Technical Scope of Work

between the

NOνA Experiment (E-929) and

Fermi National Accelerator Laboratory

Draft 1: June 17, 2013

1 NATURE OF THIS DOCUMENT

This is a Technical Scope of Work (TSW) between Fermi National Accelerator Laboratory and the NOνA Experiment. This TSW is intended solely for the purpose of providing a framework in which the roles and responsibilities of various organizations of Fermilab and the participating institutions can be stated. It reflects arrangements that currently are satisfactory to the parties; however, it is recognized and anticipated that changing circumstances of Laboratory budgets and organizations, as well as the evolving research program, will necessitate revisions. The parties agree to negotiate amendments to this TSW as needed to accommodate such adjustments.

2 INTRODUCTION

Fermilab experiment E929, the **N**uMI **O**ff-Axis ν_e **A**ppearance Experiment (NOνA), seeks to make precise measurements of neutrino oscillations, with particular emphasis on the $\nu_\mu \rightarrow \nu_\mu$ and $\nu_\mu \rightarrow \nu_e$ channels. To do this, NOνA will study the interactions of the NuMI neutrino beam in two locations: the NOνA underground cavern at Fermilab, about 1 km from the NuMI target and the NOνA Far Detector Laboratory near Ash River, Minnesota, 810 km from the NuMI target. Both of these locations are located approximately 14 mrad off the NuMI beamline in order to produce a narrow band beam from pion decay near the first oscillation maximum. The neutrino oscillations over the long baseline are studied by comparing the differing observed interactions in the two detectors.

The NuMI beam is produced by extracting protons from the Main Injector and transporting them down the NuMI beamline. The protons are focused onto a production target. A set of magnetic horns focuses the secondary particles, mainly pions and kaons, into a decay pipe 677 m long. The meson decays in this region produce a neutrino beam comprised of mostly muon-type neutrinos. A hadron absorber and rock barrier upstream of the NOνA underground cavern absorb the charged particles, leaving a beam composed only of neutrinos.

The two NOνA detectors are of an identical "totally active" design, consisting of PVC extrusions filled with liquid scintillator. The extrusion cells are 6.6 cm thick in the beam direction and have transverse dimensions of 4 cm by 15.4 m for the far detector and 4 cm by 3.85 m for the near detector. The cells are arranged in planes with the long direction alternating between vertical and horizontal orientation. The far detector will consist of 896 planes, with each plane containing 384 cells. The near detector will consist of 192 planes with each plane containing 96 cells. In addition, the downstream end of the near detector will contain a "muon catcher" consisting of a ten-layer sandwich of 10 cm iron plates, each followed by a vertical and horizontal layer of liquid scintillator cells.

Light emitted by ionizing charged particles in the liquid scintillator cells will be collected by a U-shaped wavelength shifting fiber in each cell. Light from each fiber is detected by an avalanche photo diode (APD). Signals from the APDs above an adjustable threshold are continuously output to the data acquisition system (DAQ), which sends them to a

computer farm where beam, data-driven, and random triggers select segments of the data to be written to permanent storage.

3 PERSONNEL AND INSTITUTIONS

The NOνA collaboration includes approximately 150 Ph.D. physicists and graduate students from 35 institutions in 7 countries, Brazil, the Czech Republic, Greece, India, Russia, the United Kingdom and the United States. Institutions may be added or removed by the NOνA Institutional Board, in accordance with the NOνA Collaboration Bylaws.[1]

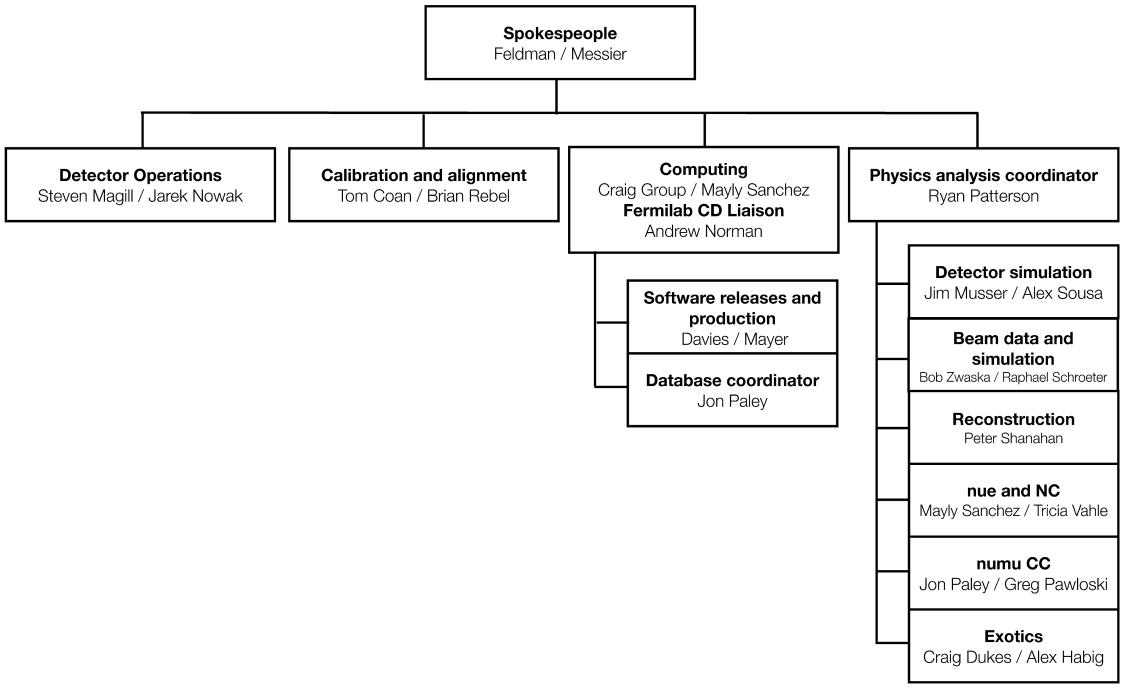
The scientific leadership of the NOνA collaboration consists of two co-spokespersons, as described in the bylaws. The co-spokespersons are elected for staggered two-year terms by the entire collaboration. Although this TSW is signed by the co-spokespersons holding office at the time of its completion, future co-spokespersons are expected to abide by its stipulations unless otherwise negotiated with the Laboratory.

The co-spokespersons are advised by an Executive Committee, which has 8 elected members and a number of ex-officio members.

The experimental activities of the NOνA experiment are implemented by physics infrastructure groups and physics analysis groups. These groups are created when needed by the spokespersons and the group conveners are appointed by the spokespersons. The organization of these groups at the time of writing this TSW are shown in the figure below.

Steve Magill, listed in the Director Operations box is presently the NOνA Run Coordinator. He is responsible for daily coordination and direction of activities involving the NOνA detectors, as well as daily liaison with Accelerator Division personnel responsible for the NuMI beamline.

The spokespersons meet as needed with representatives of the Fermilab Divisions and Sections, usually including the head of the PPD/Neutrino Dept., the head of the Accelerator/External Beam Dept., and the designated Liaison of the Computing division.



The collaborating institutions on the NOνA experiment, at the time of the writing of this TSW are listed below.

Academy of Sciences of the Czech Republic
Argonne National Laboratory
Banaras Hindu University
California Institute of Technology
Charles University in Prague
College of William and Mary
Czech Technical University
Fermi National Accelerator Laboratory
Harvard University
Indian Institute of Technology, Guwahati
Indian Institute of Technology, Hyderabad
Indiana University
Institute for Nuclear Research, Moscow
Iowa State University
Lebedev Physical Institute
Michigan State University
Panjab University
Southern Methodist University
Stanford University
Tufts University
Universidade Federal de Goias
University of Athens
University of Cincinnati

University of Delhi
University of Hyderabad
University of Jammu
University of Minnesota, Crookston
University of Minnesota, Duluth
University of Minnesota, Twin Cities
University of South Carolina
University of Sussex
University of Tennessee
University of Texas, Austin
University of Virginia
Wichita State University

4 EXPERIMENTAL AREA, BEAMS AND SCHEDULE CONSIDERATIONS

4.1 Locations

The NOνA near detector operates in the NOνA underground cavern near the downstream end of the NuMI tunnel, approximately 100 m underground. NOνA experimenters access the cavern by means of the elevator in the MINOS service building. All NOνA experimenters who work in underground areas receive the appropriate training. In general, NOνA experimenters who go underground work in the NOνA underground cavern and their activities will be in the areas downstream of the MINOS shaft. Except for occasions when it is necessary to access the muon alcoves, they go no farther up the tunnel than the "elephant" doors to the NuMI Absorber bypass tunnel. These doors separate the regions of the NuMI facility that are the responsibility of the Particle Physics Division (downstream) and the Accelerator Division (upstream).[2]

The NOνA experiment is operated from the Intensity Frontier Control Room in Wilson Hall, which is located in the northwest corner of the 12th floor, or from approved remote sites. When NOνA is the primary user of the NuMI beam, it will have experimenters on shift 24 hours a day. When NOνA is not the primary user of the NuMI beam or the beam is not operating, the shift schedule may be adjusted or suspended.

The NOνA Far Detector Laboratory is located near Ash River, Minnesota. It is operated under a cooperative agreement with the Department of Energy.

4.2 Beam Requirements

The NOνA experiment uses a neutrino beam produced by extraction of protons from the Main Injector at 120 GeV/c into the NuMI beamline. The extraction is made with a set of fast kicker magnets. The protons are then directed into the NuMI Target Hall, approximately 40 m underground. Unlike the previous MINOS target, the NOνA target cannot be moved relative to the horns, so the only practical option to change the energy of the beam will be to modify the horn currents. The NOνA experiment plans to run in the "medium" energy beam, which, at zero degrees, peaks around 7 GeV.

4.2.1 Data Taking

In order to make precise measurements of neutrino oscillation parameters, the NOνA experiment requires high-statistics data sets of both neutrino and antineutrino interactions in its detectors. Hence, the experimental goal for each of these types of runs is to maximize the integrated neutrino flux. The requested division of time between neutrino and antineutrino run and the timing of those runs will be decided as the running progresses and will aim to maximize the physics impact of the NOνA experiment given its results and the results of other experiments.

The Accelerator and NuMI Upgrade part of the NOνA project allows for a 700 kW proton beam. This is done by slip-stacking 12 Booster batches, each containing 4.3×10^{12} protons, every 1.33 s into the Recycler, and transferring the Recycler beam in a single turn to the Main Injector.

The Accelerator Division will be responsible for setting adequate measures to provide groundwater protection in the transport of 120 GeV protons from the Main Injector to the NuMI target.

4.2.2 Schedule and Run Plan

The commissioning of the accelerator upgrades and the NuMI beamline are expected to begin in late June 2013 and take six months to complete. The full NOνA far detector is expected to be completed in July 2014.

The six-year run initial NOνA run is defined as the delivery of 3.6×10^{21} protons on target after the full 14 kt NOνA far detector is completed.

5 RESPONSIBILITIES OF COLLABORATING INSTITUTIONS

5.1 The NOνA Far Detector Laboratory

Operation of the NOνA Far Detector Laboratory will be operated by the University of Minnesota under a cooperative agreement with the DOE.

5.2 NOνA Collaborating Institutions

All of the collaborating institutions are responsible for contributing manpower for shifts and the general support of the experiment.

In addition, some institutions have key hardware and online or offline software maintenance and support responsibilities, which are further described in Appendix II.

5.2.1 Shift Responsibilities

Member institutions of the NOνA collaboration are responsible for providing shift personnel in accordance with the rules established by the NOνA Institutional Board. Shift responsibilities generally are fulfilled by shifts in the Intensity Frontier Control Room at Fermilab or at remote sites under protocols established by Fermilab for that purpose.

5.2.2 Support & Maintenance of Detector Systems

Member institutions of the NOνA collaboration may have responsibilities for detector subsystems, NuMI beamline components, or other support roles for the experiment. Such responsibilities may include but are not limited to maintenance, repair, configuration, or upgrades of hardware components or supporting software. In all cases, the development, upkeep, and distribution of documentation for a subsystem are essential parts of the support and maintenance responsibility for it.

Statements of Work (SOW), negotiated between the Fermilab PPD and collaborating institutions, are created if Fermilab funds are to be dispersed to facilitate work at the institutions. An SOW is created for a defined period (specified in the SOW) and can be renewed or modified at the end of that period.

If, for any reason, a collaborating institution is unable to fulfill its support or maintenance responsibilities as specified in a SOW, that institution shall so inform the NOνA co-spokespersons, so that the responsibility may be re-assigned.

5.2.3 Support Software

Software responsibilities are fluid and are assumed to be distributed throughout the collaboration, independent of institution.

5.2.4 Experiment Decommissioning

At the completion of the NOνA experiment, decommissioning work at Fermilab will be the responsibility of Fermilab. At NOνA Far Detector Laboratory, decommissioning of the NOνA detector will be done in accordance with a decommissioning plan developed by Fermilab and the University of Minnesota.

6 RESPONSIBILITIES OF FERMILAB DEPARTMENTS

6.1 The Accelerator Division (AD)

The Accelerator Division will be responsible for commissioning, operation and maintenance of the primary proton beam line, the target station and the hadron absorber. The line of demarcation between Accelerator Division and Particle Physics Division

responsibilities is, unless otherwise noted, the large doors just upstream of the MINOS shaft.

The Accelerator Division will also be responsible for monitoring intensity and beam quality of the primary proton beam. Overall monitoring of the primary proton beam intensity within 3% is required by the experiment.

The NOνA Experiment depends on support from a number of departments within AD. AD provides a liaison to the NOνA. The deliverables and services expected from each of these groups are described below.

6.1.1 External Beams Department

The External Beams Department is the proprietor of the NuMI beamline from the Main Injector to the hadron absorber and controls access to the muon alcoves. The department provides a Machine Coordinator who is in charge of beamline operations and serves as the point of contact for NOνA questions involving the beam. The Machine Coordinator's responsibilities concern both operational status and requests from NOνA for changes in the beamline, target station or hadron absorber. The department also provides a Beamline Physicist who aids in day-to-day operational issues and assists the Machine Coordinator as required.

The External Beams Department contains personnel expert in various elements of the design, operation and troubleshooting of any beamline, and are called upon by the Machine Coordinator as needed. In addition, budgeting and purchasing of spare equipment and changes to equipment in the NuMI target hall is coordinated by this department.

6.1.2 Controls Department

The Controls Department is responsible for the front-end computers, links, crates and control cards for the operation of all equipment from the Main Injector to the hadron absorber. These responsibilities include the hardware and software of the Beam Permit System. The Department maintains several pieces of application software for controlling beamlines, specific instances of which are used by NuMI/NOνA. It is responsible for the maintenance of the accelerator consoles in the NOνA Control Room and NuMI service buildings. It installed and maintains several Programmable Logic Controllers dealing with target chase cooling and various water systems including beamline LCW, target hall and absorber RAW and near detector cooling. The computer networking in the NuMI underground and above ground installations is also the responsibility of Controls. This department is responsible for the hardware and software of FIRUS.

6.1.3 EE Support Department

The Electrical Department is responsible for all of the power supplies needed to run the magnets of the primary beamline. It is responsible for the NuMI extraction kicker and its

power supply, the large pulsed power supply of the NuMI focusing horns and the electronic control of beamline vacuum.

6.1.4 ES&H Department

The AD ES&H Department shall have ES&H oversight responsibility for the AD areas of the NuMI facility as defined in [2]. In addition, the ES&H Department coordinates underground safety training for all NuMI/NOνA areas.

The department oversees access control to the pre-target beamline enclosure, target hall, decay pipe region, absorber hall and muon alcoves. Oversight is also provided for radiation and electrical safety in the region of the primary proton beam through various access control keys, enclosure interlocks, electrical permits to power supplies, interlocked radiation detectors, and beam inhibit critical devices.

After discussions between AD/ES&H and PPD/ES&H the following responsibilities have been assigned to the AD ESH Department:

a) Radiological shielding assessment of experimental areas;
b) Radiological surveys;
c) Oversight for handling of LCW/RAW systems;
d) Radiation and electrical interlock system related matters;
e) Participation in exposure investigations as necessary;
f) Monitoring and control of underground access at MI-65 (by controlling keys for the elevator and/or radiation areas for MI-65).
g) Monitoring and control of underground access at NOνA interlocked areas (by controlling keys for the elevator and/or hadron absorber area and muon alcoves). Access to the NOνA detector area is controlled by PPD.

6.1.5 Instrumentation Department

The Instrumentation Department is responsible for the maintenance and calibration of primary beamline monitoring devices – loss monitors, total loss monitors, BPMs and toroids.

6.1.6 Main Injector Department

The Main Injector Department is responsible for providing beam with appropriate parameters on NuMI timeline cycles. Such parameters include, but are not limited to, intensity, emittance and orbit stability. Often insufficient intensity results from conditions in the Booster, and the Booster Department must also become involved in supplying proper beam to the Main Injector.

6.1.7 Mechanical Support Department

The Mechanical Support Department is responsible for operational support and maintenance, including magnet changes, of all the mechanical equipment in the Accelerator Division controlled areas. This includes vacuum and water systems throughout the beamline as well as the decay pipe region and the hadron absorber. The department has responsibility for technical support of equipment in the target hall and associated areas, including horns, targets, RAW systems, target pile cooling and dehumidification.

6.1.8 Operations Department

The AD, via the Operations Department, is responsible for accelerating and extracting 120 GeV primary protons into the NuMI Primary Proton beamline and for maintaining the beam parameters throughout the line and onto the NuMI target. The primary beamline is controlled from the AD Main Control Room.

The Operations Department is responsible for the administration of accesses to MI65 areas, the Muon Alcoves and the Absorber, and for resecuring these areas after a Supervised Access. AD provides first response to alarms in these areas.

6.1.8 Summary of AD Responsibilities and Status

Tables 6.1 and 6.2 provide a summary of AD responsibilities and status.

Institution	System	Description of Work
Fermilab	Controls hardware	All of the links, crates, etc for operation of the beamline. The computer network in the NuMI areas and appropriate interconnect hardware
	Primary beam magnets	Spares for all types of magnets have been readied. The ones difficult to transport have been staged in the beamline area.
	Power supplies	Some spare supplies exist, and spare parts for all supplies are available.
	Vacuum equipment	Ion pump failures are addressed either by repairing or by replacing faulty devices.

	Target pile components	One spare 700 kW target is in production at Fermilab and an additional spare 700 kW target is in production at Rutherford Appleton Laboratory. Both are estimated to be complete by late summer 2013. Goals for producing the 4th and 5th 700 kW targets are August 2014 and February 2015. A spare horn 1 is in production and is scheduled for completion in late fall 2013. Parts are being procured for one additional spare horn 1. The present horn 2 has been used for previous beam runs. A spare horn 2 exists. An additional spare horn 2 is being constructed with an estimated completion date of late 2013. Parts are being procured for an additional spare horn 2. There is a work cell that an irradiated target or horn module can be placed in for observation and possible repair.
	Instrumentation	Spares are available for most types of beamline instrumentation. For a few types, repair is the only alternative.

Table 6.1 Fermilab AD Hardware Responsibilities for NOνA

Institution	**System Responsibility**	**Description of Work**
Fermilab	ACNET console software	Copies of standard beamline programs: parameter page, BPM/BLM, profile monitors, vacuum, beam permit
	Microprocessor software	BPMs, profile monitors

Table 6.2 Fermilab AD Software Responsibilities for NOνA

6.2 The Particle Physics Division (PPD)

The Particle Physics Division is responsible for the operation of the NOνA experiment and experiment-related activities at Fermilab. The PPD carries out these responsibilities through the work of several departments, including the Intensity Frontier Department, the Mechanical Department, the Electrical Engineering Department, ES&H/Building Management Department, the Technical Centers, and the Site Department. The deliverables and services expected from each of these groups are described below.

6.2.1 Intensity Frontier Department

The PPD and the NOνA experiment interact primarily through the Intensity Frontier Department. This department provides an administrative organization for the Fermilab staff working on NOνA, as well as a center for experimental operations, data analysis and future planning. The PPD provides the Intensity Frontier Department an annual operating budget. In addition to providing the funds for the operation of the Department itself, this budget also provides the funds for the operation and maintenance needs of the NOνA Detectors and those parts of the NuMI/NOνA facility for which the PPD is the landlord.

The Intensity Frontier Department provides office space for both resident and visiting NOνA collaborators. Office space provided is commensurate with the aTSWnt of time spent at Fermilab.

The PPD provides a liaison to the NOνA experiment, generally from the Intensity Frontier Department..

6.2.2 Mechanical Department

The PPD Mechanical Department provides repair services for mechanical systems in the PPD-controlled areas of the NuMI facility, as directed by PPD management.

The systems include the PPD LCW water system. The Mechanical Department will change de-ionization bottles and conduct preventive maintenance as necessary, as well as performing repair work as needed.

Materials and costs for mechanical repair work are back-charged to the NOνA operations budget. The Intensity Frontier Department will request such support as needed.

6.2.3 Electrical Engineering

The PPD Electrical Engineering Department played a key role in developing the NOνA electronics and continues to provide support for them, including the DCM modules and timing units.

6.2.4 ES&H/Building Management

The PPD ES&H Department shall have ES&H oversight responsibility for the PPD areas of the NuMI facility as defined in [2].

The PPD ES&H/Building Management Department has drafted an TSW with the AD for the coordination of ES&H issues. That TSW specifies responsibilities for PPD that include:

a) Communication of pertinent ES&H issues to NOνA Spokespersons;
b) Maintenance of radiological postings in NOνA areas. Residual Activation Surveys are performed by AD under the terms of [2].
c) Wallflowers and friskers;
d) Identifying training requirements for experimenters;
e) Working together with AD if exposure investigations for NOνA experimenters are needed;
f) Coordinating use of radioactive sources in NOνA areas with the collaboration and the ES&H Section;
g) Shipping/receiving of radioactive items between NOνA areas and other areas on-site; the ES&H Section is responsible for handling off-site shipping/receiving of such items;
h) Monitoring and control of underground access at the MINOS service building;
i) Providing two (2) keys to the MCR for emergency and operational access to the NOνA area
j) Conduct of an appropriate safety review for any proposed upgrade to the NOνA detectors.

6.2.5 Technical Centers

The PPD Technical Centers Department comprises groups having special technical expertise, including alignment and metrology, detector support, machine development, and others. The NOνA experiment may solicit support from these groups as needed.

6.2.6 Site Department

The PPD Site Department provides maintenance and support for the NOνA underground cavern. The NOνA experiment may request additional services from the Site Department, including distribution of electrical power and rigging of items down the MINOS shaft or in the NOνA underground cavern. Such requests are subject to the approval of the Site Department Head.

6.2.7 Underground Access Coordination

The NOνA experiment shares PPD underground space with various tests and other experiments. Access to the underground areas is controlled via training, access keys, limited occupancy and badging in and out when entering or exiting the areas, respectively. Designation of rules and procedures for access to the underground areas and coordination of permits for work to be performed in the underground areas of the PPD are the responsibility of the PPD Underground Coordinator.

6.3 The Computing Division (CD)

The Fermilab Computing Division provides support to the NOνA experiment in the form of offline computing resources, data storage, networking services, and the provision and maintenance of electronics.

The CD provides a liaison to the NOνA experiment.

6.3.1 Offline Computing, Networking & Data Storage

The Fermilab CD has prepared a separate TSW for support of NOνA[3]. This TSW addresses computing support for the experiment and an estimate of the computing resources and CD manpower required.

6.3.2 Electronics Support

The Physics Research Equipment Pool (PREP) is responsible for repair and maintenance of certain electronics components, including

- High voltage supplies
- Low voltage supplies
- VME crates
- Front end boards
- Data concentrator modules
- Timing distribution units
- Power distribution boards
- Detector control system electronics

The NOνA co-spokespersons will undertake to ensure that no PREP equipment is transferred from the experiment to another use except with the approval of and through the procedure provided by CD management.

Any items for which the experiment requests that Fermilab performs maintenance and repair should appear explicitly in this agreement. There is no PREP equipment presently on loan to the NOνA experiment.

At the completion of the experiment, the NOνA co-spokespersons are responsible for the return of all PREP and Computing Division equipment. If the return is not completed after a period of one year after the end of running, the co-spokespersons will be required to furnish, in writing, an explanation for any items not returned.

The CD division is also responsible for the maintenance the EPICS system and DAQ networking and computers.

6.4 The Facilities Engineering Services Section (FESS)

FESS shall provide support to the NOνA experiment at Fermilab primarily through the FESS Operations Group and the FESS Services Group.

6.4.1 FESS Operations Group

The FESS/Operations Group is responsible for the support described in 6.4.1.1 - 6.4.1.2. FESS will administer the support work described in 6.4.1.3 on a case-by-case basis as requested by the customer, however, it is not within the FESS operational budget and this work may be back-charged to the experiment or to other supporting divisions as appropriate. This work may be performed by FESS staff or by subcontractors as appropriate and within the FESS core services.

6.4.1.1 First response to FIRUS and Metasys alarms

Response is on non-experimental equipment and systems, via the duty electrician and duty mechanic.

6.4.1.2 Preventive and corrective maintenance on included systems and equipment:

a) Electrical distribution (conventional power)
b) Sanitary and drinking water systems
c) Fire protection detection and suppression systems
d) Building Automation and Control Systems for Comfort Systems
e) Water Level Management for the NuMI Pond
f) Natural gas distribution
g) Industrial cooling water (ICW) system
h) Stationary emergency generators
i) Heating, Ventilating and Air Conditioning (HVAC)
j) Area Dehumidification equipment (on surface)
k) Exterior and interior lighting
l) Crane Inspections scheduling, notification and documentation
m) Sump Pumps
n) Emergency diesel pump at NOνA (Maintenance and operation)

6.4.1.3 Items not included in the FESS Operations budget

Although the FESS operational budget does not explicitly cover the cost of these items, FESS will work with the landlord to help schedule inspections and maintenance as necessary and assist in administering the pertinent subcontracts as requested.

a) Davis-Bacon Work
b) Construction / renovation Work
c) Initial spare parts (FESS will maintain stock levels of landlord supplied parts.)
d) Structure Maintenance
e) Costs and work beyond P.M./Minor Repair on stationary emergency generators, HVAC equipment and dehumidification equipment, and other major equipment.
f) The cost of crane inspections and repairs.

6.4.2 FESS Services Group

The FESS Services Group shall provide support at the MINOS service building. These services shall include standard janitorial services for the MINOS building itself as well as the roads and grounds in its environs. Specific services include:

a) Maintenance of the MINOS building parking lot (excluding resurfacing of the parking lot), including snow removal;
b) Assist in arrangement of asphalt repair contracts for the MINOS parking lot as needed;
c) Standard landscaping in the vicinity of the MINOS building;
d) Standard custodial services for the MINOS service building;
e) Maintenance and repair of the roof, overhead door, and glass in the MINOS service building is the responsibility of the landlord organization. Contracted services for these areas may be accessed through the T&M office managed by FESS, or by contracting directly with other contractors, or having the work completed by competent landlord employees.
f) Administration of elevator inspections with repairs at the landlord's expense.

6.5 The Environment, Safety and Health Section (ES&H)

The ES&H Section assumes the responsibilities specified here for the Fermilab site. The University of Minnesota assumes the responsibility for ES&H at the NOνA Far Detector Laboratory, although the Fermilab ES&H Section may play an advisory role there. The ES&H Section may also provide consultation services upon request from the experiment. While not specifically enumerated here, the requirements and recommendations of the *Fermilab Environment, Safety, and Health Manual* (including the *Fermilab Radiological Control Manual*) and the *Fermilab Emergency Response Plan* apply to NOνA operations.

6.5.1 Radiological Protection

The ES&H Section conducts and supports radiological monitoring in the NuMI facility and the environment as follows (the number of radiation monitors and detectors is approximate):

- Provide and maintain radiation monitors 4 “chipmunk” radiation monitors for NuMI beamline operations;
- Provide and maintain 3 portable survey meters as needed for access to certain NuMI enclosures.
- Provide and maintain 3 friskers and 3 wallflowers (or equivalent) at points of egress from radiological areas in the NuMI facility.
- Although preliminary measurements have shown no safety or health concerns due to radon, the Radiation Protection Group may conduct periodic radon monitoring in the NOνA underground cavern.
- In support of future intensity upgrades, the Radiation Protection Group will support shielding studies as needed to increase the Main Injector shielding assessment limits.
- Shipments of radioactive materials, including detector components containing radioactive sources that enter or leave the Fermilab site must go through the ES&H Section.

6.5.2 Environmental Protection

- Provide and operate 2 stack monitors to monitor airborne radioactivity in emissions from NuMI ventilation stacks.
- Conduct air release measurements for radio nuclides and perform calculations to ensure compliance with applicable regulations.
- Monitor surface water discharges for compliance with respect to the NPDES permit and other pollutants of interest;
- Monitor piezometers and sample groundwater monitoring wells for radio chemicals in accordance with NuMI Groundwater Monitoring Strategy[7];

6.6 The Business Services Section

6.6.1 Emergency Response

The Fermilab Fire Department is responsible for undertaking any underground rescue operations that may be necessary. To that end, the Fire Department will

- Maintain, test and replace as necessary the equipment necessary for underground rescue operations.
- Undergo recurrent training in underground rescue as necessary.

APPENDIX I: ABBREVIATIONS

AD:	Accelerator Division
APD	Avalanche photo diode
CD:	Computing Division
DAQ:	Data Acquisition
DCS:	Detector Control Systems
ES&H:	Environment, Safety, and Health
FESS:	Facilities Engineering Services Section
FIRUS:	Facility Incident Reporting and Utility Services
HV:	High Voltage
HVAC:	Heating, Ventilation, and Air Conditioning
ICW:	Industrial Chilled Water
LCW:	Low Conductivity Water
MI:	Main Injector
MINOS:	Main Injector Neutrino Oscillation Search
OM:	Online Monitoring
NOνA	NuMI Off-Axis ν_e Appearance Experiment
NPDES:	National Pollutant Discharge Elimination System
NuMI:	Neutrinos at the Main Injector
POT:	Protons on Target
PPD:	Particle Physics Division
PREP:	Physics Research Equipment Pool
RAW:	Radioactive Water
TSW:	Technical Scope of Work

APPENDX II: COLLABORATION INSTITUTIONAL RESPONSIBILITIES

All collaborating institutions on NOνA share responsibilities to the experiment, in particular in regards to shift responsibility and hence are not listed in this Appendix. The tables in this appendix list the member institutions with key responsibilities on the experiment as of the date of this TSW. Since membership and responsibilities evolve over time, this table will be periodically revised to reflect the current status. In the event that a system expert transfers from one NOνA collaborating institution to another, the question of whether the responsibility for that system remains with the original institution or with the expert will be decided on a case-by-case basis by the NOνA Institutional Board..

In general, defective modules and detector components will be replaced by Fermilab and collaborating institution personal resident at Fermilab for the Near Detector and by Far Detector staff for the Far Detector. Unless stated explicitly otherwise, the cost of technical assistance by university groups that is not covered by the university's base funds will be provided from NOνA maintenance and operations funds.

System	**Responsibilities**
High Voltage Supplies	Repair or replacement by Fermilab PREP.
Low Voltage Supplies	Repair or replacement by Fermilab PREP.
Power Distribution System	Repair and maintenance by Virginia.
APDs	Testing and evaluation by Caltech.
Thermal Electric Coolers (TEC)	Repair of controllers by Fermilab PREP. Technical assistance by Indiana.
TEC Cooling System	Maintenance by Fermilab PPD.
Front End Boards	Repair by Fermilab PREP. Technical assistance and firmware by Harvard.
Data Concentrator Modules	Repair by Fermilab PREP. Technical assistance and firmware by Fermilab CD.
Timing Distribution Units	Repair by Fermilab PREP. Technical assistance by Fermilab CD.
Detector Control System	Technical assistance by Tennessee.
Data Acquisition System	Fermilab PPD and CD with assistance from several collaborating institutions.

REFERENCES

[1] Collaboration Bylaws, http://www-nova.fnal.gov/NOvA_Collaboration_Information/index.html

[2] Letter from Roger Dixon and James Strait to Michael Witherell, subject: NuMI Facility, September 24, 2004.

[3] *Technical Scope of Work between the MINOS Experiment and the Computing Division*, ?, 2013.

SIGNATURES

_____	_____
G. Feldman – NOνA Co-spokesperson	Date
_____	_____
M. Messier – NOνA Co-spokesperson	Date

TBA – NOνA Financial Officer	Date
R. Dixon – Accelerator Division Head	Date
Y.-K. Kim – Acting Particle Physics Division Head	Date
V. White – Computing Division Head	Date
R. Ortgiesen – FESS Head	Date
N. Grossman – ES&H Director	Date
J. Irvin – Acting BSS Head	Date
S. Henderson – Associate Director for Accelerators	Date
Y-K. Kim – Deputy Director	Date
TBA – Fermilab Director	Date