Technical Statement of Work

MINOS+ Experiment
E-1016

Running MINOS with the medium energy NuMI beam

High-statistics studies of long baseline neutrino oscillations
with the on-axis MINOS detectors in the medium energy NuMI beam

December 1, 2013

INTRODUCTION

The MINOS+ experiment is a follow-on experiment to the MINOS experiment that took data with the low energy NuMI beam from January 2005 to April 2012. MINOS has produced some of the highest precision results on neutrino oscillation parameters in the atmospheric neutrino sector.

MINOS+ will exploit the existing MINOS detectors operating in the NuMI beam that will be commissioned with the medium energy setting for the NOvA experiment. The Near Detector (ND) of MINOS is also used as a muon spectrometer for the Minerva experiment, located just upstream of ND. MINOS+ was proposed and approved to run for three years, starting in 2013 or after the current shutdown. Both NOvA and Minerva will continue running over this period and beyond.

The MINOS+ collaboration is an international partnership including FNAL, University of Minnesota (the host of the Soudan Underground Laboratory where the MINOS Far Detector is located), US DOE and NSF funded university groups, UK, Brazil, Greece, and India.

MINOS is completing analyses of most of its data and the most up-to-date results were reported the Neutrino 2012 conference in Kyoto. Final publications are in preparation and a few analyses are being finished. The collaboration's operations have improved over the years and the data processing and analysis machinery has worked smoothly in producing physics result. With the addition of the new groups which will join MINOS+, the transition into the new running period with medium energy should be straightforward even though it will require some technical adjustments.

SCIENCE

Precise measurements of the neutrino's oscillatory behavior are notoriously difficult due to the weakness of their interactions (thus small cross sections at low energies) and low fluxes available at long distances from neutrino sources. The NuMI beam is the highest neutrino intensity beam in the world and enables neutrino studies that are impossible anywhere else.

MINOS+ will provide some of the most stringent tests of the shape of the neutrino oscillation disappearance curve. Given the new measurements from MINOS, SuperK, and T2K, which all are hinting at a non-maximal value of θ_{23}, there is renewed interest in measuring both θ_{23} and Δm^2_{atm} even more precisely. A precise value of Δm^2_{atm} at the level of 3%, which MINOS+ should achieve, will provide an important input to determining the neutrino mass hierarchy. When combined with NOvA and T2K, Δm^2_{atm} could reach a precision of 1%. MINOS+ will provide a stringent limit on sterile neutrinos in a large region of the parameter space relevant to LSND and MiniBooNE results. It will also be sensitive to non-standard neutrino interactions over a wide range of parameters. The neutrino time-of-flight will be measured to an accuracy of a few nanoseconds over the distance of 734 km between the two detectors. A search for tau neutrino appearance and continued measurements of atmospheric neutrinos will be carried out at

the Far Detector. Finally, a search for more exotic phenomena like new dimension 5 interactions and extra dimensions will also be pursued with the new data. The program is rich, unique, and complementary to the other neutrino experiments worldwide.

Experimental Design

MINOS+ has two detectors, the 1 kton Near Detector (ND) at Fermilab, and the 5.4 kton Far Detector (FD) in the Soudan Underground Laboratory in Minnesota. Both detectors are functionally identical, with 1 inch thick steel plates and 1cm thick scintillator strip planes read out via wavelength shifting fiber by Hamamatsu M16 and M64 multi-anode PMT's. The energy resolution for hadronic showers is 55%/√E, for electrons it is 22%/√E, and for muons the momentum resolution is about 12% from curvature and about 6%* from range. Both detectors have a magnetic field, with an average value of 1.2 T, which allows the identification of charged current neutrino and anti-neutrino interactions on an event-by-event basis. This feature used for the atmospheric neutrino studies makes MINOS a unique underground detector with this capability.

The experiment was in almost continuous operation for about 7 years. The light level in the scintillator strips slowly degraded, but the useful lifetime of the detectors is estimated to be at least another 5 years before the light level decreases below threshold for muon tracking. An upgrade to the DAQ will have been completed by April 2013, and will liberate ND readout processors that can be used for spares in the FD.

Technical background

The MINOS detectors are relatively simple by the standards of modern particle physics experiments and routinely operate with at most a few bad channels. Normal maintenance at the Far Detector is restricted to occasional replacements of electronics cards or PMT's. The computing systems are regularly maintained. Occasional mechanical work is required on laboratory infrastructure needed for operations of the Far Detector.

Historically the Near Detector has required more maintenance due to the complexity of its higher-rate electronics. In addition, in recent months the DAQ back-end electronics has begun to fail at an increased rate due to aging. The recycling of collider readout processors to provide a new Near Detector DAQ readout system should greatly ameliorate this problem. In any case, this Near Detector readout upgrade is not an increased cost associated with MINOS+.

Routine technical services for the MINOS detectors are funded by annual allocations within the Fermilab operations budget. The Near Detector is maintained by allocations under shared management by the MINOS and Minerva collaborations and is not an incremental cost for MINOS+. The Far Detector operations budget is determined annually and is managed as part of the Soudan Lab operations budget by allocations to the University of Minnesota through Fermilab.

Experimental Operations

There will be three main areas of operations of MINOS+: the accelerator and the beam, the Near Detector (at Fermilab), and the Far Detector (in Soudan). Below we focus on the operations of detectors - the main responsibility of the Collaboration. The Main Injector beam operations, critical to three Fermilab experiments (NOvA, Minerva, and MINOS+) are not covered in this document.

The main operations of the experiment entail detector maintenance, data acquisition, data processing, and physics analysis. The collaboration's effort is organized so all tasks that are necessary to sustain smooth operations are fully and redundantly covered by collaborating institutions and so that physics analysis produces results as quickly as possible. The collaboration structure is shown here. Below we comment on the most critical issues related to operations.

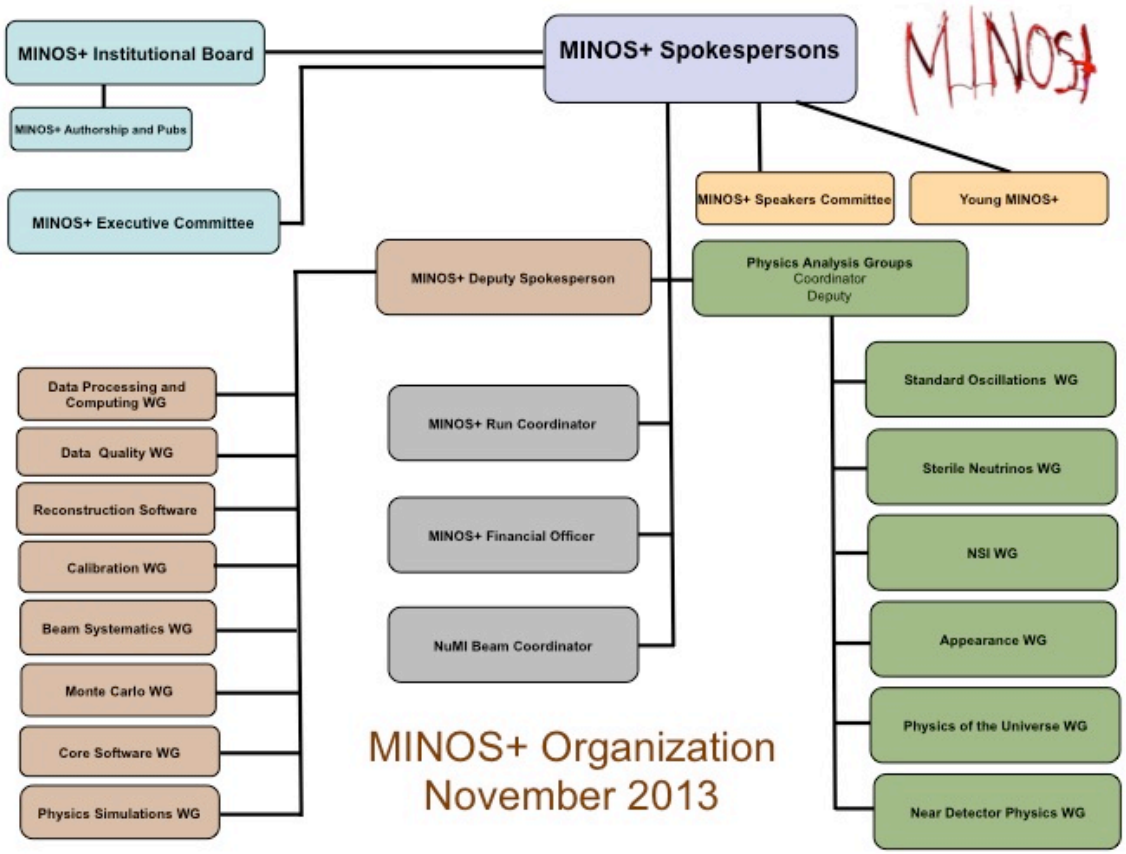

Figure 1: MINOS+ Organizational chart. Responsibility lines are discussed in text. WG denotes a term Working Group.

Near Detector maintenance

The ND electronics was designed, fabricated, and commissioned by engineers from ANL. ANL will not collaborate on MINOS+ but repairs of electronics will be possible there as they were during the MINOS running. This will also be necessary for Minerva running and is not an incremental cost for MINOS+.

The ND and its electronics are maintained by collaborators stationed at FNAL. This service is essential, and Minerva collaborators have now been trained to identify and replace bad electronics cards as well. This effort-sharing operation will alleviate the burden on both experiments in the coming years and is cost-effective.

Far Detector maintenance

The Far Detector system is maintained by the Soudan Underground Laboratory crew that works 5 days a week. Weekends and nightly access were cut for cost-saving reasons several years ago. Although this implies that occasionally the FD can be off for two days while waiting for the crew to come on shift, in practice, in the past the mine crew's commitment to the experiment has been evidenced by their willingness to intervene even on weekends. The detector has operated during the beam time with efficiency larger than 99%. Support of the crew will be the major cost driver of this experiment post FY2014, when the cohabiting CDMS detector is turned off.

DAQ

The data acquisition (DAQ) system is maintained by a combination of FNAL staff, MINOS and Minerva collaborators. The individuals rotate being on-call during periods of running. Currently, a major upgrade of the ND DAQ is underway, which will generate a considerable spares pool for the Far Detector. It is expected to be adequate for the running through FY16.

Data-taking shifts

All collaborators take shifts at Fermilab (or occasionally at Soudan) during data-taking periods. However, during the last months of MINOS running a new remote-shift protocol was developed along with technical advances (provided by the BNL collaborators) to make this possible. Remote shifts will be predominant reduce the pressure on travel budgets..

Data reconstruction and processing

These are tasks that use about 3 FTE spread over several university collaborators as well as a contribution from the FNAL CD Reconstruction is performed on the Fermilab computer farm. Some more tuning of the reconstruction will be required to run in the medium energy NuMI beam due to much higher occupancies in the Near Detector.

Monte Carlo generation

The Monte Carlo generation is predominantly done now at the University of Texas Advanced Computing Center. It is a task that uses about 0.5 FTE.

DATA PROCESSING

The MINOS+ Far and Near Detectors collect data with minimal need for user actions, typically running for many days at a time between interventions. The data rate is dominated by the rate of residual cosmic ray interactions and calibration data, generating typically 2 GByte per day. Data are locally archived at Fermilab and the Soudan laboratory and are collected even if network connectivity is temporarily lost between Soudan and Fermilab.

Data from both MINOS+ detectors are copied via the network to Fermilab's central data caching and archival systems.

Data quality checks are performed in real-time by shift personnel and daily by offline systems, including full data reconstruction. Problems in the hardware of the detector are usually detected by shift crews, however a number of subtle problems have been found by offline reconstruction checks, which also enable monitoring of long-term beam performance, such as target integrity.

All event simulations are produced off-site by collaborating institutions, and imported to Fermilab for reconstruction. Primary sites for this work are at the University of Minnesota, College of William and Mary, and Texas Advanced Computing Center at the University of Texas at Austin.

MINOS+ will use (as MINOS has) the shared Fermilab computing infrastructure, including Enstore data archives, DCache and Bluearc file caches, SAM data management, shared database servers, a few dedicated interactive and management nodes, and the Fermigrid OSG computing resources.

The necessary production computing resources are dominated by the needs to process the Far Detector data and the Near Detector data shared by MINOS and Minerva. An analysis by Computing Division liaison staff shows that the principal costs associated with MINOS+ are gradual increases in hardware resources needed to handle the integrated data load as the experiment progresses. This estimate leads to modest expenditures for CPU, disk, and tape storage, all targeted for use for MINOS+ analysis. Additional personnel costs associated with MINOS+ operations are estimated to be minimal.

Collaboration, Institutional and Partnership Roles & Responsibilities

Universities involved in MINOS+ are supported by several funding agencies including DOE, the main steward of Fermilab and Soudan Underground Lab, the UK STFC, NFS, and Brazil's FAPESO and CNPq. We are anticipating that in the future, significant effort will be provided by a consortium of universities in India. An agreement between MINOS+ and this organization is imminent.

The current membership of the MINOS+ Collaboration. There are 28 groups from five countries: US (18), UK (5), Brazil (3), Poland (1), and India (1).. Most of US groups are funded by DOE, two are funded by NSF. Institutional responsibilities are listed below.

MINOS+ Management

The MINOS+ Collaboration will be managed in a similar fashion to MINOS and according to the same bylaws developed by MINOS. The organization of the collaboration, shown earlier, outlines the main responsibility lines that are briefly discussed below:

- Spokespersons: The two spokespersons are responsible for overall scientific and personnel decisions in the collaboration. They appoint conveners of all working groups and oversee their workings. They co-chair the Executive Committee.
- Deputy Spokesperson: Responsible for organization of experiment's operational tasks (calibration, reconstruction, Monte Carlo generation, and similar). The Deputy Spokesperson is an *ex-officio* member of the Executive Committee.
- Institutional Board: Consists of one member from each institution with manpower above 1 FTE effort. It is the highest governing body of the Collaboration responsible for all rules and regulations regarding collaboration membership, publications, shift rules and any other organizational rules of the collaboration. It follows the MINOS Bylaws that have been formulated in the course of the last several years of operating MINOS. The Chair of IB is an *ex-officio* member of the Executive Committee.
- Executive Committee: Responsible for advising the spokespeople on matters of scientific nature and helps make crucial scientific policy decisions.
- Run Coordinator: Responsible for executing the run plan set by the Collaboration. Daily oversees operating conditions and is close contact with the management of the experiment. Assigns shifts according to collaboration rules.
- Financial Officer: Responsible for the FNAL financial interface with the experiment.
- Beam Coordinator: Responsible for liaison of the experiment with the Accelerator Department and beam line instrumentation group.
- Physics Analysis Working Groups: These are main centers of physics analysis and are headed by respective conveners. Activities of all groups are coordinated by the Analysis Coordinator (AC) and Deputy AC.

Internal management of the collaboration is carried about by the spokespeople and the deputy. All physics analysis working groups are managed by respective conveners. If difficult issues arise, the IB chair becomes involved, and possibly the IB itself. The Executive Committee is responsible for advising the spokespeople on matters of scientific nature and helps make crucial decisions.

The collaboration structure and lines of responsibility have been well tested over the last few years on MINOS and worked very well so will remain, at least initially, on the MINOS+ Collaboration. As new members are being integrated into this well-oiled machine some adjustments may be introduced later.

FNAL is ultimately responsible for decommissioning of the Far and Near Detectors. The UK owns the ND photo-detectors with their fiber-coupling boxes. The UK groups also own the Light Injection Calibration system and the Far Detector electronics. FNAL and the US DOE groups own the rest of the experiment.

The oversight of the MINOS+ operations is conducted by the FNAL directorate. Bi-weekly meetings are held with the head of the Fermilab Program Planning (with Jeff Appel until recently, and now with Steve Geer) where operational problems/issues are discussed. Physics results are communicated to the lab director as they become available.

COLLABORATION RESPONSIBILITIES BY INSTITUTION

In the context of the system responsibilities listed below, "maintenance" is construed to include support and preventive maintenance, documentation, upgrades as necessary, and repair or replacement due to normal wear and tear. It does not include replacement of a system due to catastrophic loss. Any disagreement concerning the scope of a specific responsibility shall be referred to the MINOS+ Institutional Board.

Institution	System	Description of Responsibilities
Argonne National Laboratory (not a collaborating institution; work under contract.)	Near Detector Electronics	Performance of routine repairs and maintenance of MINOS+ Near Detector electronics, following the initial installation and commissioning of this system; maintain an adequate supply of spare modules at Fermilab.
Fermilab	Near Detector Electronics	FNAL RA's provide monitoring of the Near Detector electronics; they replace defective modules with spares that are stored at Fermilab, and arrange for defective modules to be returned to ANL for repair
	Near Detector High Voltage	If system or component failure occurs FNAL staff will coordinate replacement with new modules from PREP
	Timing systems	Maintenance of timing systems and GPS.
	Far Detector High Voltage	If system or component failure occurs Soudan staff or shifters will coordinate replacement with new modules from PREP

	Far Detector Coil Power Supply	PPD EED Department is responsible for this system
	Near Detector Coil Power Supply	PPD EED Department is responsible for this system
	Near Detector Electronics Racks Cooling System	PPD Mechanical Support Department is responsible for this system
	Control Room hardware	Maintenance and improvements. CD staff are performing this function
	Near Detector Rack Infrastructure	Maintenance and repair rack cooling fans. Serve as interface to PPD Electrical Engineering Department for maintenance of VME timing system, VME crates, and power supplies.
	Data Acquisition System	Support, maintenance and repair of data acquisition hardware and infrastructure for both near and far detectors. Coordinate expert on-call support for operations.
University of Minnesota (Duluth)	DCS Hardware Systems: Near and Far	Support of the DCS system, both hardware and software, at both Near and Far detectors.
	Far Detector Operations	A UMD faculty member serves as the Far Detector Operations Manager.
Oxford University	Far Detector front end electronics	Technical expertise on the VFB and VA chip.
	Far Detector timing system	Technical expertise and documentation
	GPS : Near and Far	Technical expertise and hardware maintenance and support
	M64 PMTs (Near Detector) and tube bases.	Maintenance for the M64 bases; M64s can't really be maintained, but Oxford will provide high level expertise.
University of Pittsburgh	Near Detector Electronics Rack Fans	High-level expertise available.
Harvard University	Far Detector electronics	High-level expertise for VARC boards and low voltage power supplies.
University of Sussex These tasks will be shared between Sussex, UCL and Fermilab	Light Injection Calibration (near and far systems)	Responsibility for the maintenance and operation of the light-injection calibration system. Currently supplying one of the calibration co-coordinators, and a continuing responsibility for broader calibration issues is anticipated.
Rutherford Appleton Laboratory	Data Acquisition System	Consultant expert on-call support for operations.
University of Texas at Austin	M16 PMTs (Far Detector) and bases	Maintenance of a test stand and expertise for maintenance and repair of bases and PMT's, Auxiliary Detectors w/ daq for TOF.
	Hadron Monitor	Maintenance of operations (w/ Minerva) New muon monitors for Alcove 4 (detaisl in a separate MOU)/
	Muon Monitors	Maintenance of operations (w/ Minerva) New monitors for 2013 and beyond (separate MOU).
	Auxiliary Timing Detectors	Maintenance and support of operations.
Tufts University	Far Detector MUX	Maintenance of a facility for the repair or reconstruction

	Boxes	of far detector MUX boxes
College of William & Mary	Magnetic Field Calibration – B-dot system	Maintenance of the B-dot system for near and far detectors, perform magnetic calibration and generation and modeling of magnetic fields. ND operational maintenance.
University of Minnesota, Twin Cities	Wide Area Networking	Maintenance and repair network connectivity of the Soudan Laboratory.
	Far Detector Electronics	Soudan staff are responsible for repair of the front end electronics boards and VARC boards.

Table 1: Institutions with key hardware responsibilities for MINOS+ as of FY2014

Institution	**System Responsibility**	**Description of Responsibilities**
University of Cambridge	Calibration	Timing calibration of Near and Far Detectors
	Reconstruction code	Support of De-muxer, track-fitter
Fermilab	Near Detector Front End electronics	Maintenance of offline diagnostic software for monitoring Near Detector electronics.
	Run Control and DAQ	Support of run control and DAQ software
	Offline Software	CD personnel provide support for MINOS+ offline computing.
	Beamline data	CD support of database and monitoring tools used by all NuMI experiments.
Harvard University	Calibration	Calibration coordination
University College London	Calibration Support	Data processing for calibrations and monitoring
	Beam	Beam fits, beam flux generation
University of Minnesota, Twin Cities	Far Detector Operation	Daily maintenance and crew supervision
	TOF	GPS and auxiliary timing detector operations
University of Minnesota, Duluth	Far Detector operations	Daily maintenance and crew supervision.
	TOF	GPS and auxiliary timing detector operations
Oxford University		
	Timing System	Support, maintenance and development of near and far detector timing system software.
Argonne National Laboratory (not a collaborating institution	Near Detector Electronics	Support, maintenance and development of Near Detector

on MINOS+)		electronics calibration and DAQ.
University of Sussex (not a collaborating institution). These tasks will be shared by the UK groups.	Light Injection Calibration Support	Support and maintenance of software for the light injection calibration system. Coordination of calibration group efforts.
Caltech	Monte Carlo Generation	Implementation and maintenance of the Caltech processor MC farm resources
University of Texas at Austin	Data and MC events processing	Batch jobs submission, use of Texas Advanced Computer Center for MC generation; support for kNN techniques
	Beam	Beam fits and flux processing
	Auxiliary Detectors	Software, calibration, and operations support.
Tufts University	Calibration	Maintenance and support of calibration software
College of William and Mary	Monte Carlo Generation	Implementation and maintenance of W&M processor MC farm resources, calibration analysis, DAQ support
Stanford University	Operations	Operations Coordination
University of South Carolina	Beam	Beam simulations and fitting
	Calibration	Support of muon calibration software
	TOF	Support of timing calibratons
University of Warsaw	Reconstruction	3D tracking and scanning validation
Otterbein University	Calibration	Calibration support and event display development
University of Houston	Monte Carlo	Use of TACC in Monte Carlo generation
Campinas, Goias, Sao Paolo	Operations	Remote shifts, ND detector monitoring and software maintenance. Online monitoring.
Holy Cross College	Operations	Summer operations

Table 2: Institutions with key software and operational responsibilities for MINOS+ as of FY2014.

FERMILAB RESPONSIBILITIES

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.

AD will also be responsible for monitoring intensity and beam quality of the primary proton beam. Overall monitoring of the primary proton beam intensity within 1% is required by the experiment.

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

AD 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 MINOS+ questions involving the beam. 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.

AD 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/MINOS+. It is responsible for the maintenance of the accelerator consoles in the MINOS+ 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.

AD 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.

AD 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/MINOS+ 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 MINOS interlocked areas (by controlling keys for the elevator and/or hadron absorber area and muon alcoves). Access to the MINOS detector area is controlled by PPD.

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. The Department will similarly be responsible for operation of the Optical Transition Radiation (OTR) detector which is to be installed. The University of Texas at Austin was responsible for the development of segmented-foil emission monitors (SEMs), the hadron monitor, and the muon monitors. The University of Texas at Austin is proceeding with a separate MOU with the Accelerator Division to cover the responsibilities for these detectors. The Instrumentation Department will be a signatory to that MOU.

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, emitance 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.

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.

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 re-securing these areas after a Supervised Access. AD provides the first response to alarms in these areas.

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	There is a spare target and target carrier. There are no spare horns, but work is underway to produce them. 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 4.1 Fermilab AD Hardware Responsibilities for MINOS+

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 4.2 Fermilab AD software responsibilties for MINOS+

THE PARTICLE PHYSICS DIVISION (PPD)

The Particle Physics Division is responsible for the operation of the MINOS+ 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.

INTENSITY FRONTIER DEPARTMENT

The PPD and the MINOS+ Experiment interact primarily through the Intensity Frontier Department. This department provides an administrative organization for the Fermilab staff working on MINOS+, 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 MINOS+ Detectors and those parts of the NuMI/MINOS facility for which the PPD is the landlord.

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

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

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 MINOS+ operations budget. The Intensity Frontier Department will request such support as needed.

ELECTRICAL ENGINEERING

The PPD Electrical Engineering Department played a key role in developing the MINOS electronics and continues to provide support for them, including:

a) Ongoing maintenance work for the Near Detector MENU modules;
b) Participation in the production of additional MENUs, if more are needed;
c) Assist in maintaining the MINOS clock system.

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 MOU with the AD for the coordination of ES&H issues. That MOU specifies responsibilities for PPD that include:

a) Communication of pertinent ES&H issues to MINOS+ Spokespersons;
b) Maintenance of radiological postings in MINOS 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 MINOS+ experimenters are needed;
f) Coordinating use of radioactive sources in MINOS areas with the collaboration and the ES&H Section;
g) Shipping/receiving of radioactive items between MINOS 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 building;
i) Providing two (2) keys to the MCR for emergency and operational access to the MINOS area
j) Conduct of an appropriate safety review for any proposed upgrade to the MINOS detectors.

TECHNICAL CENTERS

The PPD Technical Centers Department comprises groups having special technical expertise, including alignment & metrology, detector support, machine development, and others. The Scintillator Group was instrumental in development and production of the MINOS scintillator and may play a role in any repair work that the scintillator or optical fibers may need. The MINOS+ experiment may solicit support from these groups as needed.

SITE DEPARTMENT

The PPD Site Department provides maintenance and support for the MINOS near detector coil power supply. This department also supports the Mechanical Department in maintaining the LCW water system for the near detector. The MINOS+ 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 near detector hall. Such requests are subject to the approval of the Site Department Head.

UNDERGROUND ACCESS COORDINATION

The MINOS+ experiment shares PPD underground space with future 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 permitting for work to be performed in the underground areas of the PPD is the responsibility of the PPD Underground Areas Coordinator,

THE COMPUTING DIVISION (CD)

The Fermilab Computing Division provides support to the MINOS+ 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 MINOS+ experiment.

OFFLINE COMPUTING, NETWORKING & DATA STORAGE

The Fermilab CD has prepared a separate TSW for support of MINOS+. This TSW addresses computing support for the experiment and an estimate of the computing resources and CD manpower required.

ELECTRONICS SUPPORT

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

MINOS Far Detector

- HV 1440 High Voltage Supplies; on loan from PREP
- VA Front End Boards (VFBs); developed at Oxford
- VA Readout Cards (VARCs); developed at Harvard
- VME Crates
- Weiner Power Supplies
- Low voltage power supplies; developed at Harvard

MINOS Near Detector

- HV 1440 High Voltage Supplies; on loan from PREP

The MINOS+ 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. A list of PREP equipment presently on loan to the experiment maintained by Fermilab.

At the completion of the experiment, the MINOS+ 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 FACILITIES ENGINEERING SERVICES SECTION (FESS)

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

FESS OPERATIONS GROUP

The FESS/Operations Group is responsible for the support described in 0 - 0. FESS will administer the support work described in 0, 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.

First response to FIRUS and Metasys alarms

Response is on non-experimental equipment and systems, via the duty electrician and duty mechanic that are currently staffed continuously.

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 MINOS 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 MINOS (Maintenance and operation)

Items not included in the FESS Operations budget

Although the FESS operational budget does not explicitly cover the cost of these items, FESS will schedule inspections and maintenance as necessary and administer the pertinent subcontracts.

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.
f) The cost of crane inspections and repairs.

FESS SERVICES GROUP

The FESS Services Group shall provide support at the MINOS service building. These services shall include 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, including snow removal;
b) Arrangement of asphalt repair contracts for the MINOS parking lot as needed;
c) Landscaping in the vicinity of the MINOS building;
d) Custodial services for theMINOS service building;
e) Maintenance and repair of the roof, overhead door, and glass in the MINOS service building as necessary.
f) Administration of elevator inspections and repairs.

ES&H

The Accelerator Division (AD) ES&H Department will have ES&H oversight responsibility for the AD areas of the NuMI facility. In addition, the ES&H Department coordinates underground safety training for all NuMI/MINOS 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 the keys for the elevator and/or radiation areas for MI-65).
g) Monitoring and control of underground access at MINOS interlocked areas (by controlling keys for the elevator and/or the hadron absorber area and the muon alcoves). Access to the MINOS detector area is controlled by PPD.

APPENDIX: Spare Components

This appendix lists responsibilities for MINOS spare components. These responsibilities may include maintenance, repair, testing, or storage. Replacement or provision of new components is not assumed to be an institutional responsibility unless explicitly stated. The actual number of available spares of any given component is a quantity that can change at any time, therefore no attempt is made to track the spares on hand here. The following tables are a snapshot, not a running inventory. Their purpose is to specify the status of and responsibilities for important spare components for the MINOS+ experiment.

Component	Designed by	Maintained by	Location	Notes
LI Pulser Box	Sussex	Sussex	Sussex	
				Experts available at Oxford

M64 PMT	Hamamatsu	Oxford	Fermilab	for consultation
M64 Base	Oxford	Oxford	Fermilab	Maintenance performed by Oxford
M16 PMT	Hamamatsu	Texas	Soudan/Texas	
M16 Base	Texas	Texas	Soudan/Texas	Bases were kept on high voltage for 5 years
PMT Far Detector MUX Boxes	Indiana	Indiana	Soudan	
PMT Near Detector Alner Boxes	RAL	RAL	Fermilab	
VME Master Crates	Wiener	Fermilab	Soudan	Experts at Fermilab
Near Detector Front-end Crates	Wiener	ANL	Fermilab/ANL	Experts at ANL
Near Detector Clock Boards	FNAL/IIT	FNAL/IIT	Fermilab	
ND Trigger KEEPER boards	ANL	ANL	ANL/Fermilab	
ND Minder Readout Cards	ANL	ANL	Fermilab/ANL	Experts at ANL
ND MENU Frontend Cards	FNAL	ANL/FNAL	ANL/Fermilab	Experts at ANL
Rack Protection Boxes	BIRA	Duluth	Duluth/FNAL/Soudan	Experts at Duluth
TCU	Oxford	Oxford	Fermilab	Maintenance performed by Oxford
GPS Receiver	Commercial	Oxford	Fermilab	Maintenance performed by Oxford
TRC	Oxford	Oxford	Soudan	Maintenance performed by Oxford
PVIC PCI cards	Commercial	Rutherford	Soudan mine	Maintained by RAL; Commercial repair

PVIC PCI cards	Commercial	Rutherford	Fermilab	Maintained by RAL; Commercial repair
PVIC VME cards	Commercial	Rutherford	Soudan mine	Maintained by RAL; Repairs by CES
PVIC VME cards	Commercial	Rutherford	Fermilab	Maintained by RAL; Commercial repair
PVIC Cable Connectors	Commercial	Rutherford	Soudan mine	Maintained by RAL
PVIC Cable Connectors	Commercial	Rutherford	Fermilab	Maintained by RAL
VME processors (RIO)	Commercial	Rutherford	Soudan mine	Maintained by RAL; Commercial repair
VME processors (RIO)	Commercial	Rutherford	Fermilab	Maintained by RAL; Commercial repair
Universal Device Server (UDS)	Commercial	Rutherford	Soudan mine	Maintained by RAL
Universal Device Server (UDS)	Commercial	Rutherford	Fermilab	Maintained by RAL
DAQ PC	Commercial	Rutherford	Soudan mine	Maintained by RAL
DAQ PC	Commercial	Rutherford	Fermilab	Maintained by RAL
DAQ Power Distribution Unit (PDU)	Commercial	Rutherford	Soudan mine	Maintained by RAL
DAQ Power Distribution Unit (PDU)	Commercial	Rutherford	Fermilab	Maintained by RAL

Component	**Designed by**	**Maintained by**	**Location**	**Notes**

VA Front-End Board (VFB)	Oxford	Fermilab PREP	Soudan and Oxford	Experts available at Oxford for consultation
VA Readout Card (VARC)	Harvard	Fermilab PREP	Soudan and Oxford	Experts available at Harvard for consultation

Table A.1 MINOS+ Spares