The Level 2 Managers develop quality control criteria and procedures for

testing and assembly. This process may include meetings, videoconferences and technical workshops, many of which are coordinated and documented via the DocDB database.

3.2.3 Project Reviews and Operational Clearances

Engineering design review is an important component of QA. Designs undergo internal reviews for technical scope, cost, schedule and safety. These reviews are done using a graded approach, with larger review groups for more critical systems. The internal reviews are preparatory for external reviews by the Fermilab Director and the DOE. Hazard assessments are performed by the Project at the initial design stages. The information from these hazard assessments is used to determine what reviews are necessary for the beamline and experimental apparatus. These are also used to develop the Operational Readiness Clearance (ORC) checklists for the Project and the Accelerator Readiness Review (ARR) checklists for the Accelerator and NuMI Upgrades portion of the Project. The Project must have an ORC completed, signed, and accepted prior to start-up and the accelerator and beamlines must have an ARR completed, signed, and accepted prior to commissioning with beam.

The Project Manager may commission ad hoc technical review panels from within the Laboratory or the NOνA Collaboration to review experimental apparatus when the need arises. The Project Manager also has the option to request assistance from the Laboratory Safety Committee for equipment reviews involving resources outside of the Project. Examples of this would be cryogenic systems, wire targets, flammable gas systems, mechanical apparatus, etc.

3.3 Procurement

3.3.1 Scope

This section describes the Project's program to ensure that procurement practices are in accordance with established Fermilab policies. Collaborating universities are only bound to Fermilab's procurement requirements in cases where Fermilab actually participates in the procurement process. The Fermilab Business Services Section has appointed a liaison to the NOνA Project, who advises the project on the preparation of major procurements. Subsystem managers who make procurements for NOνA as part of the work specified in an MOU or SOW may opt to do so through their home institutions. Such procurements are made in accordance with the procedures of that institution. In such cases, the procurement method is specified in the MOU or SOW.

Accelerator, beamline and Detector components are fabricated specifically for NOνA by either commercial vendors, other Department of Energy Laboratories, member universities within the NOνA Collaboration, Fermilab owned facilities, or some combination of the above. The items manufactured may be individual components, detector sub-assemblies, or a complete piece of equipment being installed as part of the Project. All components must be fabricated to pre-determined design specifications that will allow them to operate properly when integrated into the total system. Agreements will be in place with each vendor that explicitly states the operating parameters of the piece or pieces they construct. These agreements will also assign the responsibilities for testing and verification of the final product.

Procured items must meet established requirements and perform as specified. In some cases, random testing of a certain percentage of components will be performed and documented by an independent

organization. In the event that non-conforming items are discovered, they will be documented and controlled to preclude inappropriate use until compliance with the applicable technical requirements is demonstrated. Vendor qualifications are reviewed as part of the bid process and are taken into consideration prior to bids being awarded. Vendor site visits may be conducted periodically throughout the duration of the fabrication contracts to ensure quality requirements are understood and being adhered to properly. Electronic systems should have, as an essential part of their deliverable, a fully documented testing and troubleshooting procedure.

3.3.2 Equipment and Services Procurement

The NOνA Project procurement guidelines follow the *Fermilab Procurement Policy and Procedures Manual*. This manual, produced and maintained by the Business Services Section, includes instructions for the preparation of purchase requisitions and dictates responsibility for review and approval.

The Project Manager and the Project Budget Officer have established levels of signature authority for purchase requisitions written against Project cost accounts. The Project is responsible for transmitting this information to the Procurement Department and for monitoring proper conformance to the pre-determined signature levels. A review by various Project personnel may be required, depending on the dollar amount and/or type of purchase requisition or task order.

3.3.3 Budget Activity and Documentation

Budget activity and change control for the Project is handled in accordance with the approved Project Execution Plan (PEP) and Project Management Plan. The Financial Project Accounting System (PA) in use by Fermilab allows individual cost accounts to be established, where necessary. The Project Budget Officer has the responsibility for establishing the proper cost accounts. PA is also used to track and monitor such expenses as charge-backs from other Divisions/Sections, and other Fermilab related costs. At the successful completion of each project phase or WBS task, the Project Manager or designated representative is required to verify that work was performed and completed in accordance with acceptable standards before final payment is authorized by the Business Services Section.

3.3.4 Verification of Acceptable Quality

At all levels of the Project, QA of purchased material is the responsibility of the requisitioner. Parts and equipment ordered for use must include exact specifications where necessary. This may be achieved by including exact specifications on the purchase requisition and/or by using a Sole Source document. If the materials received do not meet the specifications detailed in the original requisition, then the requisitioner must notify Purchasing to resolve any discrepancies. If unacceptable parts are discovered through the normal course of use, Purchasing must be informed of the problem. Purchasing will notify the vendor involved and bring the situation to final resolution. Departments are encouraged to document QA non-conformances that may have a negative impact on system performance (see Sections 2.3.2 and 2.3.3).

3.4 Inspection and Acceptance Testing

3.4.1 Requirements

The implementation of inspection procedures and establishment of acceptance criteria are important elements of QA on the NOνA Project. This applies both to items that are procured and those that are fabricated within the Project. The Level 2 Managers assume the chief role in this process. Contracted work, purchased equipment, or items produced in Fermilab shops requiring formal inspection and acceptance testing must be identified. When an inspection or acceptance test is to be performed, the inspection techniques to be used will be defined by the testing group. Testing requirements and techniques may be referenced in the resource loaded schedule, a procurement contract, a Memorandum of Understanding, or a Hazard Assessment document. Level 2 Managers are required to identify essential safety items or systems that require formal inspection and testing.

3.4.2 Establishment of Acceptance Criteria

The Level 2 Managers develop the acceptance criteria using technically and scientifically defensible methodology. This may include Monte Carlo simulations of physics events, industry-recognized standards (e.g., ANSI), or other considerations of the detector design. For example, simulations stipulate the light yield from muons at the far end of the PVC modules. To accomplish this, the mineral oil that is the primary component of the blended liquid scintillator must have a sufficiently long attenuation length for light at 425 nm; the WLS fibers must have a long attenuation length in order to transport captured light to the APDs; the APDs must have a high quantum efficiency in order to convert a sufficient number of photons into an electrical signal. In each case the Level 2 Manager, supported by the Project Engineers and members of the NOνA Collaboration with appropriate experience and expertise, establish the acceptance criteria for items that are procured from vendors or fabricated as part of the project. Managers must ensure that the documentation for items that require inspection and acceptance testing is maintained in accordance with the appropriate DOE records retention schedules.

3.4.3 Development of Test Equipment

In cases where industry standards exist, these standards are applied and the test equipment is used and maintained in accordance with such standards. In cases where the acceptance criteria are based on the particular requirements of the NOνA experiment, industry standards may not exist and test procedures and equipment must be designed and fabricated specifically for these items. One such example is a custom device for quickly measuring the attenuation length of WLS fiber. These and other test stands and devices are developed by the Level 2 Managers, supported by the Project Engineers, members of the NOνA Collaboration and, as appropriate, members of the Fermilab ES&H staff.

The acceptance criteria and test designs are considered in meetings and reviews (see *Management Assessment*) and receive feedback from the Technical Board.

3.4.4 Test and Acceptance Procedures

The Level 2 Managers develop testing procedures for items that are procured or fabricated for their subproject. The level of detail in documenting these procedures is commensurate with the complexity

and scope of the testing. Where appropriate, test procedures are reviewed by the NOνA ES&H Review Committee. (Also see Section 3.3.4 Verification of Acceptable Quality.)

4 ASSESSMENT

4.1 Project Management Assessments

The Project Manager prepares a monthly report summarizing the status of the project. The requirements for the monthly report are specified in the PMP. Each Level 2 Manager submits a summary of their work for assessment by the Project Manager. The final report is submitted to the Fermilab Associate Director for Research and the FPD.

Level 2 subsystems within the NOνA Project are discussed and reviewed by the Technical Board during the research & development phase through weekly Technical Board Meetings. These meetings encompass the scope, technical specifications, procedures, budget, schedule and safety of the plans for constructing the subsystem. L2 Managers frequently hold regular meeting to cover all of the above issues also. A graded approach is then used to determine which subsystems need a more formal review as described below.

Additional reviews and workshops may be organized on an *ad hoc* basis for selected technical systems and components, e.g., electronics cards or software. Such reviews are organized by the NOνA Project Manager and may include the project engineers, the Level 2 Manager(s), and technical experts from the NOνA collaboration and Fermilab staff.

In addition, the Project Manager has the authority to form an ad hoc review team to investigate quality assurance or quality control non-conformances if the need arises. These formal reviews would be conducted and documented in the Fermilab ES&H Database and Tracking System (ESHTRK).

4.2 Independent Assessments

Independent assessment of the NOνA Project comes from several sources. Some of these are other neutrino experiments at Fermilab. Like NOνA, the MINOS and MINERνA experiments hold approximately quarterly collaboration meetings. The three experiments will share the same neutrino beam and have a number of interdependent physics goals. The NOνA Co-spokespersons, or their designee, typically present the status of NOνA at the collaboration meetings of its sister experiments, providing valuable feedback on physics and technical issues.

This QA Program is part of the overall project implementation and is assessed as part of the planned reviews conducted by the Directorate and selected DOE representatives. It is the responsibility of the Project Manager to ensure the information necessary for the review is available and that knowledgeable personnel are available to present the material to the review committees. The Project Manager is also charged with responding to findings from the independent assessments in accordance with schedules established by the reviewing body and taking action to correct any deficiencies identified by the independent assessments.

The NOνA ES&H Review Committee is appointed by the Particle Physics Division (PPD) Head to ensure that the project complies with Fermilab ES&H requirements. The NOνA ES&H Review Committee is composed of experts in areas such as mechanical and electrical engineering, fire protection, radiation and other potential hazards encountered in high energy physics experiments and accelerators. This committee participates in design reviews, reviews of procedures and inspections of test stands and experimental facilities. PPD requires an ORC for assembly or operation of experimental facilities, including test stands. As appropriate, the NOνA ES&H Review Committee will recommend whether to grant an ORC or partial ORC for such activities on NOνA. AD requires an ARR before allowing commissioning of a beamline with beam. The NOνA ES&H Review Committee will provide input to the ARR Committee.

5 IMPLEMENTATION

Quality Assurance begins at project conception and runs through every phase of the project. The implementation of this QAP will evolve as the project proceeds. For example, the aspects that are most important in the research & development phase may receive less emphasis in a later phase of the project and *vice-versa*. In this sense, the implementation of QA on NOνA is tailored. As the project progresses, designs and procedures may change and the QA process will adapt with them to remain an integral part of the project. Conversely, QA concepts outlined here provide guidance for changes in design or process. This synthesis of QA and process helps to ensure the level of product and performance quality necessary to accomplish the technical and scientific objectives of the NOνA Project.

6 REFERENCES

[i] NOνA Project Execution Plan, NOνA-doc-130
[ii] NOνA Project Management Plan, NOνA-doc-129
[iii] NOνA Conceptual Design Report, NOνA-doc-536
[iv] NOνA Technical Design Report, NOνA-doc-1145
[v] NOνA Project Management Plan, NOνA-Doc-129
[vi] Fermilab Director's Policy Manual, Chapter 19, Training
[vii] NOνA Configuration Management Plan, NOνA-doc-131
[viii] BTeV Document Database Design and Interface, BTeV DocDB 140
[ix] Memorandum of Understanding between the NOνA Project and the Fermilab Computing Division (to be negotiated)
[x] Fermilab Environment, Safety & Health Manual
[xi] Integrated Safety Management (ISM) on NOνA, NOνA-doc-1925
[xii] MINOS Technical Design Report, MINOS-doc-337
[xiii] Fermilab Engineering Standards Manual,
http://www.fnal.gov/faw/resources/engineeringstandards/engineeringstandards.htm
[xiv] Fermilab Environment, Safety & Health Manual,
http://www-esh.fnal.gov/pls/default/esh_home_page.page?this_page=800
[xv] Report on the Fermilab Pilot ES&H Necessary & Sufficient Closure Process