November 7, 2014

Final Report
NOvA Operational Readiness Review

1. Introduction

The Head of the Fermilab Program Planning, Steve Geer, charged a committee to review the operational readiness of the NOvA experiment for a transition to operations in the fall of 2014. The charge is provided in Appendix A and the committee membership is provided in Appendix B. The review took place on October 28-29, 2013 and the agenda and the relevant materials are available from this URL, https://indico.fnal.gov/conferenceDisplay.py?confId=8990. Following the last talk, the committee met to discuss first impressions, to formulate additional questions, and to make writing assignments. On the morning of the second review day some additional material was provided in response to requests and questions from the committee. This additional material is linked at the top of the web page in two separate documents.

This report describes the findings and recommendations of the committee based on the talks presented at the review, on the answers to the questions asked during the review, on the additional material provided during the review, and on discussions among the committee members. Prior to the issuance of this Final Report, a draft version was shared with the spokespersons of the experiment in order to provide them with an opportunity to correct factual errors. The findings and recommendations enumerated represent the consensus opinion of the committee as a whole.

Each section below addresses one of the principal charge questions. The committee members whose primary responsibility it was it address this charge question are included in parentheses at the beginning of each section. The lead writer has their name starred (*). Each section includes “Findings and Observations” and “Recommendations”.

2. Charge question #1

(D. Denisov*, N. Grossman, O. Gutsche, J. Konigsberg, J. Whitmore)

Is there a completed Experiment Operations Plan (EOP) document that includes a description of operations tasks and how they will be covered, ES&H activities and how they will be managed, organization charts showing the management structure for the experiment and how it interfaces to the laboratory, the model for data

processing and analysis including the budget and effort required, a list of identified resources available, and a description of the roles and responsibilities of each institution together with a list of the support required by each institution from the funding agencies?

Committee reply: A preliminary EOP exists that includes a thorough description of operations tasks and how they are covered, discusses ESH activities, provides org. charts for the collaboration and Fermilab and how they interface, and provides budget estimates for Fermilab for FY2015. It also references documents that provide an org. chart for the Far Site laboratory, run by the University of Minnesota, and how it interfaces with the collaboration and Fermilab (an MOU with the University of Minnesota) and that provide a detailed list of Fermilab Computing Sector responsibilities (Technical Scope of Work (TSW) with Fermilab Computing Sector (CS)). Although the collaboration has a detailed model for data processing, it is not described in the EOP or any of the documents referenced therein. The existing EOP discusses but does not quantify the resources needed or those available. The existing EOP discusses the roles and responsibilities of a small number of the NOvA collaborating institutions.

2.1 Findings and Observations

An Experimental Operations Plan for the NOvA Experiment has been written (dated October 24, 2014) and describes the main operational tasks of the experiment.

The EOP includes the estimated budget required to operate NOvA in FY2015. The FY2015 budget request, summed over the Near Detector (ND) and Far Detector (FD) and including resources for computing upgrades, additional spares, and test beam effort, is $2.3M. The budget was not justified in detail.

Organizational charts of the experiment, including operations, computing and physics analysis and interaction with the laboratory have been presented. Apart from the spokespeople, no formal term limits are defined for coordinating roles in the org chart.

The collaboration has identified the roles and tasks required for the M&O of the experiment and for the preparation and analysis of the data.

The collaboration has not quantified the personnel resources (ie. FTE) required to satisfy the detector maintenance and operations (M&O) and data preparation and analysis needs in FY2015 or beyond.

The collaboration has not quantified the personnel resources the collaboration can reasonably be expected to provide in FY2015 or beyond. They did present an extensive “Call list of Experts” that represents the collaboration’s support for detector operations.

Outside of shift responsibilities, which are assigned on a per-author basis, the collaboration has not formally established a list of institutional responsibilities or service requirements.

A Memorandum of Understanding (MOU) between the University of Minnesota for the Operation of the Ash River Laboratory and the NOvA Far Detector has been written, dated October 1, 2013. It does not reflect the current FNAL organization.

Other than specifying that the Ash River Laboratory is run by the University of Minnesota as described in an MOU, the EOP has no discussion of Far Detector M&O roles and responsibilities.

The Fermilab Neutrino Division is the host division for NOvA and is responsible for NOvA M&O and provides line management for ensuring that all applicable Environment, Safety and Health (ES&H) policies and standards are adhered to for the Near Detector M&O.

Mike Andrews is the Senior Safety Officer for the Fermilab Neutrino Division and serves as the ES&H liaison to the experiment. He is responsible for safety within the ND hall and the non-AD sections of NuMI. Mike is also supporting several other running experiments and projects.

The University of Minnesota will be responsible for ensuring that all applicable ES&H standards in the Ash River Laboratory are followed during the M&O of experiments located in the Laboratory. The Laboratory safety officer is responsible for maintaining a safe working environment, training permanent staff in safety procedures and conducting training sessions for visiting personnel.

ES&H emergency response at the Far Detector is not discussed explicitly in any of the documentation made available to the committee.

The status of the FD and ND were presented. Staffing for the M&O of the FD is provided predominantly by Ash River Laboratory personnel. The staffing for the M&O of the ND is provided predominantly by personnel from collaborating institutions and Fermilab. Critical information necessary for the detector M&O has been documented and posted on DocDB.

NOvA's processing and analysis model is well designed and tailored for the needs of the experiment. It uses many of the standard service offerings of the Scientific Computing Division (SCD), benefiting from long-term support from SCD (e.g. the art framework, SAM, CVMFS, FermiGrid).

A thorough TSW between the NOvA Experiment and the Fermilab Computing Sector for Support of Computing used in the Operation of the NOvA Experiment has been

developed and is dated October 1, 2013. It does not fully reflect the current FNAL organization.

Computing resource usage is documented and monitored. The resources provided by SCD are sufficient and are back-filled with opportunistic and commercial cloud resources as needed. The evolution of the computing resource needs has been studied and documented. There is no problem anticipated in meeting these future needs.

Neither the EOP nor the TSW provides estimates of the number of FTEs required to support NOvA M&O.

A detailed description of the roles and responsibilities of each institution together with a list of the support required by each institution from the funding agencies was not presented during the review or in the EOP.

Other than the MOU with the U. of Minnesota, as of the date of this review the collaboration has no formal agreements in place with any of the participating institutions.

The EOP for the NOvA Experiment lists spares and which institution is responsible for buying those spares in FY2015.

The total operations budget for FY2015 is significant, totaling over $2M. Aside from the "Other M&S????"

During the review it was stated that the U. of Minnesota Far Detector Laboratory Management Board last met about 1.5 years ago and has no regularly established meeting frequency.

The recent Fermilab reorganization has introduced some ambiguity in defining the laboratory roles. This is reflected in the current EOP.

Responses to recommendations from the 2013 Operations Review have not been formally documented.

2.2 Recommendations

1. Update the Experimental Operations Plan for the NOvA Experiment
   - to include a summary of the required FTE's needed for detector M&O; break-out the ND and FD requirements
   - to include a summary of the required FTEs needed to prepare the data for analysis
   - to include a summary of the available FTE resources from the collaboration

- to include the FTE summaries discussed in the top three sub-bullets for FY2015 – 2017
- to specify which Division/Section/Department within Fermilab is responsible for the purchase of any given spare assigned to the laboratory
- to include a summary of the roles and responsibilities at the FD with reference to the U. Minnesota MOU
- to include a signature page and a revision page.

2. Update "University of Minnesota NOvA Far Detector Building Safety Plan"
- to reflect the transition from FD assembly to FD M&O
- to reflect the current Fermilab organization
- to discuss emergency response plans
- to include signature and revision pages.

3. Update the MOU between University of Minnesota for the Operation of the NOvA Far Detector Laboratory and the NOvA Far Detector
- to reflect the current Fermilab organization
- to reference the above safety plan
- to require the Management Board to meet at least annually
- to include signature and revision pages.

4. Include signature and revision pages (or equivalent via DocDB) in all EOP, TSW, SOW, and MOU documents.

5. The current Neutrino Division Senior Safety Officer has significant ES&H responsibilities for multiple other experiments. Work with the laboratory to ensure sufficient effort is assigned to overseeing and managing the ES&H risks associated with NOvA operations.

6. As the details of the laboratory reorganization evolve, continue working with Fermilab to ensure you maintain access to the required level of laboratory personnel resources. Consider whether the EOP needs to include a discussion of the Particle Physics Division and its roles and responsibilities in NOvA M&O.

7. Consider whether to include in the EOP a discussion (or summary with reference to a document with additional details) of the plan for monitoring tritium production in the water collected along the NuMI beamline and RAW water systems.

8. Formally document a response to the NOvA recommendations from the February 2013 Fermilab Experiment Operational Readiness Review.

3. Charge question # 2

(J. Cherwinka, D. Glenzinski*, W. Louis)

Has it been demonstrated that the detectors are ready for physics-quality data taking? If not, what actions are required to make the detectors ready? Is there a clear plan for monitoring the data quality and has the associated infrastructure been tested? If not, what actions are required to adequately monitor the data quality once beam returns?

Committee reply: Yes, it has been demonstrated that both the Near Detector and the Far Detector are ready for physics-quality data taking. Yes, NOvA has a clear plan for monitoring the data quality, and the associated procedures and infrastructure have been demonstrated and are mature.

3.1 Findings and Observations

The FD and ND are both taking high-quality data with high efficiency.

The FD is operating with 0.8% bad channels, well below the maximum of 5% required to accomplish their physics goals. The FD uptime is about 95%.

Currently 12 out of 14 diblocks are fully instrumented and operational at the FD. The last two diblocks should be instrumented by December, 2014.

The ND is operating with 2.3% bad channels after a very short commissioning period. The collaboration expects to reduce this to <1% by December 2014. The ND uptime is about 90%. The ND is fully instrumented.

The ND has so far collected about a million neutrino events, while the FD has collected approximately a dozen neutrino events.

The FD is observing approximately 8 photoelectrons per cm of cosmic muon track length, which is well above the required 5 photoelectrons per cm.

Software is in place to perform data analysis. There is good agreement between the data and Monte Carlo events for many quantities in both the ND and FD. High-level discrimination of cosmic ray background using beam timing, detector geometric limits, and transverse momentum has been demonstrated. A final fitting framework, CAFAna, is working for Monte Carlo events.

There are three levels of real-time monitoring and two levels of higher latency monitoring. All levels of monitoring are performing at a high level. 652 TB of RAW data have been recorded so far and its quality checked using these monitoring tools.

The full suite of available monitoring tools provides a thorough check of the data quality from raw detector quantities to high-level analysis quantities after full reconstruction. These include a well-defined calibration workflow for each system. All the tools have been demonstrated and are being exercised regularly.

A Failure Mode Analysis has been performed for the most important detector elements, online systems, and offline systems. These have been used to develop first estimates of the required spares. A thorough Failure Mode Analysis has not been performed for the required infrastructure (e.g. building environment control or the cooling, dry air, and electrical back-up systems).

3.2 Recommendations

9. Consider quantifying the maximum number of bad channels allowed for both the FD and the ND. As failures occur, use these thresholds to balance the effort required for repair against the physics impact of delaying the repair. This may prove useful in later years when failures may be more frequent and personnel resources more limited.

10. Consider including environment and infrastructure monitoring to the suite of monitoring programs.

11. Perform a Failure Mode Analysis for infrastructure items (e.g. building environment control or the cooling, dry air, and electrical back-up systems). Use the analysis for appropriate plan maintenance and other risk mitigations associated with these items.

4. Charge question #3

(D. Denisov, J. Konigsberg, V. O'Dell*, J.Whitmore)

Have adequate resources from the laboratory and the collaboration been identified for the efficient and safe running and maintenance of the detectors, and is it clear who is responsible for what?

Committee reply: It appears that there are adequate resources, for the time being, to safely and efficiently maintain and operate the detectors. Clear roles and responsibilities have been defined. The collaboration has not yet quantified the effort needed to perform these tasks nor the amount of effort available from the collaboration and laboratory. Thus, the committee does not have sufficient information to comment on whether or not adequate resources have been identified for longer-term maintenance and operations.

4.1 Findings and Observations

Both the ND and FD are taking high-quality data with high efficiency. The detector M&O model is well thought-out and appears to be working well.

The NOvA collaboration has demonstrated that, for the time being, it can safely and efficiently maintain and operate the detector and prepare and analyze the data.

The detector M&O tasks as well as the tasks required to prepare and analyze the data have been clearly defined by the collaboration. For the time being, there appears to be adequate personnel resources available to accomplish these tasks.

The collaboration has not quantified the personnel resources (i.e. FTE) required to satisfy the detector M&O and data preparation and analysis needs in FY2015 or beyond.

The collaboration has not quantified the personnel resources the collaboration can reasonably be expected to provide in FY2015 or beyond.

Service contributions to data-taking shifts are tracked by the collaboration. Institutional quotas are assigned on a per-author basis. Each institution is responsible for ensuring they fulfill their quota of shifts.

Outside of shift quotas, the collaboration has not formally established a list of institutional responsibilities besides the MOU with the University of Minnesota for the M&O of the Ash River Laboratory and the FD.

The collaboration is in the process of developing formal agreements (e.g. Statements of Work or equivalent) with some collaborating institutions for the support of hardware spares and/or the maintenance of hardware/firmware.

A list of spare parts required for the detector operation has been developed. The quantity of spares appears to be sufficient for the anticipated 6yr operation of the detector with the exception of a few items. In particular, it may be necessary to purchase additional spare TEC control valves for the ND and additional spare APDs for the FD.

During the review it was stated that at 700 kW of beam power the NuMI target will have to be replaced about every six months. There are sufficient spare NuMI targets and horns on hand for the coming year and the operations plan includes purchasing additional spares each year as necessary.

The collaboration has begun a study of the rate of failures for various components. The detector has not been operating long enough to predict long term trends with confidence.

The Fermilab support required by NOvA crosses divisional boundaries. Specifically, the detector M&O and data processing needs will require resources from the newly formed Neutrino Division, the Computing Sector, and, likely, the Particle Physics Division.

4.2 Recommendations

12. Quantify and develop multi-year estimates of the personnel resources needed and those available from collaborating institutions to safely and efficiently maintain and operate the near and far detectors and to safely and efficiently prepare and analyze the data.

13. Formalize institutional responsibilities for shift quotas, detector M&O, and data analysis preparations via MOUs (or equivalent) with all collaborating institutions.

14. Continue to study and monitor the rate of component failures. Modify the plan for purchasing and repairing spare parts accordingly.

15. Determine the appropriate number of spare APDs required for the FD. Work with Fermilab and the vendor to develop a cost-effective plan for obtaining the required number. Ensure the Neutrino Division budget includes the resources required to enact this plan.

16. Ensure the laboratory has enough space to appropriately store the spent radioactive components generated by expected NuMI target and horn replacements. Consider adding a discussion of this to the EOP.

5. Charge question #4

(M. Convery*, O. Gutsche, W. Louis)

Based on realistic expectations for accelerator performance, is there a well-understood run plan for FY15, and are there clear science goals for the Summer 2015 conferences? Have adequate resources from the laboratory and collaboration been identified for the data analysis to meet these goals?

Committee reply: Yes, clear science goals have been defined, consistent with realistic expectations for protons-on-target (POT) in FY2015. It appears that adequate resources have been identified to meet these goals.

5.1 Findings and Observations

The NOvA experiment expects to collect 2-3 x 10^{20} POT in FY15. The run plan for FY15 is well defined. No special runs or changes of run configuration are planned.

The main physics measurements planned by the NOvA experiment are statistically limited, even after the full exposure (36 x 10^{20} POT). A ν_μ disappearance measurement requires a minimum of $4x10^{20}$ POT to reach a sensitivity comparable to that currently achieved by competing experiments. A minimum of $6x10^{20}$ POT will be needed for a 5σ $\nu_\mu \rightarrow \nu_e$ appearance signal. These measurements use information from both the ND and FD.

The ND has collected over a million neutrino events over a running period of less than a month and will provide very high statistics datasets with which to perform analyses.

The collaboration has identified a set of physics topics that can be pursued using the expected FY2015 data sets. Topics include using the ND data to measure cross-sections and to search for exotica. Topics also include using the FD to study cosmic-rays, atmospheric neutrinos, and supernovae.

The collaboration has implemented new triggers that enable the physics program discussed in the previous paragraph. Since physics trigger processing is done in software, triggers can be changed quickly to accommodate the physics interests of the collaboration.

The collaboration has developed extensive analysis tools to support the high-profile neutrino-mixing analyses. It was unclear to the committee if any additional tools are required to perform the cross-section, exotica, etc. analyses that will dominate the NOvA physics program in the near term.

It is important that the accelerator reaches 700 kW on target and provides to NOvA the nominal 6 x 10^{20} POT per year in a timely manner. Extrapolations of NOvA's sensitivity show that if the accelerator performance cannot be increased as planned, the experiment's goals are in danger. In particular, NOvA's sensitivity to the neutrino mass hierarchy and to CP-violation in the neutrino sector is significantly compromised.

5.2 Recommendations

17. The collaboration is encouraged to continue pursing physics analyses beyond the high profile neutrino analyses in order to grow the number of viable thesis/paper topics.

18. Revisit the suite of analysis tools available in light of the short-term physics analyses that are likely to be completed and published. Ensure the appropriate tools have been developed and tested.

19. The collaboration should work with the Fermilab Program Planning Office to coordinate run plans with the rest of the NuMI program, e.g. neutrino vs. anti-neutrino running.

20. The laboratory should continue to work toward upgrading the Booster to 15 Hz operation in order to increase the POT/yr delivered to NOvA and the rest of the Fermilab program.

6. Summary

The NOvA experiment was reviewed for its readiness to transition from detector assembly to data-taking and analysis operations. The review committee was provided with a set of NOvA documents relevant to addressing the charge questions. The NOvA collaboration also made a full day's worth of presentations to the review committee. The committee was very grateful for all of the collaboration's efforts to provide the required input.

The committee wishes to first congratulate NOvA on completing the detector construction in a timely manner and for their rapid turn-on of the detector. The committee was impressed with the maturity of the online tools and procedures in use, the professional approach of the offline processes, and the preparedness of the collaboration for analysis. The collaboration has developed a thorough model for detector maintenance and operations, for preparing the data for analysis, and for analyzing the data. It appears that the necessary resources have been identified to accomplish all the necessary tasks in a safe and efficient manner, although work remains to quantify the required personnel resources and to formalize commitments from the collaborating institutions. Good channels of communication have been established with Fermilab and the Ash River Laboratory and bode well for the continued success of the experiment.

The committee identified no significant issues, but has provided above a list of 20 recommendations that are meant to mitigate the remaining operational risks. The committee recommends that items 1-4, 8, and 15 be addressed by March 2015 and that the NOvA collaboration provide regular progress reports concerning the remaining items at the Experiment Management Group meetings.

The committee believes that the NOvA collaboration is poised for success in the coming year and for many years to come.

Appendix A – Charge

October 1 , 2014

NOvA Experiment Readiness Review
October 28th, 2014

The NOvA Near and Far Detectors are now complete and are expected to receive about 2E20 protons on target (POT) in FY15, and a total of 36E20 POT within the coming decade. We would like the committee to review the preparations for running, maintaining the detectors, and data taking and analysis, including the current status of the detector, the status of the online and offline software and the run plan. In particular:

1. Is there a completed Experiment Operations Plan (EOP) document that includes a description of operations tasks and they will be covered, ES&H activities and how they will be managed, organization charts showing the management structure for the experiment and how it interfaces to the laboratory, the model for data processing and analysis including the budget and effort required, a list of identified resources available, and a description of the roles and responsibilities of each institution together with a list of the support required by each institution from the funding agencies?
2. Has it been demonstrated that the detectors are ready for physics-quality data taking? If not, what actions are required to make the detectors ready? Is there a clear plan for monitoring the data quality and has the associated infrastructre been tested? If not, what actions are required to adequately monitor the data quality once beam returns?
3. Have adequate resources from the laboratory and the collaboration been identified for the efficient and safe running and maintenance of the detectors, and is it clear who is responsible for what?
4. Based on realistic expectations for accelerator performance, is there a well-understood run plan for FY15, and are there clear science goals for the Summer 2015 conferences? Have adequate resources from the laboratory and collaboration been identified for the data analysis to meet these goals?

We would like a brief written report addressing these questions by November 7th, 2014.

Appendix B – Committee Membership

Jeff Cherwinka (Wisconsin)
Mary Convery (Fermilab)
Dmitri Denisov (Fermilab)
Doug Glenzinski (Fermilab – Chair)
Nancy Grossman (ANL)
Oliver Gutsche (Fermilab)
Jaco Konigsberg (U. Florida)
Bill Louis (LANL)
Vivian O'Dell (Fermilab)
Julie Whitmore (Fermilab)