NSF ATLAS Final Design Review

September 2019

Executive Summary

- **Panel's opinion:**
  - *We believe the project will be ready for the scope of activities proposed for MREFC funding by April 2020 – **<u>we unanimously consider this FDR successfully passed</u>**.*
  - *Scope/budget/schedule/risk information has been developed and was explored in detail by the Panel; we found the project definition to be well-structured, comprehensive, detailed and precise.*
  - *Technical and programmatic risks/uncertainties are well-documented, understood, impacts appear understood and reasonably bounded, and careful risk management is underway.*
  - *An experienced and well-prepared team is in place, including significant Phase 1 experience. Effective management of the subsystems by the project office is apparent.*
  - *The ATLAS MREFC team is planning to appropriately leverage the project as an opportunity to educate & broaden participation. Further development of these plans are a priority.*
  - *External risks are visible: CERN schedule, commodity prices etc. – and the project has developed detailed estimates of impacts and have developed workarounds/mitigations to address.*

- *Separation of the pre-MREFC and MREFC tasks (an issue noted at PDR) is now adequately defined and appropriate.*
- *The work remaining between this review and the start of project (April 2020) includes key activities and important decisions – we encourage the project and NSF to work together closely to monitor the outcomes through the end of the pre-MREFC phase.*
- *We believe the Construction Readiness Criteria items 1-5 (Completion of Design Development Phase; Project Scope Definition; Project Budget detailed; Project Schedule Integrated; PM/PEP/subaward management in place) have been met by all four technical subsystems.*
- *Risk Management procedures and positive attitudes/culture are highly-visible and being used effectively by the project.*
- *Project Office leadership and interactions with CAMs is effective and provides confidence that the MREFC project will be well managed.*
- *An excellent science case and exemplary flow down to technical and operating requirements was demonstrated. "Highlight of the review"*

Strengths

- Exciting science case
- Effective pre-MREFC development phase
- Timely technical interaction with CERN over past few years…
- Informative Phase 1 experience + experienced teams/management
- Excellent team/project evolution over CoDR/PDR/FDR sequence
- Project has developed a strategy which minimizes coupling to external schedules & deliverables
- BNL partnership re: Project Management systems

Weaknesses

- Some exposure to commodity price changes…
- Dependency on scientific workforce (funded by NSF/DOE through other programs and "guaranteed")
- While the project has minimized potential external impacts, some dependencies on external schedules and deliverables inevitably remain

(All of these quantified in risk methodology)

Opportunities

- Some "up scope" options are available depending on positive project outcomes
- If (CERN delay) & if (careful management) then some additional testing/development possible? *(PM discipline required…)*
- As EPO plan develops, additional opportunities may arise.

Threats

- External factors (mentioned)
- Poor outcome in remaining testing (e.g. rad hardness, forcing redesign).

Management

- **Based upon the panel's examination of the project team's technical preparation and preconstruction planning, is the project team ready to undertake MREFC-funded construction in April 2020?**
- We believe the Construction Readiness Criteria items 1-5 (Completion of Design Development Phase; Project Scope Definition; Project Budget detailed; Project Schedule Integrated; PM/PEP/subaward management in place) have been met by all four technical subsystems.

- **Based upon the FDR panel's assessment of the project team's risk planning, advise NSF of the panel's level of confidence that the project team can complete the proposed scope of work within the budget and schedule requested.**

- We have confidence that the project can complete the proposed scope of work within the budget and schedule requested. Detailed risk analysis of the program is underway, and in many cases mitigations and "Plan Bs" are identified. Risk Management procedures and positive attitudes/culture are highly-visible and being used effectively by the project. We believe the risk management criteria have been met.

- **Does the project team have a meritorious plan to leverage NSF’s MREFC investment in the high luminosity detector upgrade to achieve broader societal impacts?**
- Their focus on the people doing the work has a lot of merit. Although in a relatively early stage of development (compared to the technical definition of the project), planning for these activities is actively underway.

- **Recommend issues, if any, for special NSF attention during remaining planning activities or during the first year of construction. Advise NSF on the adequacy of plans for financial and technical status reporting, and for oversight of subawardee performance by the awardee.**
- The Panel cannot identify anything in the remaining development phase requiring additional scrutiny.

Subsystems

Trigger

- **L0 CalorimeterTrigger**

- **Comments/Conclusions:** This is a straight forward project to complete with little technical risk.

Trigger

- **HTT**

- **Comments/Conclusions:** The project is well motivated by a multitude of physics channels. The late fabrication of the hardware is appropriate for a project of this nature. The addition of engineering to the project is very welcome, although, there is a risk (included in the risk register) that it may still not be adequate.

Trigger

- **Global trigger**

- **Comments/Conclusions:** The project appears to be particularly well organized, which is important given the variety of institutions participating in it. The project is very strongly motivated by the physics goals of the project.

Liquid Argon

Comments:

- The team has clearly demonstrated the positive science impact of the LAr system upgrade with specific examples. The design choices and specifications are rooted in physics goals such as the dynamic range of the FEB board for precision Higg's mass measurements.
- The Interface between the NSF and DOE scopes are clearly defined, though the dependence on the preamp/shaper ASIC continues to carry risks for the FEB2 deliverables and should be closely monitored.
- The staged approach for developing the ADC ASIC has provided confidence and validation to the designs. Issues occurred in COLUVAv1 and v2 of the pre-prototypes have been identified and addressed in the v3 design. The radiation test for the COLUVAv3 chip should be scheduled as early as feasible so the test results can provide input into the prototype design.

Liquid Argon

- The number of development and protype design cycles of calorimeter system ASICs is well motivated.
- There has been excellent progress on the custom ADC development evident if performance of version-2. Version-3 is a substantial fully functional evolution from version-2. The project is well advised to retain the COTS risk mitigation strategy through to comprehensive radiation hardness studies of version-3.
- The project has studied system strategies to fall-back from the nominal dual 14-bit range design to a single range design. The project is well advised to retain and develop as necessary this fall-back option in order to preserve descope options.

Tile Cal

Comments:

The Tile Calorimetry design is mature and has benefited from a well thought out program of prototypes and beam tests.

- The “Main Board” (6.5.1) design is particularly mature and is construction ready.

- The Low Voltage Power Supply (LVPS) control card “ELMB2” motherboard (6.5.3) scope has been substantially simplified with CERN’s recent decision to postpone development of the ELMB++ controller in favor of evolving the existing ELMB controller to ELMB2. The reduced scope is now relatively modest and could reasonably combined with the LVPS (6.5.4) scope.

- The power distribution system has been simplified since the NSF PDR and is considerably more robust through point-of-load regulation on the Main Board. Radiation qualification of components is underway. Radiation tolerance of the ELMB2 control board is potentially an issue.

Tile Cal

Recommendations:

- The Project teams should clarify and clearly document the requirements for LVPS radiation tolerance and the strategy for verifying compliance. Mitigation strategies in the case of marginal tolerance should be identified and clearly documented.

Muons

Comments:

- L0MDT trigger: the post-PDR technology change (adoption of the Apollo standard) results in a streamlined design, fewer on-board FPGA's, and better cooling of the trigger boards. It creates an additional external dependence on the CMS project, however it might also allow to benefit from the board testing by CMS.
- CSM dependence on lpGBT is common for all LHC upgrade projects. The existing version of lpGBT chip satisfies radiation tolerance requirements of the ATLAS muon upgrade.
- The team has an excellent track record with many decades of experience in the design and test of gas detectors, precision timing electronics, and online data processing.
- The current status of the muon system meets the technical criteria for NSF FDR.
- We believe the project is on track to be ready for production in April 2020.

Education/Public Outreach

The Education and Outreach plan presents substantive, implementation ready plans for leveraging MREFC funding to promote educational outreach and broader impacts. It is centered on a few crisply defined activities that showcase how NSF's MREFC funding will be leveraged within the context of the broader base experimental particle physics research program at the LHC. It includes plans for assessment of impacts.

Findings:

The Education and Outreach (EPO) plan identifies that the major opportunity for leveraging MREFC funding to promote educational outreach and broader impacts is through the specific project work opportunities for 100 undergraduates and high school students in the activity of the participating institutions.

Comments/Conclusions: Overall the outcomes of the EPO plan could be articulated better. This is an amazing opportunity to engage 100 students in work on a major project involving many institutions across the country. Most of these participants will become an important addition to the physics and technical community in the future. During the FDR the project agreed to explore this idea and also to add the inclusion of EPO reporting requirements from the level 3 projects through level 2 leaders to the project EPO leader and the project leadership as a whole. This latter addition will provide the mechanism to make sure that the EPO goals are pursued by the project.

Recommendations:

- The EPO plan and goals need to be more clearly defined articulated (see number 2 below as well)
- The proposed creation of a network of the individual EPO leads that meets periodically to provide a cross project (and across field) learning opportunity as well as reinforcement of participation in the cross project student activities.
- The proposed inclusion of EPO reporting requirements from the level 3 projects through level 2 leaders to the project EPO leader to provide confidence that the EPO goals will be addressed by the project.

The Education Plan includes a diversity plan, with an implementation strategy and metrics.

Findings: The project does not yet provide a clear project level diversity plan with a specific implementation strategy and metrics. There are no baseline or goals established to work from. While the project depends on the existing diversity strategies of the individual institutions to carry out this work that may be effective, there is no rollup of what this would mean at the project levels.

Comments/Conclusions:

The lack of an overall project level plan and a set of goals on diversity may limit the potential of this project to affect diversity and inclusion. To develop this plan further it would be helpful for the project team to get further advice from others engaged with Diversity and Inclusion including experienced members of QuarkNet and the US ATLAS Diversity and Inclusion Committee. During FDR response the project discussed future efforts to connect with the US ATLAS Diversity and Inclusion Committee and the development of a US ATLAS HL-LHC EPO committee that would be helpful. As mentioned in #2, there is a great opportunity for the project to develop a network of the EPO provider leaders to support a discussion of best practices. During the FDR the project agreed to explore this idea.

Recommendations:

- Develop a plan at the project level that identifies an implementation strategy and metrics that can be reviewed at the next project review.
- Develop a project diversity and inclusion steering committee (US ATLAS HL-LHC EPO committee) with knowledgeable members of the US ATLAS Diversity and Inclusion Committee, QuarkNet, and other diversity and Inclusion specialists as advisors.
- Add a periodic meeting of the EPO leads from each engaged campus to discuss diversity issues and metrics progress

The plan documents additional education and outreach opportunities, beyond those with (relatively) assured funding through the MREFC and base programs. Additional activities described could further expand the reach and impact of the MREFC/Education leveraging plan, using additional funds obtained following successful competitive review of additional proposals to NSF (or elsewhere).

Findings: Additional education and outreach opportunities exist at the individual institutional level that can be leveraged by the HL-LHC Upgrade project. The local project staff is well prepared to take advantage of these opportunities. There could be additional funding opportunities for additional EPO work.

Comments/Conclusions:

- It would be helpful to develop a periodic mechanism to collect these more ad hoc local institutional EPO events at the project level. Given the fact that the public does not understand how major science instrument projects are developed and supported, it would be useful for the project to develop a common communication path (IE logo set or introductory PowerPoint slide to provide project and NSF identity.
- There is also potential mentioned for additional EPO projects to be developed for funded by NSF and others. It is not clear who will be responsible for driving this opportunity in the project.

Recommendations:

- The project should identify a mechanism to identify and collect at the project level the local additional EPO activity and also develop a way to commonly identify the connection of these activities publically to NSF and the ATLAS Hl-LHC Upgrade project

- The project should identify potential partners/collaborators for further EPO work and the project point person who will be responsible for identifying additional funding for this EPO work.

Cost/Schedule/Risk

- ***Project Budget***
  - ***The complete scope of work to be funded by NSF with MREFC funds is captured in a detailed WBS format, accompanied by a WBS dictionary defining the scope of all entries.***
- *FINDING: The Panel finds that complete Atlas NSF scope is captured in a detailed WBS format and is accompanied by a WBS dictionary which defines the scope of all entries.*

The bottom-up cost estimate is well-supported, assumptions are reasonable, and all costs (including estimated costs for project management staff, common costs, COLA, and teaching buyouts) are incorporated into the resource-loaded schedule.

- *FINDING: The sampled bottom-up cost estimates were well supported and the assumptions were generally reasonable. All costs sampled were incorporated into the resource-load schedule.*
- *COMMENT: The procurement plan for the WBS 6.8.2 HTT purchases anticipates the purchase, manufacture and receipt of $5.6M of hardware in a single year. The Project recognizes this as a risk and plans to mitigate it by working with the ultimate supplier(s).*
- *RECOMMENDATION: The Project should contact potential suppliers prior the start of the MREFC phase to verify that its assumptions regarding throughput are reasonable.*

- ***The NSF funding and obligation profiles from NSF to the project are consistent with risk-adjusted project obligation/expenditure plan (i.e. the risk-adjusted budget profile includes the contingency budget profile based on forecast risks and when they might be realized).***

- *FINDING: The NSF funding plan appears to be adequate to cover the planned annual risk-adjusted costs estimated by the Project.*

- *COMMENT: The Project's 'best estimate' anticipates the expenditure of all of its contingency. In addition, the Project has prepared a reasonable plan which identifies about 15% of the budgeted cost (descopes) for removal subject to negotiations with CERN.*

- ***Task durations and schedule estimates are reasonable and based on the technical requirements and past experiences, including the schedule needs for testing new technologies.***

- *FINDING (a & b): The Project has prepared a critical path for the overall project. Durations for individual tasks are based on best case scenarios and individual tasks do not generally do not contain schedule slack. Generally, all float is aggregated at the highest WBS level.*
- *COMMENT: Given that all float is aggregated at a high WBS level, the use of float will be a draw on contingency.*

- ***The project has satisfactorily documented interfaces (internal and external of the NSF scope) and has processes in place for controlling interface changes.***

- *Finding: The Project is fully capable of documenting and controlling both internal and external interfaces.*

- *ATLAS has schedule substantial float (one to two years) prior to current CERN need dates. ATLAS Global Risk ($1.1M – $3.9M cost range) RN-06-10-01-005 also addresses this issue.*

- ***The RLS defines adequate schedule float for delivery and acceptance testing in advance of the "need by" dates of the international construction effort.***

- *Finding: The Project has ample schedule float in each WBS to accomplish tasks by the need by dates of CERN.*

- *Comment: If the Project were to use all of its float, it may require a reduction in scope to remain within the $75M cap.*

- *Finding: The ATLAS total risk-adjusted cost of $75 million includes contingency developed via a Monte Carlo simulation and has an overall confidence level of 78% CI which is within the 70-90% range recommended by the NSF Large Facilities Manual.*

– ***The RMP addresses project needs. It describes the current understanding of major project risks ("known unknowns") and key challenges/issues, including external partnering. The risk register appears to include all foreseen risks. It includes the description and assessment of the impacts of any changes since PDR. The RMP identifies risks, quantifies impacts, estimates probabilities, describes plans for risk avoidance, and plans for mitigating realized risks.***

- Finding: ATLAS has a well-developed Risk Management Plan and Risk Register. The Project Office and the CAMs are utilizing the risk management process and they seem well educated in its proper use. External partnering is specifically addressed (Risk RN-06-10-01-005).

- Comment: The Risk Register appears quite comprehensive for this stage of the project and the ATLAS team regularly reviews and adjusts the Risk Register to reflect the latest state of project knowledge. This includes dependencies on the external program and anything that can impact the TPC, schedule, or add risk are addressed. Dependencies on the international ATLAS or CMS upgrades programs are documented and foreseen risks

- ***Schedule Risk Management:***
  - ***The project critical path and schedule float are defined and optimized.***
  - ***Formal schedule contingency management is used to manage schedule risk.***

- Finding: ATLAS has provided critical path schedules for each level L2 item in the NSF scope WBS. This P6 based process that has been developed and managed by the experience BNL/Columbia team appears sound.

- Comment: Contingency management appears sound. For example, uncertainties in external delivery interfaces (CERN) are being addressed by substantial schedule float on activities that are affected by these dates.

Systems Engineering/QA-QC

- The Scientific Objectives and Scientific Requirements are clearly explained in the Project Execution Plan. L-2 and L-3 subsystem requirements flow down from “Physics Goals” to “Object Performance” to “Technical Specifications” is summarized in the US ATLAS HL-LHC Science Flowdown document, referencing a number of ATLAS documents and publications.
- The project established and exercises basic configuration management.
- Project systems engineering procedures are documented in the Systems Engineering Management Plan.
- Each L-3 subsystem presented initial QA/QC plans and verification methods, although in general there are no overall standards imposed by International ATLAS. The key requirements for each L-2 subsystem are well understood and on the panel’s request compliance assessments were presented for these key specification items. While compliance with most of the key specifications have been established by prototype or demonstrator tests, in some cases compliance expectations are based on engineering estimates and analogies.
- The project should establish the customary verification and compliance matrices to track predicted performance. Compliance expectations are management tools precipitating risks and in turn mitigation. Verification matrices and plans will ensure a consistent framework and methodology for system, subsystem, and component verification.

- The systems engineering products and procedures of the US ATLAS project are mature to support the MREFC-funded construction starting in April 2020. Systems engineering is carried out in close collaboration with the International ATLAS project, ensuring that specifications, interfaces, reviews and the technical decision-making processes are consistent with overall ATLAS objectives.

Additional Comments

- Information delivery (organization, presentations, slides, web interface) very effective.
- Noted: Ombudsperson system for project (spanning institutions) to be considered.

Summary

- The Panel congratulates the project on passing the Final Design Review.
- Congratulations on the CoDR/PDR/FDR journey – impressive to see.
- May your lpGBTs be delivered on time.

Many thanks to NSF (Mark Coles, Shannon Scrivner) for logistics.

The ATLAS FDR is complete, safe trip home.