ATLAS MREFC NSF FDR Director's Review

July 2019

Background Information:
The review was held at Columbia University in New York, NY, starting the morning of Monday and adjourning early in the afternoon of Monday, July 29 and adjourning early in the afternoon of Wednesday, July 31, 2019.

Members of the review committee were: Charlie Baltay (Yale), Rick Cavanaugh (UIC), Sridhara Dasu (Wisconsin), Sara Eno (Maryland), Rick Farnsworth (NRAO), Raj Gutta (BNL), Will Johns (Vanderbilt), Dan Marlow (Princeton), Dave Morrison (BNL), Meenakshi Narain (Brown), Paul Rubinov (FNAL), and Paul Tipton (Yale). In addition to the committee, Dmitri Denisov (BNL) and Mark Coles, Erica Stein, and Rebecca Yasky (all from NSF) were present throughout the review.

This report is organized as follows. An overview comprising general comments is followed by comments on the technical aspects of the subsystems under review as well as comments on management, cost, and schedule. Finally, a separate set of comments is provided on the Education and Public Outreach aspects of the presentations. The technical and managerial comments are aligned with the NSF Construction Readiness Criteria, which were provided with the charge.

General Comments

1. The ATLAS HL-LHC MREFC is generally in good shape in terms of substance.
    a. Most elements of the project are currently ready for production and those that require additional effort are on track for an April 2020 start.
    b. The cost estimates are credible and backed by solid BOE's.
    c. The backup documentation is generally well prepared and well organized.
    d. Risk estimates are generally reasonable, with a few exceptions where the assigned risks appear to be on the low side. The overall level of contingency is appropriate. The "double counting" noted by the PDR has been removed.
    e. A strong management team is in place and working well.
    f. The schedule appears to be credible.
2. Some work remains to be done to arrive at a set of presentations that properly reflect the strong substance of the project.

   a. In some cases, the talks were too long and/or overly detailed.
   b. There was too much redundancy between the technical and management talks.
   c. The agenda for the breakout sessions was difficult to follow, leading to a situation where the reviewers were often not clear on what talks to expect in a given session.
   d. The EPO presentation did not adequately highlight the strong opportunities for education and outreach that are embodied in the project.
   e. The review team noticed that documents in DocDB were being revised as the review progressed. This was tolerable in the context of this review, but should not be done during the FDR.

3. The possibility of a one-year delay in the schedule for the HL-LHC may have cost and schedule repercussions for the ATLAS MREFC. Although the project is to first-order insulated from such a change, the possibility of "knock-on" effects remains.

Suggestions:

1. Prepare talks that concentrate on the key points, without excessive detail (such details can be placed in backup slides to address questions).
2. Keep in mind that the FDR committee will be well acquainted with the project. The FDR committee will be largely the same as the PDR committee and they will have been examining the material prior to the review.
3. For technical breakout talks, add words to the slides about various prototyping rounds and the lessons learned that give confidence that the prototypes are indicative of future success.
4. Ensure that any references to internal ATLAS documentation (not available to the review committee) are removed from the material provided to the review committee.
5. For each technical area, indicate what constitutes success (have a crisp definition that includes an adequate level of testing).
6. For management breakout talks, limit the technical summary information to the minimum needed to indicate what is being costed, scheduled, and managed. Additional technical material, needed in response to possible questions, can be placed in the back-up slides.
7. Organize the agenda in a manner that is easy to follow. It should be possible to provide for parallel sessions in Indico. Failing that, a separate document should be provided to help the review team understand what will be presented when.

8. The science talk should:
    a. include a brief summary accessible to the layperson
    b. provide the information needed to help the committee understand the flow down of science requirements to technical requirements (this part can be aimed at experts)
    c. be one end of a coordinated "hand off" with the individual technical presentations (do this in a uniform way)

Muon Spectrometer

The excellent overview and breakout presentations described the overall scope of the project, how it fits into the current detector, and the motivation for the upgrades. Specifically, we were convinced that the upgrades covered by US NSF scope, were necessary as follows:

1) To cope with the high rates of HL-LHC, the readout electronics of the MDT system must be replaced
2) To reduce fakes and improve trigger efficiency, pT selectivity of tracks for the trigger needs to be improved by integrating the MDT info into L0 trigger
3) MDT chambers in the inner layer must be replaced with smaller MDT chambers (sMDT) to allow space to install RPC

A clear and consistent picture, showing the flow of data from the MDT chambers to Mezzanine to CSM to L0MDT helped the reviewers understand the big picture and made it clear that the project as a whole was well integrated and well motivated. Interfaces to other systems are well defined.

Comments:
A huge amount of material was presented, making it clear that this is a project operating at a world class level, both in terms of management and technology. The presenters attempted to strike a balance between presenting information directly in the slides for both the L2 presentation and each of the L3 presentations and having pointers to other documents- making the presentation shorter and "crisper" but risking making the sheer volume of information more confusing and harder for the reviewers to navigate. The charge-to-documentation map greatly aided in navigating the documents.

1. Completion of design and development phase:
    a. The project has achieved the necessary level of technical preparation and readiness to begin construction.
        i. 6.1.1 sMDT tubes and chambers
            1. Findings: The MDT design is mature and has been frozen for some time. The only difference is the shorter length of the tubes. The project has been reviewed by international ATLAS and has been found to be ready to go into production (EDMS-2048104). This WBS is expecting to receive site certification for tube production and this will mark the readiness for MREFC.
            2. Comments: This WBS has a compelling story to tell. The proponents should make more direct connection between the physics goals and the technical specs such as the wire

position and tube alignment specs. This WBS item is ready to proceed to FDR.

3. Recommendation: None

ii. 6.6.3 TDC

1. Findings:

The TDC is making good progress towards readiness for production but the v2 prototype is expected to be submitted in Sept and therefore the results will not be available in time for the FDR review- but should be available in time for the beginning of the MREFC period. The TDC meets all specs but lacks TMR protection. TMR is being added to the V2 TDC prototype and, if it is successful, the TDC will be ready to move forward to radiation testing and pre-production.

2. Comments:

TDC presentation lacked technical details regarding TMR implementation and testing. The prototype v2 testing is a pre-MREFC critical path activity and closely coupled to the start of MREFC activity - "pre-production design start". Hence any delays in the prototype v2 may be flagged in the FDR as issues that may delay readiness for MREFC

The WBS item is ready to proceed to FDR.

3. Recommendation:

The QA and QC plan should add details describing how the testing of TMR protected parts of the chip are to be handled.

iii. 6.6.4 CSM

1. Findings:

CSM has made significant progress since the PDR review. The CSM prototype vI testing, which began in Jun 2018, has achieved many successes including demonstrating integration with the legacy Mezzanine cards. This WBS appears on track to complete v2 prototype in the fall of 2019 and to complete testing by the end of calendar 2019.

2. Comment:

There was not enough time to drill down into some of the technical details regarding the technical choices for the changes from v1 to v2. For example, the need for the lpGBT given the success achieved with the GBTx, the architecture of the lpGBT to GBT-SCA communications, the choice to use FEAST or bPOL (which one?) and so on.

There appears, on p11 of the CSM L3 presentation a diagram that shows a “Fanout ASIC,” which does not appear elsewhere in the documentation. In the BOE, this appears to be an Artix FPGA. Is the diagram on p11 a typo or out of date? This may raise questions in the FDR review.

The WBS item is ready to proceed to FDR.

3. Recommendation:

Clarify the motivation for the differences between the successful v1 prototype and the v2 prototype currently being designed.

iv. 6.6.5 L0 MDT

1. Findings:

The L0 MDT Trigger Processor consists of a relatively small number (87 including spares) of board pairs based on the Apollo architecture. The pair consists of a service module and a command module. The command module carries the large FPGAs and all optical links. The service module handles external control and blade infrastructure. The WBS 6.6.5 scope includes the design and production of all the service modules, the production of about half of the command modules (design by MPI) and about 75% of all the firmware. This WBS appears to be making reasonable progress towards the MREFC milestone.

2. Comment:

The L0 MDT Trigger Processor sits at the center of the MDT system and has bidirectional links to the SCM, Sector Logic and FELIX. This makes clear, and agreed-upon interface specifications critical. However, this seems to be in good shape with interfaces to the MDT CSM (EDMS2054329), Sector Logic (ATL-COM-DAQ-2019-101 & ATL-COM-DAQ-2019-103), TDAQ (EDMS 1563801), and even DCS (EDMS 1992002). However, the reviewers could not easily access the ATLAS internal notes listed above, though the presenters offered to make them available.
The availability of tested and functional service module and command module demonstrators is a critical path item and defines the end of pre-MREFC activity and should be watched carefully,

tracking the pre-MREFC milestones. Delays in meeting these milestones could lead to delay in MREFC start.

This WBS item is ready to proceed to FDR.

3. Recommendation:

Make all documents referenced in the review available to the reviewers.

b. The project's scientific and technical contributors are credibly expected to accomplish the proposed work scope within the requested budget and schedule duration.
    i. 6.6.1 sMDT, 6.6.3 TDC, 6.6.4 CSM, 6.6.5 L0MDT
        1. Findings:

        The team members have decades of experience and experts in their respective areas. They will be able to deliver the project.

        2. Comment:

        The BOEs seem well thought out and of high quality. At this point in the project, the schedule seems reasonable though some of the goals listed to be accomplished before MREFC seem aggressive (e.g. 6.6.4)

        3. Recommendation: None.
c.
d. The project has finalized all necessary commitments and partnerships, including definition of project deliverables, performing organizations, and schedules.
    i. 6.6.1 sMDT, 6.6.3 TDC, 6.6.4 CSM, 6.6.5 L0 MDT
        1. Findings: Each of the subsystems presented a list of collaborators, both US institutions and international partners (mainly MPI). The project schedule and deliverables are also well defined.
        2. Comment: none
        3. Recommendation: none
e. The project has a defined acquisition strategy for purchased items. Designs, specifications and work scope comprising bid packages to industry are in advanced states of maturity and available for NSF review. Bid packages to be released in FY2020 are sufficiently clear and well defined as to be ready for bid.
    i. 6.6.1 sMDT, 6.6.3 TDC, 6.6.4 CSM, 6.6.5 L0 MDT

1. Findings: Detailed quotes for M&S items have been obtained. Procurement plans were presented. Bid packages have not yet been developed.
2. Comment:
3. Recommendation: none

f.

g. Tools and technologies needed to construct the project are available. Industrialization of key technologies needed for construction is complete.
   i. 6.6.1 sMDT, 6.6.3 TDC, 6.6.4 CSM, 6.6.5 L0 MDT
      1. Findings: We find that the tools are well advanced and there are no new technologies required for construction.
      2. Comment:
      3. Recommendation: none

2. Project Scope
   a. Project documentation describes how the construction-ready design is derived from the flow-down of science goals to science requirements then on to technical performance specifications and requirements. The documentation is in a format that enables traceability, is clearly explained, and is aggregated into a dedicated section of the PEP.
      i. 6.6.1 sMDT, 6.6.3 TDC, 6.6.4 CSM, 6.6.5 L0 MDT
         1. Findings:
            a. The flow-down of science goals to science requirements are well motivated and they are documented in the respective subsystem TDRs, though not always in a easy-to-trace format. The technical specifications are also developed and they are documented.
            b. The driving factors (and how they are connected to realizing the momentum resolution goal) which led to the technical specifications, for example the location precision, tube location precision on chamber and the alignment platform precision on chamber etc. are not easy to find. We reviewed the TDR, chapter 6 and were not able to find how these precisions were obtained http://cdsweb.cern.ch/record/2285580/files/ATLAS-TDR-026.pdf]. There is some info in section 2.2.1 of the TDR. The documentation is not in a format that enables EASY traceability.

c. The Muon Trigger Requirements (in the current US ATLAS HL-LHC Science Flowdown document) state that "MDT chambers used in L0 trigger" is a requirement, but there is no upstream goal motivating that requirement within the same document. Such an upstream goal might be: "Increase the acceptance of some-physics-process". Which could then be followed by: "Increase the muon trigger efficiency in the barrel from 65% to 95%". Which then, finally, motivates the requirement in the current Science Flowdown document that states "MDT chambers used in L0 trigger".

2. Comments:
    a. It would be helpful to provide a mechanism that facilitates quick and easy drill-downs on the Science Flowdown during a review. Currently, the ability to find specific science goals and the corresponding science and engineering requirements are sometimes hidden deep within large, complex, external technical documents that are difficult to navigate and digest. When providing references to external documents for particular scientific or technical requirements, the proponents might consider including fully specified pointers (for example, the page number) that enables easy traceability to the particular requirement in question.
    b. Please double check and ensure that the US ATLAS HL-LHC Science Flowdown document reflects the most recent requirements (the current document dates back to 2017).
3. Recommendation:
    a. Develop documentation, clearly showing the connection between the science requirements and technical specification, to convince a review committee that the specifications are science-driven. Additionally, in the Science Flowdown document, please ensure that all downstream requirements can be self-consistently traced to at least one upstream requirement within the same document.

b. All detector functions and requirements are reflected in the Performance Measurement Baseline.
    i. 6.6.1 sMDT, 6.6.3 TDC, 6.6.4 CSM, 6.6.5 L0 MDT
        1. Findings:

The technical specifications were provided for all subsystems. In many cases these are EDMS documents and in many cases the subsystems have gone through international ATLAS reviews. As a result there is very good and thorough description of the detector functions and there are milestones to track the progress of the development required to meet these.

        2. Comment:

It might be helpful to the reviewers for the L3 presentations to highlight the milestones that will allow management to measure the progress of development on all the detector functions and requirements, especially for those WBS items that may not have fully completed development before Apr 2020

        3. Recommendation: None
    ii.

c.

d.

e.

f. Specialized technologies enabling the scope fabrication are sufficiently mature to begin construction.
    i. 6.6.1 sMDT
        1. Findings: tube and chamber construction does not use any specialized technologies
        2. Comment:
        3. Recommendation:
    ii. 6.6.3 TDC
        1. Findings: The first prototype of the TDC ASIC has been designed, fabricated and tested, no design problems found so far. A second prototype with TMR will be submitted for fabrication soon.
        2. Comment: The project is on track for start of pre-production design in April 2020, and has production scheduled for May 2021.
        3. Recommendation: None
    iii. 6.6.4 CSM
        1. Findings: The proposed technologies are off-the-shelf; there are no specialized technologies to consider.

2. Comment: None
3. Recommendation: None

iv. 6.6.5 L0 MDT

1. Findings: The proposed technologies are off-the-shelf; there are no specialized technologies to consider.
2. Comment: None
3. Recommendation: None

g. Technical scope elements of the performance baseline remain consistent with what was approved for advancement to Final Design stage following PDR.

i. 6.6.1 sMDT, 6.6.3 TDC, 6.6.4 CSM, 6.6.5 L0 MDT

1. Findings:

No technical scope has changed since PDR for sMDT, TDC, CSM. There has been a change to the strategy for the L0MDT. These changes have undergone reviews within ATLAS and are a simplification that leverages the Apollo platform and simplifies technical development.

2. Comment: The new approach is simpler and safer
3. Recommendation:

3.
4.
5. Project management and the Project Execution Plan, including governance of the project, working with interagency and international partners, and subaward management.

a.
b.
c.
d.
e.
f.
g.
h.
i.
j. Performance verification and acceptance test policies for all deliverables are defined and complete. Documentation describes how acceptance tests will verify that deliverables meet design performance specifications and safety requirements.

i. QA plans and activities are integrated into the RLS.

ii. QA and radiation exposure policies are applied consistently across the project.

6.6.1 sMDT, 6.6.3 TDC, 6.6.4 CSM, 6.6.5 L0MDT

1. Findings: QA/QC procedures are documented and integrated in RLS.
2. Comment: The description of the QA/QC procedures are, for the most part, presented in a very compact format. Where appropriate, they should link to a more detailed document. There is no section for QA for the sMDT, since those tasks are complete- however, it would be helpful to link there relevant documentation.
3. Recommendation: none

k. There is a vetted safety plan and appropriate safety experts are available to the project to implement and oversee the safety plan.
   i. 6.6.1 sMDT, 6.6.3 TDC, 6.6.4 CSM, 6.6.5 L0MDT
      1. Findings: All subsystems have an ES&H plan and the relevant risks have been considered. Contacts responsible for ES&H at each institute have been identified.
      2. Comments: none
      3. Recommendation: none

l. Plans and justifications for fabrication of spares within the construction program are defined and well justified.
   i. 6.6.1 sMDT, 6.6.3 TDC, 6.6.4 CSM, 6.6.5 L0MDT
      1. Findings: yes, the fabrication of spares is defined
      2. Comment:
         a. in some cases, the justification can be strengthened, for example by justifying the assumed yields (L0MDT - 90%, CSM - 95%).
         b. Please add the yields for L0 MDT in the description of “production” activity in the BOE.
      3. Recommendation: none

m. Plans and schedules for shipment of deliverables to CERN are credible and appropriately integrated into the RLS.
   i. 6.6.1 sMDT, 6.6.3 TDC, 6.6.4 CSM, 6.6.5 L0MDT
      1. Findings: yes, the plan is available where applicable.
      2. Comment: none
      3. Recommendation: none

Trigger

1.

a. The project has achieved the necessary level of technical preparation and readiness to begin construction.

i. 6.8.1 L0Calo Fiber Optic Plant

1. Findings:

The L0 Calorimeter Fiber Plant is well scoped, understood, and the production plan appears to be straight forward.

2. Comment: This WBS item is ready to proceed to FDR.

3. Recommendation: None

ii. 6.8.2 Hardware Track Trigger (HTT)

0. Findings:

The HTT is well scoped and is in final design stages, which appear solid. Nevertheless, the demonstrator card has not yet been produced or tested. Hence, there appears to be a potential for possible design changes in the HTT, following the upcoming demonstrator testing program.

2. Comment:

a. It would be appropriate to explicitly present the HTT testing program (scope, timeline, tests scheduled to be performed) of the demonstrator cards in more detail (possibly in backup slides), including what conclusions the proponents hope to draw from the testing program to inform the next prototype boards and firmware, leading to final production.

b. Not all documents were public and viewable by the reviewers.

c. Minor comment (scientific labor units of 900 in TFHW10240 TFM Demonstrator QA Testing (20 12-Feb-20 11-Mar-20) seems way too large).

d. Overall, this WBS item is ready to proceed to FDR

3. Recommendation:

Ensure that all references to external, supporting documentation are explicitly made available to the committee before the review takes place. Ensure that any references to private, internal ATLAS documentation (and hence not available to the review committee) are scrubbed from all talks and from any other material provided to the review committee.

iii. 6.8.3 Global Processing

1. Findings:

The Global Event Processor Firmware is ambitious, but the project has a solid plan and has made significant progress in prototyping and testing algorithms.

2. Comment: This WBS item is ready to proceed to FDR.

3. Recommendation: None

b. The project's scientific and technical contributors are credibly expected to accomplish the proposed work scope within the requested budget and schedule duration.

i. 6.8.1 L0Calo Fiber Optic Plant

1. Findings: Yes, the personnel bring their experience and expertise from a similar phase-1 project.
2. Comment: None
3. Recommendation: None

ii. 6.8.2 Hardware Track Trigger (HTT)

1. Findings: Yes, the group is strong and has extensive experience from carrying out similar projects in the past.
2. Comment: None
3. Recommendation: None

iii. 6.8.3 Global Processing

1. Findings: Yes, the team is very knowledgeable about the algorithms to be implemented and has the necessary expertise to deliver the project.
2. Comment: None
3. Recommendation: None

c.

d. The project has finalized all necessary commitments and partnerships, including definition of project deliverables, performing organizations, and schedules.

i. 6.8.1 L0Calo Fiber Optic Plant, 6.8.2 Hardware Track Trigger (HTT), 6.8.3 Global Processing

1. Findings: Each of the subsystems presented a list of collaborators. The project schedule and deliverables are also well defined.
2. Comment: None
3. Recommendation: None

e. The project has a defined acquisition strategy for purchased items. Designs, specifications and work scope comprising bid packages to industry are in advanced states of maturity and available for NSF review. Bid packages to be released in FY2020 are sufficiently clear and well defined as to be ready for bid.

i. 6.8.1 L0Calo Fiber Optic Plant, 6.8.2 Hardware Track Trigger (HTT), 6.8.3 Global Processing

1. Findings:

Detailed quotes for each M&S item has been obtained. Bid packages have not yet been developed.

2. Comment:

The full specification of the HTT demonstrator board was sparsely outlined in the presentation. Since this is a "Final Design Review" the proponents should consider presenting (in the talk, possibly as backup material) a complete and explicit description of the technology choices that now fully specify the current demonstrator boards (e.g. the PCBs are currently in layout and expected to be delivered by the end of 2019). This information was referenced in the talk (pointing to internal ATLAS documentation) and could be inferred by examining the BOE (and corresponding quotes), but the technical specifications of the board designs were not easily available nor readily visible to the reviewers.

3. Recommendation: none

c.

d. Tools and technologies needed to construct the project are available. Industrialization of key technologies needed for construction is complete.

iii. 6.8.1 L0Calo Fiber Optic Plant, 6.8.2 Hardware Track Trigger (HTT), 6.8.3 Global Processing

0. Findings: All deliverables use industrial technologies
1. Comment: The tools are well advanced and there are no new technologies required for construction.
2. Recommendation: None

2. Project Scope

a. Project documentation describes how the construction-ready design is derived from the flow-down of science goals to science requirements then on to technical performance specifications and requirements. The documentation is in a format that enables traceability, is clearly explained, and is aggregated into a dedicated section of the PEP.

i. 6.8.1 L0Calo Fiber Optic Plant, 6.8.2 Hardware Track Trigger (HTT), 6.8.3 Global Processing

1. Findings: similar comment as for MUONS
2. Comment:
3. Recommendation: same as for MUONS

b. All detector functions and requirements are reflected in the Performance Measurement Baseline.

i. 6.8.1 L0Calo Fiber Optic Plant

1. Findings: Yes, the work described in the RLS targets deliverables that meet or exceed specifications.
2. Comment: None
3. Recommendation: None

ii. 6.8.2 Hardware Track Trigger (HTT)

1. Findings: Yes, the work described in the RLS targets deliverables that meet or exceed specifications.
2. Comment: None
3. Recommendation: None

iii. 6.8.3 Global Processing

1. Findings: Yes, the work described in the RLS targets deliverables that meet or exceed specifications.
2. Comment: None
3. Recommendation: None

c.

d.

e.

f. Specialized technologies enabling the scope fabrication are sufficiently mature to begin construction.

.6.8.1 L0Calo Fiber Optic Plant

1. Findings: The proposed technologies are off-the-shelf; there are no specialized technologies to consider.
2. Comment: None
3. Recommendation: None

i.6.8.2 Hardware Track Trigger (HTT)

1. Findings: The proposed technologies are off-the-shelf; there are no specialized technologies to consider.
2. Comment: None
3. Recommendation: None

ii.6.8.3 Global Processing

1. Findings: The proposed technologies are off-the-shelf; there are no specialized technologies to consider.
2. Comment: None
3. Recommendation: None

g. Technical scope elements of the performance baseline remain consistent with what was approved for advancement to Final Design stage following PDR.

.6.8.1 L0Calo Fiber Optic Plant, 6.8.2 Hardware Track Trigger (HTT), 6.8.3 Global Processing

1. Findings: Yes. No technical scope has changed since PDR
2. Comment: None
3. Recommendation: None

3.

4.

5. Project management and the Project Execution Plan, including governance of the project, working with interagency and international partners, and subaward management.

a.

b.

c.

d.

e.

f.

g.

h.

i.

j. Performance verification and acceptance test policies for all deliverables are defined and complete. Documentation describes how acceptance tests will verify that deliverables meet design performance specifications and safety requirements.

i. QA plans and activities are integrated into the RLS.

ii. QA and radiation exposure policies are applied consistently across the project.

6.8.1 L0Calo Fiber Optic Plant, 6.8.2 Hardware Track Trigger (HTT), 6.8.3 Global Processing

1. Findings: yes. QA/QC procedures are documented and integrated in RLS.
2. Comment: None
3. Recommendation: none

k. There is a vetted safety plan and appropriate safety experts are available to the project to implement and oversee the safety plan.

i. 6.8.1 L0Calo Fiber Optic Plant, 6.8.2 Hardware Track Trigger (HTT), 6.8.3 Global Processing

1. Findings: All subsystems have an ES&H plan. Contacts responsible for ES&H at each institute have been identified.
2. Comment: None
3. Recommendation: none

l. Plans and justifications for fabrication of spares within the construction program are defined and well justified.

i. 6.8.1 L0Calo Fiber Optic Plant

1. Findings: N/A
2. Comment: None
3. Recommendation: None

ii. 6.8.2 Hardware Track Trigger (HTT)

1. Findings: yes
2. Comment: the assumed yield is 95%, which is higher than typical. It would be useful to justify this assumption
3. Recommendation: None

iii. 6.8.3 Global Processing

1. Findings: N/A, as this WBS is firmware development.
2. Comment: None
3. Recommendation: None

m. Plans and schedules for shipment of deliverables to CERN are credible and appropriately integrated into the RLS.

i. 6.8.1 L0Calo Fiber Optic Plant

1. Findings: The deliverable will be constructed at CERN.
2. Comment: None
3. Recommendation: None

ii. 6.8.2 Hardware Track Trigger (HTT)

1. Findings: Yes, the shipment plan to CERN exists.
2. Comment: None
3. Recommendation: None

iii.6.8.3 Global Processing

1. Findings: N/A
2. Comment: None
3. Recommendation: None

Calorimeter (Tile/LAr)

The committee was very impressed by the progress on this technically challenging and important upgrade. The calorimeter team has an experienced, dedicated team of physicists, engineers, and technical staff contributing to project development while ensuring readiness for construction on time and on budget. While the calorimeter front end is still in the prototyping stage, all parts do appear to have a credible schedule with potential mitigations built into the schedule where prototyping is present.

1. The project has achieved the necessary level of technical preparation and readiness to begin construction.
    a. 6.4.1 LAr ASICS and optics
        i. Findings: The ASICS are still in the prototyping stage. Several prototypes have been made. The backup ADC chip suffers from SEUs.
        ii. Comment: The extent of the progress on the ASICs is difficult to assess due to inadequate documentation. However, based on the slides provided at the meeting, the progress looks good and seem to be on track for production. The technical presentations had too much on material that was not technical, reducing time available to discuss technical details. For the optics, the lpGBT may be delayed if Run 3 is delayed.
        iii. Recommendation: More words on the slides about various prototyping rounds and their lessons learned would help give confidence that the prototypes are indicative of future success. It should be available before the review. Management should ensure the slides are released to the committee on schedule.
    b. 6.4.2 FEB2
        i. Findings: This project has a large number of external dependencies, on the DOE preamp/shaper and on the optical links. The board also requires a level-0-sum-er child card, a responsibility that has not yet been assigned, and might be a US scope increase.
        ii. Comments: While the DOE preamp/shaper is a US project and thus should remain on schedule in the event of a delay for the Run 3 start, the optical links are produced by CERN may be delayed. The addition of the sum-er card to the US scope is an opportunity.
        iii. Recommendations: none
    c. 6.4.3 backend sRTM and firmware

i. Comments: the interface between the processing fpga and the rest of the sRTM seems well defined so that even if this external fails the project should be able to proceed.
ii. Recommendations: none

d. 6.5.1, 6.5.4, 6.5.3 LVPS bricks, main board, and ELMB2 Motherboard
   i. Findings: this project is a simple extension of a previous successful project. However, the method for using 6 wires to turn on/off 8 bricks is not finalized; there is a recent change in the proposed methodology The tile community agrees on the change, but it needs to be finalized at cern pdr in september. There is also a vertical slice test is in october. Testing for new method (tri-voltage solution) has been tried on the bricks, but not via the “aux” board off detector in USA16 that feeds into the motherboard to the bricks and is a Prague responsibility.
   ii. Comments: Despite the recent change, the project seems on track for production, as the board is relatively straightforward.
   iii. Findings: The motherboards have an external dependence on the Elmb2 chip. The Elmb2 neutron radiation tests are not complete. Data is not completely analyzed yet. Results from a previous test were marginal, but perhaps due to unknown particle content. Mitigation would be to swap half way through the run.
   iv. Comment: since this is important for many CERN applications, the elmb2 will be made to work. The schedule seems to have plenty of time slip. Swapping the power supplies half way through the run should be an acceptable solution.
   v. Recommendations: none

2. Tools and technologies needed to construct the project are available. Industrialization of key technologies needed for construction is complete
   a. LAr ASICS and optics
      i. The most exotic technology needed is for ASIC production. 65 nm and 130 nm technologies are well established
   b. FEB2
   c. backend sRTM and firmware
   d. LVPS bricks and main board
   e. motherboards
3. The project’s scientific and technical contributors are credibly expected to accomplish the proposed work scope within the requested budget and schedule duration.
   a. 6.4.1 LAr ASICS and optics

    i. Findings: Key members of the team working on the LAr ASICS and optics have extensive experience stemming from work on the original ATLAS construction as well as Phase I upgrades.
    ii. Comments: The scope of the technical work being proposed seemed carefully considered and is commensurate with the available expertise and the resources requested. It seems very likely that they will accomplish the work within the requested budget and schedule.
    iii. Recommendations: none

b. 6.4.2 FEB2
    i. Findings: The FEB2 incorporates elements of 6.4.1 and supporting circuitry onto a board to digitize and transmit LAr signals.
    ii. Comments: The L3 CAM has extensive and relevant experience dating back to the original ATLAS construction, leading the Columbia group that developed the original FEB and five custom ASICs. The technical progress on the FEB2 is encouraging, with clear steps ahead in remaining R&D and pre-MREFC. The FEB2 estimates are largely in the category of Analogy, but the extensive prior experience with this sort of development lends credibility to this. It seems credible that the work of 6.4.2 will be accomplished within the requested budget and schedule
    iii. Recommendations: None

c. 6.4.3 backend sRTM and firmware
    i. Findings:
    ii. Comments: The new “smart” RTM incorporates an FPGA and some of the functionality that had been found on the original FEB, providing LHC clock recovery, synchronization with ATLAS, monitoring functionality, and data transmission to the ATLAS read out system. Members of the team have experience from the design, production, and testing of Phase I ATLAS upgrade LAr trigger board and firmware. Manpower for the firmware development has been increased since the PDR, reflecting experience stemming from Phase I upgrade. It seems credible that the work of 6.4.3 will be accomplished within the requested budget and schedule.
    iii. Recommendations: None

d. 6.5.1 main board, 6.5.4 LVPS bricks, and 6.5.3 motherboards
    i. Findings:
    ii. Comments: The team working on these WBS items is very knowledgeable and is experienced with the tilecal electronics. Key

members of the team were responsible for the design and implementation of the original tilecal electronics.

iii. Recommendations: None

4. The project has finalized all necessary commitments and partnerships, including definition of project deliverables, performing organizations, and schedules.

    a. 6.4.1 LAr ASICS and optics-
        i. Finding: The ASICs are still in development and hence the schedule is not final at this point. Allowing for changes between the final prototype and pre-production mitigates the uncertainty to some extent. Overall, the LHC schedule uncertainty as well as the delivery of shared ATLAS/CMS ASICs (lpGBP and the Versatile Link) are large unknowns mostly out of the control of the project.
    b. 6.4.2 FEB2
        i. Comment: In general, it would be helpful for the review process to match the FEB2 batches to the ATLAS installation schedule visually to highlight the float discussion.
    c. 6.4.3 backend sRTM and firmware
    d. 6.5.4 LVPS bricks and 6.5.1 main board
    e. 6.5.3 motherboards
        i. Comment: The discussion on the ELMB2 motherboard cost was confusing and it was not clear to the reviewers what cost will be used in the final schedule. The board cost is supposed to be redone before the NSF FDR.
        ii. Finding: A linkage to a board, needed to implement the tri-state solution, but not in control of the NSF project, was mentioned. This situation, was not, however, not obvious from the presentation material.

5. The project has a defined acquisition strategy for purchased items. Designs, specifications and work scope comprising bid packages to industry are in advanced states of maturity and available for NSF review. Bid packages to be released in FY2020 are sufficiently clear and well defined as to be ready for bid.
    a. 6.4.1 LAr ASICS and optics, 6.4.2 FEB2,6.4.3 backend sRTM and firmware BE, 6.5.4 LVPS bricks, 6.5.3 motherboard, and 6.5.1 main boards
        i. Finding: For all of these projects except 6.5.3, the current costs of the necessary components has been found. The responsible institution for the purchase has been identified. Bid packages have not yet been developed, as the designs are not yet finalized. For

6.5.3 there are quotes for the manufacture of PC boards in Prague, not in the US

ii. Comments: The bids should be fairly simple and we don't anticipate problems. But for the ELMB2 motherboard, it is not clear what the correlation between this price and the price for manufacturing in the U.S. is.

iii. Recommendations: US-based price estimates should be obtained for any manufactured item.

6. Performance verification and acceptance test policies for all deliverables are defined and complete. Documentation describes how acceptance tests will verify that deliverables meet design performance specifications and safety requirements.QA plans and activities are integrated into the RLS. QA and radiation exposure policies are applied consistently across the project.
   a. LAr ASICS and optics
      i. Comment: The ATLAS collaboration has internal reviews to establish official specifications and production readiness. This WBS has assurance guidelines from the similar phase 1 project and this should provide a good framework for QA/QC for the deliverables for the production. The collaboration has an irradiation testing policy that subsystems must follow for qualification.
      ii. Comment: We have commented elsewhere that the development prior to production deserves extra scrutiny.
   b. FEB2
      i. See (a: i and ii) above
   c. backend sRTM and firmware
      i. See (a: i) above
   d. LVPS bricks and motherboards
      i. See (a: i) above
   e. Main boards
      i. See (a: i) above
      ii. Comment: There were concerns about the long length and via types and complexity of the main board. The project has agreed to consider the whole "bathtub curve" in its testing/burn-in methodology.
      iii. For such a mature design, it should be possible to trace the documentation through all levels. During the drill down to check that a schematic was in EDMS there was some difficulty navigating the documentation chain. The project is aware of this issue and the specific concern was fixed during the review and the project is aware of the general issue now.

7. Project documentation describes how the construction-ready design is derived from the flow-down of science goals to science requirements then on to technical performance specifications and requirements. The documentation is in a format that enables traceability, is clearly explained, and is aggregated into a dedicated section of the PEP.

    There is a dedicated Section 1.2 Science Requirements in the PEP and the summary in section 1.2.1 is a useful compilation of the various science-driven requirements. The path from PEP to TDR is navigable.

    However, there is a recommendation in the January 2018 NSF PDR review report regarding the science flowdown, “Add detailed technical specifications for all systems of the MREFC project to the Science Flowdown document.” and a related comment, “The Science Flowdown document (#269) provides clear logic how high level science requirements are propagated into high level technical specifications, but does not yet extend to sufficiently low for FDR level.” The last listed revision in that document is dated 12/28/2017 so it doesn’t seem to reflect any changes related to the recommendation yet. While the talks on 6.4 and 6.5 did show illustrative examples of science flowdown to technical requirements, the comments from the PDR remain valid.

    a. 6.4.1 LAr ASICS and optics, 6.4.2 FEB2, 6.4.3 backend sRTM and firmware
        i. The talks on these elements did show illustrative examples of science flowdown to specific technical requirements.
    b. 6.5.1 Main board, 6.5.4 LVPS bricks, and 6.5.3 motherboards
        i. The requirements on the LVPS bricks and the ELMB2 motherboards do follow from the science goals of enabling the proper functioning of the tilecal for O(TeV) jet measurements and O(100 MeV) MIP signals in the high rate, high radiation environment of HL-LHC. This importance of the tilecal performance to measurements of physics objects was shown clearly in the L2 tilecal talk, but see general comment about science flowdown above.

8. All detector functions and requirements are reflected in the Performance Measurement Baseline.
    a. 6.4.1 LAr ASICS and optics

        i. Comment: The ADC ASIC development should be followed closely in the period before the MREFC start. The next iteration, v3, which will be submitted in August is an important step towards the final prototype where multiple ADCs are incorporated in the same package. At this point (of course) it is not known if the multi-ADC chip, v3, will meet goals.
        ii. Finding: The COTS ADC alternative identified as a risk mitigation for the ASIC ADC has a set of risks associated with adoption that make it highly undesirable: e.g. SEU issues.
    b. 6.4.2 FEB2
        i. Comment: The first slice prototype with a multi-ADC ASIC deserves extra scrutiny as it is not known at this point whether a successful multi-ADC ASIC can be incorporated successfully in a multi-chip board.
        ii. Comment: If the v3 ADC ASIC is sufficiently performant, the FEB2 development should be followed closely in the period before the MREFC start.
    c. 6.4.3 backend sRTM and firmware
    d. 6.5.1 main board, 6.5.4 LVPS bricks, and 6.5.3 motherboards

9. Specialized technologies enabling the scope fabrication are sufficiently mature to begin construction.
    a. 6.4.1 LAr ASICSand optics
        i. Finding: there is a default and backup ASIC. The default is a 65 nm technology. A 14 bit ASIC in this technology is still being developed. The backup is an existing off-the-shelf 14 bit ADC that would be used in case of failure of the 65 nm technology
        ii. Comment: The progress on the 65 nm technology looks good, although the documentation on the performance of the current prototype was inadequate. Also, the documentation on the tests of the performance on the alternative was not adequate to be sure of its performance, although we were told verbally that they did verify that it had true 14 bit performance. However, due to its 1 Hz rate for SEUs, the backup solution may not be a real backup solution.
        iii. Recommendation: none
    b. 6.4.2 FEB2
    c. 6.4.3 backend sRTM and firmware
    d. 6.5.1 main board ,6.5.4 LVPS bricks and 6.5.3 motherboards

10. Technical scope elements of the performance baseline remain consistent with what was approved for advancement to Final Design stage following PDR.
    a. 6.4.1 LAr ASICS and optics, 6.4.2 FEB2

i. Findings:
ii. Comments: The scope presented here seems quite consistent with that presented at PDR
iii. Recommendations:

b. 6.4.3 backend sRTM and firmware
    i. Findings:
    ii. Comments: The decision to build the "smart RTM" (sRTM) instead of a "Main Board" and "RTM“ was taken following the PDR. Additional resources for the firmware development have been added to the RLS.
    iii. Recommendations:
c. 6.5.1 main board, 6.5.4 LVPS bricks, and 6.5.3 motherboards
    i. Findings:
    ii. Comments: The scope presented here seems quite consistent with that presented at PDR
    iii. Recommendations:

11. There is a vetted safety plan and appropriate safety experts are available to the project to implement and oversee the safety plan.
    a. 6.4.1 LAr ASICSand optic
    b. 6.4.2 FEB2
    c. 6.4.3 backend sRTM and firmware
    d. 6.5.4 LVPS bricks and 6.5.3 motherboard -
        i. Finding: The use of higher voltage (200 V) for the power input seems the most compelling safety issue and the project has taken ownership.
    e. 6.5.1 main board
12. Plans and justifications for fabrication of spares within the construction program are defined and well justified.
    a. 6.4.1 LAr ASICS fine
    b. 6.4.2 FEB2 fine
    c. 6.4.3 backend sRTM and firmware fine
    d. 6.5.4,6.5.1 LVPS bricks and main board fine
    e. 6.5.3 motherboards fine
13. Plans and schedules for shipment of deliverables to CERN are credible and appropriately integrated into the RLS.

Comments: The schedules for 6.4 and 6.5 in the RLS seem appropriately detailed, reasonable, and contain explicit milestones for acceptance at CERN. The tilecal schedule has external “need by” milestones in the schedule, which is helpful for judging the suitability of schedules leading to that date. Similar explicit “need by” external milestones might be considered for the LAr schedule. The LAr ADC pre-prototype 3 was originally scheduled for May; it is now anticipated for August; if that happens on schedule and is successful it appears it will allow the schedule for the ATLAS PDR to be maintained.

5. Project Management Review

The project management has demonstrated the necessary level of preparation and readiness such that project construction can begin.

Overview:
Findings:
1. The core management team has extensive experience with similar HEP construction projects and has a track record of working well together as a team.
2. The bigger ATLAS HL-LHC project is complicated by multiple funding sources and reporting. One team handles all projects including this MREFC proposed work.
3. The project planning and scheduling is handled for both funding sources in the same way and allows for reporting to both agencies.
4. The management teams for the 4 sub-projects, muon, LAr, trigger, and Tile Cal are also quite experienced, with detector experts represented in each team.

Comments:
1. ***The management structure and core management personnel are very well suited to the complex task of managing this project***
2. ***The sub-project management teams are strong, with more than adequate experience and training for their respective management tasks.***
3. ***The NSF FDR charge map was particularly useful in confirming that all required documentation has been prepared.***
4. ***There is some concern among reviewers that in a number of cases, L3 and L2 management positions were held by the same person. The fear is that during excessively taxing periods, the management team will be stretched too thin. If new L3 managers can be identified, even if they need additional mentoring, it would be ideal.***

Management PEP Documentation:
Findings
1. The Project Execution Plan (PEP) conforms to NSF guidelines and adequately describes the scientific objectives and governance of the project. It also describes the project definition, the roles and responsibilities of all stakeholders, the scope management and cost estimation plans as well as risk, contingency and change management plans. The Agency reporting plan is also described. Safety is the highest priority of management and that is reflected in the PEP.

Management RLS:
Findings
1. Following NSF guidelines, the project management team prepared a Resource Loaded Schedule (RLS) of sufficient granularity to manage this project was presented to this review committee. The RLS was used in conjunction with a detailed and vetted risk registry to estimate the project contingency in compliance with NSF.

Recommendations:

Suggested changes to **PEP:**

pg41 – EVMS practice from last qtr of FY18… Not true… needs to be updated

pg 60 – BOEs are not in the cost book reports

Pg61 – talks about use of CET. This is not correct and not supported by BNL anymore.

Control accounts are at L3, but progress report/CPR show EV data at L2

3. Project Budget

Summary-

The cost and schedule documents are put together well and there is credible backup for the estimates. The L2s and CAMs are very aware of their scope and understand Project Management processes. CAMs received enough EVMS training and we think it is time to start practicing, particularly the monthly EV process. There are some minor housekeeping tasks to do in terms of P6/cobra data detailed below.

Findings-

- Base cost from P6, estimate uncertainty/risk register/risk analysis make up the contingency
- 85% Confidence level used as benchmark;
- 36.5% contingency is reasonable; comparing contingency % situation with Phase1 at various periods is a very good idea
- Overall scope contingency is 15% and overall scope opportunity is 11%
- Drilldown of few random activities confirmed that estimates have credible backups
    - LOC1130M; TPHW20790M40; PCR NSF-015; FEE30540M40; FEE30345M40
    - BEE10840M; SMDT630275M40; CSM2661M40
- Team has been practicing EVMS from Mar-19, the little issues are being ironed out

- Very good back up documentation in place, traceability is good. Significant portion of base estimates at L2 levels are based on vendor quotes and historical costs.
- Materials estimate that don't escalate have been separated from the ones that normally escalate. (CSM2661M40) This is a very good practice
- Checked for double counting of estimates where similar work is being done by different institutions. For example, prototype of chip cycle at Columbia and UT Austin – found that these are complementary
- WBS dictionary is well written and ties out to P6
- Contributed labor is included in P6

Comments-

1. Even though the project thinks the cost profile is good enough for comparing funding profiles, the best practice is to look at the obligation profile. NSF criterion 3e specifically mentions use of the obligation profile.
2. Gustaff's presentation should show variance thresholds. Also, a little more explanation of Estimate uncertainty/ risk register/ risk analysis and how all these contribute to the contingency would benefit the review committee, particularly the technical team.
3. There is too much variance to begin project reporting. If the near term activities (carefully planned) are slipping in terms of cost and schedule, it doesn't convey a positive outcome for future activities.
4. Reported EAC is different than BAC as current variances are considered, at the same time project thinks that they will recover from these variances, meaning EAC may not be accurate. We suggest that the project team have multiple EACs in Cobra (statistical/manual) if not done already, and report only what the project team thinks is real… all other EACs should be used only for internal analysis
5. Standing army costs, if any, should be part of contingency analysis.
6. There is a small difference between P6 and Cobra data. Probably because of rounding in P6 resource table. Try to increase the decimals to bring P6 and Cobra as close as possible. This is not required, but makes it so much easier for baseline management and any future PCR's
7. P6 files posted on review site should have columns for labor and total costs.
8. There were few MREFC activities costed (CSM2510), and some obligated (MAB1240M400) before Apr-20. Not high costs but should follow guidance. Coding of MREFC and Pre-MREFC may not be consistent across P6 and Cobra data
9. Review the milestones properly. For example, MAB19430 - Tile project complete is marked as start milestone, this should be a finish milestone. Delivery times for many procurements are just one month. The proponents may need to revisit and make sure these are realistic
10. Drilldown for BEE10840M – CAM acknowledged that there is a minor error between P6 and BOE and will be corrected by FDR
11. Earned value Hours for Contributed labor should be monitored

12. Showing drilldown as an example in presentations is ok, not a common practice. Suggest the presenters tell that this is an example and offer to drilldown any other activity.

Recommendations-

1. L2s and CAMs are very knowledgeable and have received EVMS training. They may need a little more training on analysis of EV reports, ETC, variance analysis etc.
2. Fuse analysis using DCMA metrics shows that the "Critical Path Test" failed. Project needs to further drill down and identify the cause for this and address them. It may be because of hard constraints that are used like "must finish on" instead of using "finish on or before"
3. ***The base year for rates is not consistent across resources. This may lead to costly mistakes if not handled with caution. Suggest bringing all rates up to date and have one base year for all rates***
4. ***54% of activities on Muon subsystem are critical. When we have a handful of critical activities it gets attention, when more than half of the activities are critical the natural tendency is to ignore all. Suggest project team to revisit the schedule contingency at L3 levels to address this issue***

(a) 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.

(b) A significant proportion of the budget is based on externally provided information such as current vendor estimates or quotes, publicly available supplier prices, and the like, especially for FY 2020 and FY 2021 budgets.

(c) 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.

(d) Methodologies for estimating equipment and material quantities and labor hours are reasonable. Any adjustments from historical data are valid.

(e) 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).

4. Project Schedules

4.1 Findings

The US contribution to the ATLAS detector upgrades for the High Luminosity LHC is funded about 1/3 by NSF and 2/3 by DOE funding. The NSF funded effort is focused on triggering, implying mostly upgrades to electronics and not detector components (except for the sMDT chambers for the muon subsystem). This report addresses the NSF funded effort. The NSF funded US project is divided into four subsystems: Triggering, Tile Calorimeter, Liquid Argon Calorimeter, and the Muon system. ***The schedules*** for all of these ***are driven by the LHC Long Shutdown 3, scheduled from 2024 to mid 2026***, during which the upgrades are to be installed, and thus the dates by which CERN needs the US deliverables.

4.1.1 Triggering

The ***triggering sub-system has*** three Level 3 tasks. CERN needs deliverables from the US for all three in the 3rd Quarter of 2025. The project schedules call for completion of these tasks in the 1st, 2nd and 3rd Quarters of 2024 respectively. This represents ***a schedule float of close to a year.***

4.1.2 Tile Calorimeter

The Tile Calorimeter sub-system has four Level 3 tasks. The Main Board task is needed at CERN in the 3rd Quarter of 2024. The project schedule shows completion of this task by the 3rd Quarter of 2023, a year schedule float. The other three task deliverables are needed at CERN on the 1st Quarter of 2025. The project schedules show these tasks being completed by the end of 2022 or by mid 2023. This represents ***18 months of schedule float.***

4.1.3 Liquid Argon Calorimeter

The Liquid Argon Calorimeter subsystem has three Level 3 tasks. The Front End electronics task is not to be delivered to CERN as such but will be needed at Columbia University to be incorporated in the FEB2 task. The ***FEB2 boards*** will be ***installed at CERN in stages***, starting in mid 2025 and finishing in the 1st Quarter of 2026. ***The project schedule shows half of the boards completed by the end of 2023 and the full set of boards by the end of 2024. This represents a schedule float of more than a year.*** The Back End electronics will be needed at CERN in the 1st Quarter of 2026. ***The Project schedule shows the completion of the BE electronics task by the 1st Quarter of 2025, again a one year schedule float.***

4.1.4 The Muon Detector

The Muon Detector subsystem has four Level 3 tasks. These tasks have different dates needed at CERN and scheduled completion dates, as follows:

Task	Date needed at CERN	Project schedule completion
MDT	Quarter 2 of 2025	Quarter 4 of 2023
TDC	Quarter 1 of 2024	Quarter 1 of 2023
CSM	Quarter 2 of 2024	Quarter 3 of 2022
L0MDT	Quarter 4 of 2025	Quarter 3 of 2024

All of these tasks have a schedule float of a year or more.

4.2 Comments

All four of these subsystems have done a careful and thorough job in developing their project schedules, as presented at this review. They include critical path and near critical path milestones, end dates and schedule contingencies. Task durations and schedule estimates are reasonable, based on technical requirements and previous experience. The schedules include complete scope of work, including quality control and acceptance testing. Milestones associated with scientific labor have appropriate tracking metrics. Project control systems include means of monitoring contributions from scientific labor. The projects have feasible methods in place to track, manage and report on the progress as the project proceeds. Milestone granularity is appropriate to allow timely corrective management decisions. The Resource Loaded Schedules (RLS) have evolved from those presented at the Preliminary Design Review last year by incorporating considerable technical progress, final MOU negotiations, and alignment with the latest international ATLAS baseline schedules.

As summarized in the Findings section above all of the tasks in the four subsystems have a schedule float of close to a year or more. This appears to the review committee to be sufficient at this stage of the project.

4.3 Recommendations

None

6. a) Risk Management Plan

Findings:

Overall, the Risk Management Plan is well done and largely consistent with the DOE Risk Management Guide (DOE G 413.3-7A). The risk management plan outlines the techniques, tools and responsibilities for risk identification, risk analysis, risk response planning and risk monitoring and control well. The panel feels that consideration of the following observations could strengthen the plan.

Comments:

Figure 2. Risk Ranking. This was well thought out, though incomplete and it seems inconsistent with the risk register. There were Very low, low, moderately low, moderately and high in the risk register, while the RMP only had 3 (Low Med, High). The risk register and the RMP do not seem to match. In the risk register it seems the risk probability categories are more granular below 50% probability (3 categories) than above (2 categories). This means that higher probability risks are less granularly assessed than lower probability risks (less than 50% probability).

Risk Sensitivity: Section 4: Qualitative risk analysis assigned a value for the probability and impact of each risk when calculating the risk factor. The risks were prioritized and the highest scoring risks (threats and opportunities) are most actively managed as part of risk response planning. Risk sensitivity is not specifically addressed (though Monte Carlo analysis is). It should be noted that risk probability is not a fixed value, but are a range of values and dependent on other impacts. I would recommend a comment about this and regular assessment of the determined values as part of the risk monitoring process.

Section 6.1 Residual and Secondary Risks. Though the risk management plan addresses residual risks, it does so in a cursory manner, and there does not appear to be any treatment of residual risk (that I could find) in the risk register. ***On documenting***

risk retirement mention should be made of residual risk (either the identification of the residual risk element, or secondary risk spawned, or a statement of 'no residual or secondary risks were identified following retirement of this risk).

The RMP did not address 'Risk Triggers'. A risk trigger is a condition or other event that will cause a risk to take place. Risk triggers for a given risk are identified during the risk analysis. ***This could be called out in section 7***, Risk Monitoring and control of the RMP. Triggers tell you when you need to implement or plan or call a lien against contingency.

The RMP does not address "Force Majeure" clause (French for "superior force"). Force Majeure issues (also known as 'acts of God') arise from circumstances that well beyond the control of the project team which make performance inadvisable, commercially impracticable, illegal, or impossible. ***There is no need to have a plan for these sorts of events, but it should state this in the RMP. This caveat will often keep the project team focused on risks that can be controlled.***

b) Risk Register.

Comments:

As a tool for documenting and managing risks, the risk register seems well done and largely comprehensive. Risks are logged on the register and response actions are detailed. ***The risk register has a high level of technical detail, which is good.***

The team did not seem to consistently apply risk probabilities across the various level 2 groups in the risk register. This is quite common in distributed teams like ATLAS, but there should be some peer review function across the project whereby project leadership agrees with the Level 2 managers scoring. In particular, the muon subsystem stands out as having a large number of risks in the "very low" category.

The previous (PDR) review noted that risks were double counted. The panel notes that this issue has largely been addressed, although L0MDT seemed to be an area where risk can be evaluated more closely for this double counting.

The risk of the standing army costs, due to a potential one-year delay in CERN schedule, was not sufficiently addressed.

Education and Public Outreach (EPO)

Findings

1. The US ATLAS HL-LHC EPO effort starts from a strong position due to a track record of success in US ATLAS EPO activities to date.
2. The PDR report notes, "The team did present a plan for Education and Outreach, but has not allocated specific MREFC resources for this purpose." The NSF has clarified that MREFC funds cannot be directly used for EPO purposes. With that understanding, several considerations regarding an approach to EPO were presented.
3. Coordination with US CMS on some EPO issues, such as a survey, is being pursued.
4. The role of the US ATLAS EPO coordinator has been expanded to specifically include EPO regarding HL-LHC activities.
5. The proposed EPO effort leverages those existing US ATLAS EPO programs and would include technical work involving undergraduates. The individual ingredients comprising the proposed EPO effort appear to be strong with good potential.
6. The HL-LHC EPO 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. It includes a diversity plan, with an implementation strategy and metrics.

Comments:

1. The value that the proposed HL-LHC EPO effort adds is somewhat unclear, beyond the already existing (separate) US ATLAS EPO programs. One motivation given was that of providing "coordination across the existing programs". The proponents should consider improving the messaging (in the slides of the presentation) of how the proposed effort would address cross-program coordination issues in a way that is transformative to the existing (separate) US ATLAS EPO programs.
2. The coordination with US CMS and the involvement of a STEM education professional to conduct and interpret surveys of the workforce is commendable. Surveys can be an important part of the proposed HL-LHC EPO effort, but the proponents should consider improving the message (in the presentation slides) regarding the purpose of the surveys. For example, is the purpose of the surveys to provide data to experts who would publish academic research in education journals? Or, is the end goal to demonstrate the "value" or to improve the proposed HL-LHC EPO effort -- if so, it would be helpful to (briefly) outline (in the slides) how the results of the surveys would feedback and contribute to the "big story" (see Recommendation below) of the proposed HL-LHC EPO effort.

3. The proponents might consider documenting additional EPO opportunities, potentially obtained following successful competitive review of additional proposals to NSF (or elsewhere) that are outside the MREFC. Including a description of such additional (albeit speculative) activities might further expand the reach and impact of the MREFC/EPO leveraging plan.
4. Many of the L2 talks provided good EPO messaging, but given the tight time constraints and technical focus of those talks, it would seem more effective to collect the most compelling of those EPO elements into the plenary talk.
5. The plenary EPO presentation did not adequately highlight the strong opportunities for education and outreach that are embodied in the project. The statement from the NSF FDR guidance memo (# 651), "NSF would like to have focused discussions about how to make the education/outreach programs "shine" at FDR." clearly indicates the importance the agency places on this aspect of the project.

Recommendation:

1. The narrative of the proposed EPO effort should be made clearer. The proponents should work to articulate a compelling "overarching theme," "punch-line", and/or "title" of the proposed effort, which reviewers can quickly understand and appreciate.