October 29, 2015

Final Report
LArIAT Operational Readiness Review

1. Introduction

The Fermilab Program Planning Office (Steve Geer, Pushpa Bhat) charged a committee to review the operational readiness of the LArIAT experiment in the fall of 2015. The charge is provided in Appendix A and the committee membership is provided in Appendix B. The review took place on October 14-15, 2015 and the agenda and the relevant materials are available from this URL, https://indico.fnal.gov/conferenceDisplay.py?confId=10518. Following the last talk, the committee met to discuss first impressions, to formulate additional questions, and to make writing assignments. In the days following the review some additional material was provided in response to requests and questions from the committee.

This report describes the findings, comments, 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 in the days following 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 to 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", "Comments", and "Recommendations".

2. Charge question #1

(D. Denisov*, A. Hemmati, V. O'Dell, M. Quinn, J. Whitmore)

Is there a completed Experiment Operations Plan (EOP) document? The document should include (a) a description of operations tasks and how they will be covered, (b) ES&H activities and how they will be managed, (c) organization charts showing the management structure for the experiment and how it interfaces with the laboratory, (d) the model for data processing and analysis including the budget and effort required, (e) a list of the identified resources available, and (f) 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.

Yes, a completed EOP document exists.

2.1 Findings

- There is a LArIAT EOP document dated October 1, 2015 with 22 pages.
- The EOP contains information on the experiment science goals, the experiment layout, the collaboration organization, the responsibilities of Fermilab's Divisions, the table of available spares, past spending and resources, as well as run plan and institutional responsibilities.

2.2 Comments

- (a) EOP includes a brief description of the operation plan, while no detailed information about resources required for Run II is provided.
- (b) There is no information about ES&H activities and how they will be managed in the EOP.
- (c) A collaboration organizational chart is provided in the EOP and the relevant TSW documents exist. The organizational chart provided in the EOP and the accompanying discussion is relevant for the lifetime of LArIAT. The names that appear are for Run I and it is not mentioned if changes are required for Run II. While TSW with computing divisions is recent, the test beam TSW is from 2013 and does not fully represent current status of the activities.
- (d) While analysis of the Run I data is actively progressing the EOP does not include models for the data processing and analysis and there is no information about budget and effort required.
- (e) The list of the identified resources from the collaboration groups is available in the EOP.
- (f) There is a comprehensive list of resources provided by the collaboration groups and by the laboratory. However, the EOP does not contain an explicit estimate of the required effort to operate the experiment and perform data analyses. The EOP does not contain information on the support required from the funding agencies.

2.3 Recommendations

1. The EOP should be updated to include a more detailed discussion of the ES&H organization, functional role, responsibilities, and personnel.
2. In consultation with Program Planning, the EOP should be updated to address the other deficiencies identified in the Comments of Sec. 2.2.

3. Charge question # 2

(M. Convery, D. Glenzinski*, W. Louis)

Has it been demonstrated that the detector is ready for physics-quality data taking? If not, what actions are required to make the detector 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?

The LArIAT detectors took physics quality data in 2015. Assuming a smooth reassembly and commissioning, they will be ready for physics-quality data taking in 2016. A clear monitoring and DQ plan exists and the required tools were successfully employed in 2015.

3.1 Findings

- The LArIAT beamline detectors were commissioned in a 2 week run in August 2014.
- The full suite of LArIAT detectors, including the TPC, were commissioned and took 6 weeks of high quality data from May-July 2015 (Run-1).
- Online and Offline DQ tools were used to monitor data quality and Ar purity during Run-1.
- Preliminary results were shown using Run-1 data from the MWPC, TOF, Halo Veto, TPC, and TPC-LC systems.
- There is a short list of detector improvements for Run-2, including some to the TPC, which has been disassembled.
- For a limited number of detector components there are no spares.

3.2 Comments

- Prior to Run-2 implement the Aerogel Cerenkov reconstruction to verify its physics performance for low momentum muon/pion separation.

3.3 Recommendations

3. For components that have no spares, either identify tenable backup plans or work with ND to purchase the required components.
4. Develop a prioritized plan in preparation for Run-2 that integrates detector preparations with Run-1 analysis goals. Identify people to do the work. Understand external competition for resources. Develop fallback plans for the highest risk activities.

4. Charge question #3

(D. Denisov, A. Hemmati, V. O'Dell*, M. Quinn, J. Whitmore)

Is there a well-understood run plan for FY16, consistent with accelerator schedule and performance? Have adequate resources from the laboratory and the collaboration been identified for an efficient and safe running of the experiment and for maintenance of the detector, and is it clear who is responsible for what?

The goal for 2016 is to collect 6x the 2015 statistics in a 10-14 week run beginning in February or so. A detailed run plan, including the requested beam settings, will be developed once analysis of Run-1 data has further matured. Most of the required resources have been identified but a shortfall in Run Coordinator effort needs to be addressed. Responsibilities are clearly spelled-out in the EOP. It may be prudent to formalize laboratory commitments.

4.1 Findings

- The Run-2 goal is to collect 6x the Run-1 statistics in a 10-14 week physics run. While a comprehensive list of physics goals for Run-2 exists, the required beam settings to accomplish these goals with Run-2 will be detailed only after analyzing data from Run-1.
- A few repairs/improvements to the LArIAT experiment are required before Run-2. Some of the people involved in the detector work are also analyzing Run-1 data and/or are involved in other experiments that will operate simultaneously.
- The current FNAL accelerator schedule accommodates sufficient beam to LArIAT from mid-February to the start of the summer shutdown that starts in July of 2016.
- The EOP includes an organization chart that specifies a lead person for each of the detector subsystems, the trigger, and the DAQ. It also specifies an Accelerator liaison.
- The EOP includes sections that summarize the responsibilities of the relevant FNAL divisions as well as a table that specifies institutional responsibility for the detector subsystems.
- The addition of some steel in the upstream portion of the LArIAT beamline could significantly reduce beam halo at the detector, resulting in a significantly improved beam quality.
- Implementing the halo suppressing steel will require beam tests, without the LAr detectors, in Nov-Dec 2015.

4.2 Comments

- Since the beam settings for Run-2 are informed by the Run-1 analysis, it is critical to finish the Run-1 work in a timely fashion.
- In order to collect 6x the statistics in a 10-14 week physics run, the accelerator duty cycle, beam quality, and LArIAT data collection and

reconstruction/selection efficiencies must collectively provide a factor of 3-4 improvement.

- Some LArIAT collaborators are working on detector improvements and analysis simultaneously. Prioritizing tasks is paramount for the success of Run-2. However, we note that most of the improvements are small and do not require much time (~days) to implement. An exception is for the planned modifications to the cryogenics system, which is projected to take 4-6 weeks. These modifications will not impact physics performance, but might save around $100/day in LAr costs. It should be noted that these modifications do not require much effort from the collaboration.
- LArIAT and MicroBooNE experiments share personnel and close communication will be critical during simultaneous operations of the two experiments to ensure resource conflicts are understood well in advance of a crisis.
- The TSWs for LArIAT and the FTBF detail the FNAL and non-FNAL responsibilities for the experiment, however there is no mention of the Neutrino Division since it didn't exist at the time these were first written.

4.3 Recommendations

5. A clear statement of run time and beam settings for 2016 should be made once the Run-1 analysis is far enough along. The run plan should include time for beam tuning and optimization studies as required.
6. The shielding to suppress beam halo background appears to be critical to the efficient collection of the required statistics. This shielding should be actively pursued for Run-2, including beam tests without the LAr detector in place well in advance of the February start of Run-2.
7. LArIAT leadership should work with their collaboration and Fermilab to identify the resource short fall for the Run-2 Run Coordinator effort.

5. Charge question #4

(J. Konigsberg, W. Louis, A. Norman*)

Are there robust plans for data processing and data analysis? Have adequate resources from the laboratory and the collaboration been identified for data analysis to meet these goals?

Good progress has been made in establishing a robust data processing and analysis plan. The data reprocessing plan seems reasonable. The resource needs are quite modest and the available resources appear to be adequate.

5.1 Findings

- Preliminary analysis results for pion-argon scattering cross sections, for light yield and muon charge identification studies using Michel electrons, and for light-charge correlation studies were presented.
- The collaboration has enumerated a list of analysis topics and has identified institutions that are interested in participating in each topic.
- The collaboration has identified the need for centralized data processing and Monte Carlo production to support their analysis activities.
- They have identified a group of four individuals (1 senior scientist, 3 post-doctoral researchers) who will carry out the data processing activities for the current Run-1 dataset.
- The scope of the data processing/reprocessing efforts has been partially demonstrated by reprocessing of the cosmic ray data from 2 months of running in 2015. Using current resources, this effort took approximately 1 week of calendar time.
- The estimated size of the raw LArIAT data set for a 12-14 week run is about 10 TB.
- LArIAT estimates that they need about 4 FTE to meet their full Monte Carlo plan, while only 2 FTE of effort have been identified.

5.2 Comments

- The number of studies/analysis projects that have been identified is large when compared to the size of the collaboration. The impact of these projects to the primary analysis efforts should be understood, especially with respect to decisions that must be made regarding Run-2 run plans.
- Formally document the resources required to reconstruct data in terms of computation time, event sizes, inflation factors, etc. Use these to estimate future resource needs.
- The Monte Carlo effort needs to be coordinated and prioritized across the physics groups. Additional simulation FTE effort and high priority simulation samples need to be identified.

5.3 Recommendations

8. Work with SCD to ensure adequate computing resources are available to complete Run-1 analyses and to begin Run-2 analyses assuming 6x the current statistics.
9. The impact of the resource shortfall in the simulations group should be evaluated and appropriate mitigations should be developed.

6. Charge question #5

(M. Convery*, D. Glenzinski, J. Konigsberg)

Are there clear goals set for reporting and publishing the results from the experiment in a timely fashion?

LArIAT has established a clear set of reporting and publishing goals in the near term using Run-1 data. It appears that fast-track analyses will be ready for early 2016. The full suite of analysis goals will follow and appear to be progressing according to plan..

6.1 Findings

- The LArIAT collaboration has identified a set of physics goals that include scattering cross sections of pions and kaons with argon, discrimination between electron- and photon-initiated showers, investigation of recombination effects, energy calibration of charge and light measurements, and validation of GEANT4.
- LArIAT has identified a short list of "Fast-track" analyses and "Foundational" analyses that they are pursuing at high priority.
- LArIAT's goal is to publish within 6 months of the end of Run-1 data taking. They are aiming to have publication-quality pion-argon cross section results by January 2016.
- The preparations for Run-2 are also needed by early 2016.
- The internal approval procedures are currently under discussion by the LArIAT collaboration.

6.2 Comments

- Consider developing an integrated plan that includes the preparatory work for Run-2 and the Run-1 analysis work. Specify the people doing the work. Consider the effect of resource competition.

6.3 Recommendations

10. Finalize the internal approval procedures well ahead of first Run-1 results to ensure expediency without compromising quality.
11. Develop a plan to ensure a strong showing at the LAr Workshop in January 2016.

7. Charge question #6

(J. Konigsberg, W. Louis, A. Norman*)

Does the proposed scope and run plan serve the purpose of the neutrino community? Does the committee recommend further actions to ensure full exploitation of the LArIAT program?

Yes. LArIAT physics goals appear consistent with the needs of the neutrino community, but the degree to which these will be addressed is not completely clear. The issue will be discussed at the January LAr Workshop. The 2016 run will not address the full list of possible studies. There needs to be a coordinated effort to prioritize and address the remaining items.

7.1 Findings

- The amount of data required to achieve the stated physics sensitivities of the individual analyses has been estimated to be 6x the current Run-1 data set.
- A list of physics goals for Run-2 was presented.
- There is significant overlap in the personnel on LArIAT and those on other neutrino experiments, some of which will take data simultaneously with LArIAT.
- There is a strong demand in the LAr community for an R&D facility in which to test a wide variety of detector and analysis ideas that might affect the design and optimization of future experiments.

7.2 Comments

- An effort should be made to develop a run plan that directly addresses the highest priority goals of the experiment while minimizing the risks associated with delays or set backs in the analysis efforts.
- LArIAT should understand the pros and cons of having a large fraction of personnel involved in efforts outside of LArIAT.

7.3 Recommendations

12. Participate in the January 2016 LAr Workshop.
13. The relevant stakeholders in the LAr community, in consultation with FNAL and the funding agencies, should develop a prioritized list of R&D studies of importance to future LAr-based experiments. This list should be mapped onto planned LAr facilities/experiments. There should be an evaluation of the need for a LAr R&D facility at MCenter (or similar) beyond 2016.

8. Summary

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

The committee wishes first to congratulate LArIAT on the rapid commissioning and successful data taking in 2015. The committee was impressed with the organization, professionalism, and enthusiasm of the collaboration. The committee was encouraged by the preliminary physics studies shown and believes first results are on track for an early 2016 showing. The committee believes that LArIAT is in a good position to capitalize on 2016 running and deliver on many of its physics goals.

The committee identified no show stoppers, but has provided above a list of 13 recommendations that are meant to mitigate the most significant remaining operational risks. Since 2016 data taking is scheduled to begin in February, the responses will have to be pursued with some urgency. The committee suggests that the LArIAT collaboration provide regular progress reports at the Experiment Management Group meetings.

Appendix A – Charge

September 4 , 2015

LArIAT Experiment Operational Readiness Review

October 13-14, 2015

CHARGE

The LArIAT experiment (Liquid Argon TPC in a Test Beam) has completed the commissioning of its detector and is beginning operations with beam, which may last for 1-2 years. The primary goal of the experiment is to develop a comprehensive characterization of the performance of LArTPC to a variety of charged particles and photons, relevant to future neutrino physics experiments. We would like the committee to review the preparations for running, plans for maintenance & operations of 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? The document should include (a) a description of operations tasks and how they will be covered, (b) ES&H activities and how they will be managed, (c) organization charts showing the management structure for the experiment and how it interfaces with the laboratory, (d) the model for data processing and analysis including the budget and effort required, (e) a list of the identified resources available, and (f) 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 detector is ready for physics-quality data taking? If not, what actions are required to make the detector 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?

3. Is there a well-understood run plan for FY16, consistent with accelerator schedule and performance? Have adequate resources from the laboratory and the collaboration been identified for an efficient and safe running of the experiment and for maintenance of the detector, and is it clear who is responsible for what?

4. Are there robust plans for data processing and data analysis? Have adequate

resources from the laboratory and the collaboration been identified for data analysis to meet these goals?

5. Are there clear goals set for reporting and publishing the results from the experiment in a timely fashion?

6. Does the proposed scope and run plan serve the purpose of the neutrino community? Does the committee recommend further actions to ensure full exploitation of the LArIAT program?

We request a brief written closeout report from the committee addressing these questions by October 30, 2015.

Appendix B – Committee Membership

Mary Convery (Fermilab)
Dmitri Denisov (Fermilab)
Doug Glenzinski (Fermilab – Chair)
Ali Hemmati (Fermilab)
Matt Quinn (Fermilab)
Jaco Konigsberg (U. Florida)
Bill Louis (LANL)
Andrew Normal (Fermilab)
Vivian O'Dell (Fermilab)
Julie Whitmore (Fermilab)