Experimental Operations Plan

MicroBooNE (E974)

Fermi National Accelerator Laboratory

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Experimental Operations Plan for the MicroBooNE Experiment

1. INTRODUCTION

MicroBooNE (E974) is a short-baseline neutrino oscillation physics experiment designed to address the anomalous low energy excess [1] observed by the MiniBooNE experiment in its search for electron neutrino appearance in a muon neutrino beam. In addition to its oscillation physics goals, MicroBooNE will measure a suite of low energy neutrino cross sections on argon. MicroBooNE combines these physics goals with development towards future Liquid Argon (LAr) Time Projection Chamber (TPC) detectors. These detectors have been in regular use in the U.S. for test experiments such as ArgoNeuT and LArIAT and are part of our future planning both with prototypes (DUNE 35 ton and protoDUNE) and for short and long-baseline neutrino physics experiments (SBND, ICARUS, and DUNE).

MicroBooNE was proposed in 2008 and received CD-0 in 2009. Since then, the MicroBooNE project and collaboration worked to design, review, fabricate, and assemble the detector. The detector is sited in the Liquid Argon Test Facility (LArTF) 470m downstream from the Booster Neutrino Beam (BNB) production target. The detector is 25 feet below grade, centered on the neutrino beam. CD-4 was achieved in December 2014. Commissioning and the LAr fill proceeded through summer 2014. On August 6, 2015, first cosmic ray tracks were observed in the MicroBooNE LAr TPC. In October 15, 2015, the experiment received its first Booster neutrino beam and first neutrino interactions were observed in the detector. Presently, the MicroBooNE detector is running stably and taking physics-quality data. Over the first few months of beam data-taking, final commissioning of the PMT trigger will be completed, as planned. Until our PMT trigger is fully commissioned, we are saving all data collected to tape.

2. SCIENCE WITH MICROBOONE

The MiniBooNE experiment observed a ~3σ excess of electromagnetic events above background in both neutrino and antineutrino running in the energy range from 200-475 MeV [1]. These electromagnetic events could be electrons from electron neutrino interactions in the MiniBooNE detector. If this is the case, this could be signaling new physics such as the existence of a sterile neutrino. However, the excess could also be single photons, which could arise either from an unexpected background or as an indication of new physics, for example, new particles suggesting the existence of a dark sector. Unfortunately, MiniBooNE's Cerenkov imaging detection technique cannot differentiate electrons from single photons. The main physics goal of the MicroBooNE experiment is to now, using a LArTPC, observe and understand the nature of the low energy excess observed by MiniBooNE. MicroBooNE's detection technique takes advantage of its fine-grained topology and total absorption calorimetry to be able to accomplish this. The MicroBooNE detector sits just upstream of MiniBooNE, at nearly the same distance from the neutrino production target and in the same beam. If the excess is due to electrons (photons), MicroBooNE will be sensitive at ~5σ (4σ) with an exposure $6.6\text{x}10^{20}$ POT which, with nominal Booster running, should take ~3 years to collect.

In addition to MicroBooNE's oscillation physics goals, MicroBooNE will measure a suite of low energy neutrino cross sections on argon. This data is both crucial for probing important "new" sources of nuclear physics revealed by the MiniBooNE cross section program and for providing first measurements of neutrino scattering in the low energy range needed for DUNE. For the former, MicroBooNE will be the first LAr TPC with high enough statistics to make measurements of rare channels. The only other LAr TPC experiment to measure neutrino-argon cross sections is the ArgoNeuT test that collected approximately 10,000 neutrino interactions in the low energy NuMI beam with an average neutrino energy of 3 GeV [2]. By contrast, MicroBooNE will collect more than an order of magnitude more interactions and will extend the ArgoNeuT program by collecting data with an average neutrino energy of 800 MeV. This energy range is useful for DUNE. The DUNE experiment will take advantage of a wide-band beam to measure both the first and second oscillation peaks in their beam. The experiments running on the BNB will specifically measure neutrino cross sections in the range of the second oscillation maxima which peaks at about 800 MeV.

3. DETECTOR TECHNOLOGY DEVELOPMENT

In addition to MicroBooNE's science goals, MicroBooNE advances the LAr TPC technology for future short and long baseline experiments that will use this same technology, such as the SBN program and DUNE. These development goals include:

- the design, fabrication, and long-term operation of cold (in liquid), low noise electronics
- the purification of the liquid argon (specifically, removal of electronegative contamination) in a fully instrumented, un-evacuated vessel
- the implementation of a general detector design appropriate for the next phase in the LAr TPC program

Beyond these goals, MicroBooNE has learned many lessons and is documenting these to pass on to future LAr TPC experiments. Now during MicroBooNE's operations phase, this experience is already proving to be invaluable. We are continuing to learn how to operate the electronics, handle sources of noise in the detector, and monitor and operate all of the detector systems: cryogenics, UV laser, TPC, PMTs, and drift HV.

4. EXPERIMENTAL DESIGN

The MicroBooNE detector is a 2.33 x 2.56 x 10.37 m LAr TPC. Figure 1 shows a cross sectional view of the TPC with the cathode plane on the left side and the anode wire chamber planes on the right. Passing charged particles ionize the argon and the ionization tracks are drifted over a 2.56 m drift distance to the anode wire chamber planes to be readout. A field cage ensures a uniform drift field from the cathode plane to the wire chambers. The ionization charge induces signals on the first two wire planes and the third plane collects the charge. The signals are amplified in the LAr and readout by the warm electronics outside the cryostat. The wire plane readout is then combined with the electron drift time to produce 2D and 3D images of the interaction. An array of 32 8in Hammamatsu photomultiplier tubes sits behind the wire chamber planes to record the prompt scintillation light produced by passing charged particles. A photograph of the assembled TPC before insertion into the cryostat is shown in Figure 2.

In total, the TPC encloses 89 tons of active LAr volume. The cryostat holds a total volume of 170 tons of LAr. The purification system cleans the LAr of electronegative impurities by filtering the liquid through a molecular sieve and carbon granules. The purification system is presently purifying to < 50 ppt of electronegative (O_2) impurities or an equivalent electron lifetime >6 ms (the design goal was 3 ms [4]).

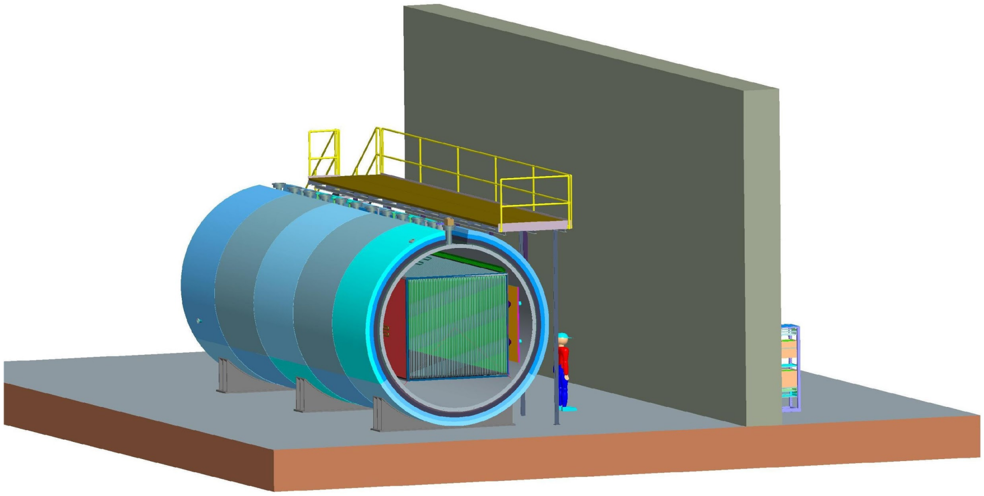

Figure 1: Cross sectional view of the MicroBooNE TPC inside the vessel.

Figure 2: Photograph of the MicroBooNE TPC as it was being assembled at the DZero Assembly Building before being inserted in the cryostat and transported to LArTF.

5. THE MicroBooNE COLLABORATION

The following two sections describe the organization of the MicroBooNE collaboration and shift-taking procedures.

5.1 Organization and Governance

The MicroBooNE collaboration [3] presently consists of 138 collaborators from 28 institutions (6 non-U.S). This includes 33 postdocs and 32 graduate students.

MicroBooNE has a Faculty and Senior Research Scientists (FSRS) group that meets at each collaboration meeting to discuss MicroBooNE policies and to consider new petitions to join the experiment. The FSRS is comprised of all faculty and senior research scientists on the experiment. In addition, MicroBooNE has an Institutional Board (IB) consisting of one representative from each collaborating institution. The Institutional Board has an elected chair. The Institutional Board receives recommendations from the FSRS. The IB approves and modifies the collaboration bylaws, admits new collaborators, and develops and sets policies by which the collaboration is governed. The scientific leadership of the MicroBooNE collaboration consists of two elected co-spokespersons, who are advised by the Institutional Board.

To carry out the mission of the experiment, the spokespersons have appointed a set of conveners to cover the main areas of the experiment, as can be seen in the MicroBooNE Organizational Chart in Figure 3. These co-conveners, working together with the spokespeople, appoint leaders for the different subgroups in their respective areas. This organizational chart has recently been updated to reflect steady state operations for MicroBooNE. The four main areas are: *Operations, Technical Coordination, Analysis Tools,* and *Physics Analysis*. Details on each of these are provided below:

Operations: The *Operations* team is responsible for the day-to-day running of the experiment. This includes organizing shifts, training shifters, and ensuring that shifters are successfully monitoring and responding to operational issues of the detector. The *Operations* team is run by a Run Coordinator. The Run Coordinator has a Deputy Run Coordinator to assist her/him in Operations. Short term task forces and efforts critical to stable operations are under the coordination of the Run Coordinator. Presently there are three such groups under the umbrella of *Operations*: the PMT Trigger Task Force, the Radon Task Force, and the Data Quality Monitoring group. In addition there are sub-system points of contact for each major detector sub-system.

Technical Coordination: Longer term detector activities are coordinated under *Technical Coordination*. The convener of this group, the Technical Coordinator, is responsible for overseeing such long term hardware activities, for example, detector work that will be performed during accelerator shutdowns. Presently this includes 5 such activities: DAQ upgrades, drift HV development, a larger muon tagger system, additional overburden for the experimental hall, and detector electronics.

Analysis Tools: Coordination of the development of the analysis tools needed by the experiment falls under this group which, unlike the more newly formed *Operations* and *Technical Coordination* groups, has been active and meeting regularly for 2.5 years. The co-*Analysis Tools* conveners oversee the following 7 sub-groups: Data and MC Production, Databases, Event Displays, Reconstruction, Code Releases, Simulations, and Software Tools. They are responsible for developing the tools needed to perform the physics analyses for the experiment. They work closely with the *Physics Analysis* co-conveners to set priorities in developing these tools.

Physics Analysis: Coordination of physics analysis for the experiment falls under this group, which, like *Analysis Tools*, has been active and meeting regularly for the last 2.5 years. The *Physics Analysis* co-conveners oversee the following 5 sub-groups: Astroparticle Physics and Exotics, Beam, Cross Sections, Detector Physics, and Oscillations. The *Physics Analysis* co-conveners are responsible for overseeing and driving the physics analyses associated with these topics.

In addition to these groups, the experiment has a number of liaisons shown on the lefthand side of the organizational chart. These roles represent linkages to organizations or groups external to MicroBooNE. With the exception of the ELO and cryogenics liaison, each of these roles are filled by MicroBooNE collaborators. They are 6 such points of contact:

- *Experimental Liaison Officer (ELO)*: coordinates Fermilab's resources to problems encountered by the experiment, as requested by the MicroBooNE Run Coordinator. This includes possible issues related to the building and mechanical equipment inside the building, with the exception of the MicroBooNE cryogenics system.

- *Cryogenics Liaison*: ensures that MicroBooNE cryogenics system is monitored 24/7, maintenance occurs as needed, and repairs occur as quickly as possible after a failure.

- *Computing Sector Liaison*: ensures proper communications between the experiment and Fermilab's Computing Sector, develops annual budget plans to support MicroBooNE computing, and oversees collaboration resources dedicated to data management and simulations. Specific support for MicroBooNE computing is covered in the MicroBooNE TSW [5].

- *Beam Liaison*: responsible for communication between MicroBooNE and Fermilab's Accelerator Division.

- *Neutrino Outreach Liaison*: responsible for working with the Fermilab Office of Communications on outreach activities associated with or requested of MicroBooNE.

- *GENIE Liaison*: responsible for communication between the experiment and the GENIE neutrino event generator collaboration.

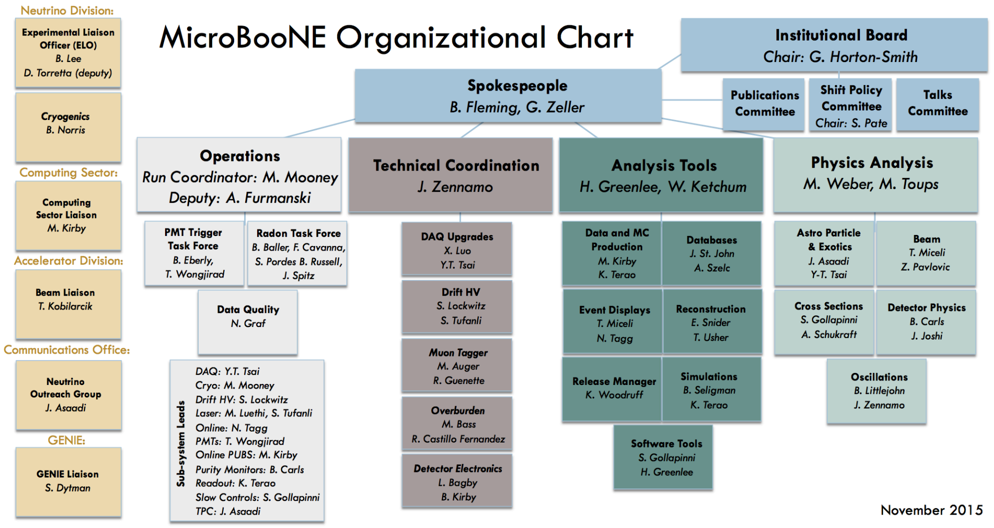

Figure 3: The MicroBooNE collaboration organizational chart as of November 2015.

5.2 Shifts

24/7 shift-taking on MicroBooNE commenced on June 1, 2015, approximately 4 months before the start of neutrino beam data-taking. In general, shift-taking is expected to be shared equally by all MicroBooNE collaborators during MicroBooNE running. The PI of each institution is responsible for specifying which personnel will be authors on MicroBooNE publications. This headcount then sets the shift quota per institution. While each MicroBooNE author is encouraged to fulfill a per-person shift quota, the quotas are an institutional responsibility. As long as the institution covers all of their shift points, then all of the institution members can authors on MicroBooNE publications.

Shifter responsibilities include executing the run plan set by the Run Coordinator, verifying that the detectors are running properly, and ensuring that the data is of high quality, as determined from the diagnostic online monitoring. In addition to regular shifters, "on-call experts" are assigned to provide assistance when problems arise that are beyond the expertise of the shifters. These experts are expected to be contactable 24/7 when they are on call to respond to major issues that are first identified by shifters.

Shifts will be conducted 24/7 from the ROC-W control room during the first defined MicroBooNE data taking period, leading up to the summer shutdown in 2016. There are two people required to be on shift; however, one of these shifters can be a "remote shifter" located at a remote site approved by the Run Coordinator. When access to LArTF is needed, one of the local shifters may be called upon to accompany personnel to LArTF to ensure we have fulfilled the two-person rule we have as a requirement for work performed in the detector hall. If there is only one local shifter, then the Run Coordinator arranges to serve as the second person for work in LArTF. Shift-taking during the accelerator shutdown will be determined as the summer approaches and as we further develop a plan for our activities during the shutdown.

6. FERMILAB ROLES AND RESOURCES

The MicroBooNE experiment receives support from the Accelerator Division (AD), Fermilab Computing Sector (CS), Neutrino Division (ND), and Particle Physics Division (PPD).

Accelerator Division (AD): AD is responsible for the commissioning, operation, and maintenance of the primary proton beam line, the neutrino production target, the horn, and the decay pipe. AD is responsible for maintenance of all existing standard beamline elements, instrumentation, controls, and power supplies. AD will also be responsible for monitoring intensity and beam quality of the primary proton beam. The effect of delivering beam to MicroBooNE impacts the amount of protons available to the NuMI experiments. The number of protons routed to each neutrino production target is set by the Fermilab Office of Program Planning.

Fermilab Computing Sector (CS): Fermilab Core Computing and Scientific Computing Divisions (CCD, SCD) support the computing needs of the MicroBooNE experiment through provision, maintenance, and support of common, and in some cases experiment-specific, core and scientific services and software. The Computing Liaison's responsibilities include maintaining excellent communications between the experiment and CCD/SCD as well as attention to ensuring the computing needs, agreements, issues and other relevant items between the experiment and CS are addressed in a timely and mutually agreed upon manner. Please see MicroBooNE's TSW with the Fermilab Computing Sector for a complete description of responsibilities and agreements [5].

Neutrino Division (ND): The newly formed Neutrino Division is responsible for the operation of the MicroBooNE experiment and experiment-related activities at Fermilab. It provides operating funds for running and maintenance of the MicroBooNE detector and technical support personnel including cryogenic engineers who are experts on the MicroBooNE cryogenics system. It also provides administrative support for MicroBooNE collaborators as well as a control room, ROC-W. The Neutrino Division provides office space for both resident and visiting MicroBooNE collaborators. Office space provided is commensurate with the amount of time spent at Fermilab.

Particle Physics Division (PPD): the Particle Physics Division is responsible for those aspects of the MicroBooNE detector and enclosure (LArTF) for which it is the landlord. They also provide a 24/7 cryogenic technician team whose responsibility it is to monitor the MicroBooNE cryogenics system and contact the on-call MicroBooNE/ND cryogenic engineer when problems arise.

7. SPARES

To ensure minimal downtime, single-point failures have been identified and each sub-system has provided spares for these components (Table 1). Depending on the sub-system involved, downtime for such a swap is expected to be between one hour and one day. Ideally spares would be kept at LArTF; however, available space there is limited. Small items and parts used in teststands are kept at LArTF and the Run Coordinator/Deputy Run Coordinator are working to build a single spares cabinet at DAB where additional items will be kept. An updated list of spares is kept as a Google spreadsheet, which can be edited by experts when spares are added or relocated. The following describes the status of spares for each of the most critical MicroBooNE sub-systems:

Drift High Voltage (HV): The drift HV system has replacements for the power supply, cable, feedthrough, filter pot, and spring tip. Most of these spares are currently at PAB and are in active use in test experiments. The spare HV feedthrough is stored in the MiniBooNE building. Drift HV replacements are expected to take less than a day.

PMTs: The only identifiable failure mode for the PMT system is the high voltage power supply module. The PMTs themselves cannot be accessed as they are housed inside the sealed MicroBooNE cryostat. A spare PMT high voltage module exists.

Readout: The warm electronics involves a large number of critical components. A readout teststand exists in LArTF which contains a single spare PMT readout crate, a single spare TPC readout crate, and a trigger board and clock fan-out. In addition, the readout requires a large number of NIM logic modules. Each of these has a spare located at LArTF either in a teststand or in a dedicated readout spares box. Every readout rack at LArTF is equipped with a rack protection system that the rack will not operate without. Spares for these exist at DAB. Most readout parts can be swapped out quickly, once experts are on-site; however a longer time would be needed to replace an entire crate.

DAQ: The DAQ system is semi-replicated in the readout teststand at LArTF. If required, the machines in this teststand can be used to replace production machines which are housed in an adjacent rack. Spare network cards are kept in storage cabinets at LArTF.

Purity monitor: Purity monitors are used to measure the LAr purity in the MicroBooNE cryostat. Spare bulbs, housings, and power supplies are stored either in racks at LArTF or in Wilson Hall. MicroBooNE is equipped with three purity monitors, one of which is replaceable. If the purity monitors are unavailable or offline for some reason, we can also use offline analysis of cosmic ray muon tracks to produce a redundant in-situ argon purity estimate.

Shifts: In ROC-W, shifters use four workstation computers. A fifth is always powered on, ready for use, and simply needs to be attached to the relevant monitor and keyboard in the event of a failure. This swap can be done in a matter of minutes. No critical processes are run on these workstations, as the DAQ and slow monitoring are run on virtual desktops on remote machines.

UV Laser: The MicroBooNE UV laser system is used to measure space charge effects in the active TPC volume. Smaller components such as mirrors and lamps are available on-site. Larger parts such as the feedthrough motor are costly and would be produced as needed if a failure occurs. This type of failure is not expected and would not prevent MicroBooNE from running; however, it would mean that laser runs could not take place for a number of weeks.

Subsystem	Part name / description	Model number	Quantity	Current location	Expected final location
Readout Electronics	PMT XMIT Board		1	LArTF	LArTF
Readout Electronics	PMT Shaper Board		1	LArTF	LArTF
Readout Electronics	PMT Shaper Board		1	LArTF	LArTF
Readout Electronics	PMT FEM Board		1	LArTF	LArTF
Readout Electronics	PMT CTRL Board		1	LArTF	LArTF
Readout Electronics	TPC Trigger Board		1	LArTF	LArTF
Readout Electronics	PMT FEM Board		1	LArTF	LArTF
Readout Electronics	TPC XMIT Board		1	LArTF	LArTF
Readout Electronics	TPC CTRL Board		1	LArTF	LArTF
Readout Electronics	TPC FEM Board		12	LArTF	LArTF
Readout Electronics	NIM module	688AL (level adapter)	2	LArTF	LArTF
Readout Electronics	NIM module	623 (discriminator)	3	LArTF	LArTF
Readout Electronics	NIM module	365AL (coincidence)	1	LArTF	LArTF
Readout Electronics	NIM module	365ALP (coincidence)	1	LArTF	LArTF
Readout Electronics	NIM module	375L (coincidence)	1	LArTF	LArTF
Readout Electronics	NIM module	222 (gate generator)	2	LArTF	LArTF
Readout Electronics	NIM module	428 (fan-in-fan-out)	1	LArTF	LArTF
Readout Electronics	NIM module	620AL (discriminator)	2	LArTF	LArTF
Readout Electronics	NIM module	1880 scaler	3	LArTF	LArTF
Readout Electronics	NIM module	622 (coincidence)	1	LArTF	LArTF
Readout Electronics	NIM module	429A (fan-in-fan-out)	1	LArTF	LArTF
HV	Glassman power supply	LX150N12	1	PAB	PAB

HV	Cable		1	PAB	PAB
HV	Filter Pot		1	PAB	PAB
HV	Cable			PAB	PAB
HV	Feedthrough		1	MiniBooNE	MiniBooNE
HV	Spring tip		1	PAB	PAB
PMT	HV module		1	Wilson Hall	DAB
Laser	Steerable Mirror	T-OMG	1	Wilson Hall	DAB
Laser	Dichroic Mirror	266nm Dichroic Mirrors	4	Wilson Hall	DAB
Laser	Water Filters	Flow XF6 3/8	4	Wilson Hall	DAB
Laser	Flash Lamps	Flashlamps	2	Wilson Hall	DAB
Laser	Brewster Polarizer	2-BFP-0266-2040	4	Wilson Hall	DAB
Laser	Waveplate	2-CPW-ZO-L/2-0266	2	Wilson Hall	DAB
Cabling	warm cabling			LArTF	LArTF
DAQ	uboonedaq-evb		1	LArTF	LArTF
DAQ	uboonedaq-seb01		1	LArTF	LArTF
DAQ	uboonedaq-seb10		1	LArTF	LArTF
DAQ	10 Gigabit Network Interface Card		2	LArTF	LArTF
DAQ	PCIe Card w/ fuse		1	LArTF	LArTF
Slowmon	Slow controls rack monitor		1	DAB	DAB
Racks	Rack protection system		4	DAB	DAB
Electronics	Calibration fanout		1	DAB	DAB
Racks	AC switch box		3	DAB	DAB
Purity Monitor	LAr PM Electronics Module	Type 2, Jan 2013, Ser #15	1	Wilson Hall	DAB
Purity Monitor	LAr PM Automation Module		1	LArTF	LArTF
Purity Monitor	Flash Lamp Bulb	6427, 5J Large Bulb Xe	3	Wilson Hall	DAB
Purity Monitor	Flash Lamp Housing		1	Wilson Hall	DAB
Purity Monitor	Flash Lamp Power Supply	68826	1	LArTF	LArTF
Purity Monitor	HV Feedthrough		2	Wilson Hall	DAB
Shift	Shift workstation		1	ROC west	

Table 1: List of MicroBooNE spares, their quantity, and location.

8. BUDGETS AND RESOURCES

The cost of operating and maintaining MicroBooNE is roughly \$220k/year in M&S. This includes the cost of consumables (liquid nitrogen and liquid argon), and other items such as tube trailer re-certification contracts and recirculation pump maintenance. The level of effort supplied by the MicroBooNE collaboration for operating the experiment is detailed in Appendix B.

9. RUN PLAN AND DETECTOR OPERATIONS

The official start of neutrino data-taking on MicroBooNE began on October 15, 2015 when AD delivered the first high intensity protons to the BNB. Since this time, the experiment has been running with a DAQ uptime of typically >97% when the beam is on. MicroBooNE will record ~1100 TB of data in the first three months of data taking. This data rate will be reduced by roughly an order of magnitude once the PMT trigger is commissioned. The experiment is running in neutrino mode and is not requesting any special runs at this time.

9.1 Safety

In all activities, MicroBooNE practices a culture of safety. Collaborators are required to be up-to-date on safety training at Fermilab and are encouraged to have ODH training. In order to enter the stairwells, platform, or pit at LArTF, collaborators must have ODH training. A two-person rule is enforced for ODH areas at LArTF, requiring either more than one person with ODH training to be present for any work in the pit or on the platform, or one person in continuous visual and auditory contact (from the top level) with an ODH-trained person working on the platform.

For collaborators making an access to the ODH areas in LArTF, a specific procedure of access is enforced. Those entering ODH areas must first remove a key from the keytree on the top level, wait 60 seconds to make sure there are no alarms related to stairwell pressurization, leave a valid Fermilab ID in the keytree to indicate that said-person is making access to an ODH area in the building, and take appropriate safety gear with them. This safety gear includes both an oxygen monitor and a hard hat. If the stairwell is an ODH area at the time (due to possible pressurization issues in the stairwell), it is also necessary for the collaborator making access to take an oxygen rescue pack with them down to the pit or platform.

9.2 Detector and Data Quality Monitoring

The operation of the detector is monitored 24/7 by shifters in ROC-W and remotely by making use of an extensive suite of monitoring software developed and maintained by MicroBooNE collaborators. Shifters use this software to identify issues with the detector and/or in data-taking. In addition, on-call experts are available for critical systems, as described above. A shifter checklist is completed twice per shift and helps focus shifter attention on the most critical components of the detector to be monitored. This checklist also reinforces appropriate actions to be taken if something abnormal is seen in the monitoring software.

Offline data quality monitoring is performed by the Data Quality Monitoring (DQM) group, which works closely with the Run Coordinator and Deputy Run Coordinator as part of *Operations.* This group makes use of the TPC and PMT data readout from the detector to determine if the data is suitable for use in physics analyses, as well as to provide a calibration for the data on a per-run basis. In addition, beam data from ACNET that is merged with the TPC/PMT readout data is examined to determine if the BNB and NuMI beams had protons in the spill and if the protons were on-target.

Appendix A: List of Acronyms

ACNET	Accelerator Control Network
AD	Accelerator Division
ArgoNeuT	Argon Neutrino Test (T-962)
BNB	Booster Neutrino Beam
DAQ	Data Acquisition System
DUNE	Deep Underground Neutrino Experiment
ES&H	Environment, Safety, and Health
FC	Fermilab Computing
FY	Fiscal Year
HV	High Voltage
ICARUS	Imaging Cosmic And Rare Underground Signals
LAr	Liquid Argon
LArIAT	LArTPC In A Testbeam
LArTPC	Liquid Argon Time Projection Chamber
MCR	Main Control Room
MicroBooNE	Micro Booster Neutrino Experiment (E-974)
ND	Neutrino Division
NuMI	Neutrinos from the Main Injector
PPD	Particle Physics Division
PS	Power Supply
ROC-W	Remote Operations Center – West
SCD	Scientific Computing Division
SWIC	Segmented Wire Ionization Chamber
TPC	Time Projection Chamber
TSW	Technical Statement of Work (formerly MOU)

Appendix B: Collaboration Institutional Responsibilities

The following list represents a snapshot of the responsibilities of MicroBooNE institutions (as of October 2015). In each case, a total FTE collaborator count follows the institution's name. When there are specific responsibilities of the institution, they are broken out in lists that follow. Participation in the experiment that applies generally (for example, analysis, shifts, supervision of students) is not broken out in these smaller totals.

TO BE ADDED

REFERENCES

[1] A.A. Aguilar-Arevalo *et al*. [MiniBooNE], Phys. Rev. Lett. 110, 161801 (2013)
[2] R. Acciarri *et al*. [ArgoNeuT], Phys. Rev. D89, 112003 (2014)
[3] A complete and up to date list of MicroBooNE collaboration members can be found here: http://www-microboone.fnal.gov/public/collab-list-scientific.pdf
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[5] Technical Scope of Work between MicroBooNE and Fermilab Computing Sector, http://microboone-docdb.fnal.gov:8080/cgi-bin/ShowDocument?docid=3537, January 16, 2015