

# **DOE-NSF U.S. ATLAS Operations Program Review Closeout Report**

**Sridhara Dasu, University of Wisconsin at Madison  
Katrin Heitmann, Argonne National Laboratory  
Elmie Peoples-Evans, Argonne National Laboratory  
Steven Ritz, UC Santa Cruz  
Paolo Rumerio, University of Alabama  
Louise Skinnari, CERN  
Julia Thom-Levy, Cornell University  
Carol Wilkinson, PM Consulting, Cornell University  
Frank Wuerthwein, UC San Diego**

**California Institute of Technology  
May 30-31, 2019**

# Charge (I)



- **The purpose of this review is to assess:**
  - the U.S. contributions to the maintenance and operation of the Large Hadron Collider (LHC) detectors, and the software and computing infrastructure for the fiscal years 2019–2020;
  - the U.S. efforts within the operations program for the installation and commissioning of detector components of the initial [Phase-1] upgrades by the end of Long-Shutdown 2 (LS2); and
  - the development of software and computing models that will facilitate efficient and cost-effective processing of data during the High-Luminosity (HL)-LHC running period.

**Therefore, DOE/NSF request an evaluation of the status of the U.S. LHC Operations Program including commitments to detector maintenance and operations, the computing facilities, the infrastructure developed for data analysis, the allocation of funds in FY 2019, and the proposed spending plans for FY 2020 – 2022.**

- 1. Management:** Assess the ability and performance of management to track program scope and assess outcomes relative to planned performance metrics for the prior year; prioritize activities and define appropriate deliverables; assess and manage risk; balance the personnel effort and funding of detector operations, software and computing, and upgrade R&D efforts; and respond to unforeseen technical or funding challenges. Evaluate the appropriateness of planned performance metrics.
- 2. Budget:** Examine the budgets in an activity-based format. Are the costs and budget projections for operations consistent with meeting operational performance measures or goals under the current LHC program and schedule while adhering to the funding guidance for FY 2019 – 2022 from each agency? Report on whether plans for operations under the guidance are appropriately developed and recommend improvements where applicable. Examine each experiment's plans for setting priorities to fit within their guidance, including consideration of risks.

3. **LHC Detector Maintenance and Operations (M&O):** Evaluate the U.S. efforts and plans to efficiently complete the detector maintenance tasks in LS2 and be ready for operations during Run 3. Discuss foreseen risks to the operation programs and the expected effectiveness of the mitigation plans in place. Report any overlooked risks and recommend strategies for their mitigation.
4. **LHC [Phase-1] Detector Upgrades:** Are adequate resources in place within the Operations Program to complete the installation and commissioning of the U.S. Phase-1 detector upgrade deliverables by the schedules established by the international collaborations? Do plans include adequate estimates of impacts on personnel, M&O and S&C obligations, and the project period of the HL-LHC upgrades? Are risk management plans appropriately developed to guide the installation and commissioning?
5. **LHC Software and Computing (S&C):** Assess the quality and appropriateness of U.S. contributions to the LHC experiments and report whether this is commensurate with the level of U.S. participation.

- 6. HL-LHC S&C:** U.S. LHC researchers contributed to a Community White Paper (CWP)<sup>1</sup> to identify and prioritize R&D investments in S&C for the future LHC and HL-LHC programs. The CWP also identified a set of goals and milestones for evaluation and prototyping of computational tools and data structures in advance of the computing technical design reports expected in 2020–2021 from the ATLAS and CMS experiments. Within the framework of the CWP, evaluate progress and plans by the U.S. LHC Operations Programs to address these goals and recommend actions to strengthen current efforts, where appropriate. Are the programs developing mechanisms that ensure efficient and cost-effective acquisition and processing of data, including the expected increase in its volume during HL-LHC? Are synergies between the two experiments being exploited to develop future computational models? Are existing efforts outside the U.S. LHC Operations Program being properly leveraged?

<sup>1</sup>“A Roadmap for HEP Software and Computing R&D for the 2020s”, a white paper outlining R&D areas in software and computing to ready the HEP community for the future particle physics experimental program, including operations during HL-LHC, was prepared by the HEP Software Foundation in December 2017. The roadmap is available online at: <https://arxiv.org/pdf/1712.06982.pdf>.

**7. Assessment of U.S. Contributions:** Assess the quality and appropriateness of U.S. contributions to the LHC experiments and report whether this is commensurate with the level of U.S. participation.

**8. Response to Previous Reviews:** The previous reviews for the U.S. LHC Operations Programs were held in January 2017 at the University of California at Irvine. Has each program responded satisfactorily to the comments and/or recommendations from this review?

FY 2017 U.S. ATLAS Program	Review Recommendations
<b>Management &amp; Budget</b>	1) By July 2017, revise and expand the list of milestones defined for each WBS element to be more comprehensive. 2) Revise and extend the risk registry by July 2017, and use it to implement a more direct risk-based management plan for the program.
<b>LHC Detector M&amp;O, I&amp;C</b>	3) Develop a detailed schedule of activities for the installation and commissioning of the Phase-1 upgrade, including dependencies on external constraints and milestones prior to commencing installation and commissioning under the operations program by end of Summer 2017.
<b>LHC S&amp;C</b>	4) In consultation with DOE, NSF, and the LHC experiments, develop a detailed plan for the evolution of critical computing services currently provided by the Open Science Grid [OSG] by the end of April 2017. 5) Continue developing plans with the agencies for the additional S&C CPU, disk, and tape contributions to meet the higher luminosity challenges. Develop by June 2017 detailed plans for “no additional”, “one-third” and “two-third” funding scenarios with respect to the total budget request for FY 2017 and FY 2018. 6) Work with the agencies to explore the possibility of obtaining a dedicated allocation of high-performance computing [HPC] resources.
<b>Leadership and Team Diversity</b>	7) Develop a diversity plan by July 2017 for the U.S. ATLAS operations program with specific strategies and methods for measuring their effectiveness.

1. **Management**
2. **Budget**
3. LHC Detector Maintenance & Operations (M&O)
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-  **Main Components for Management, Budgets, and Priorities**
-  **Secondary Components for Management, Budgets, and Priorities; Such Components Also Addressed Later**

## Findings (1)

- US ATLAS Operations is currently a \$39M/year program (DOE+NSF) that is part of the international ATLAS collaboration. DOE funding is distributed through the program office at Brookhaven National Laboratory and NSF funding is distributed through SUNY at Stony Brook.
- US ATLAS has 532 authors, as of March 2019, out of 2,929 authors in international ATLAS collaboration (or 18.1% of the collaboration).
- Gender demographics were presented by job category, with notably low relative numbers of women Research Scientists, Engineers/Technicians, and Managers compared to the overall US ATLAS gender fractions.
- The Program presented a budget plan for the current and out years, fitting within the budget guidance given by the funding agencies. Budget allocations within the [low] -5% guidance and corresponding impacts were also presented.
- The resource profile presented shows a gradual decrease in personnel over the next four years of approximately 32 FTEs.
- The program developed a comprehensive Risk Management Plan and maintains a risk register that includes 17 S&C risks and 46 M&O risks.



## Findings (2)

- The program includes provision of appropriate management reserve that covers an amount equal to historical values for M&O plus estimated risk exposure based on the risk register.
- The program maintains detailed milestone (MS) lists at Level 1, with baseline and actual or forecasted dates and comments. It also produces a distribution of actual versus planned dates for the overall program. The lists are helpful in tracking scope and progress for each of the Level 1 areas and the distribution provides a metric indicating that the program does a good job of meeting schedule dates.
- The program has an intensive, clearly articulated annual budget process, called the “summer scrub”. The top five priorities used in the summer scrub are as follows:
  - consistency with the mission and the priorities of the US ATLAS operations program;
  - impact on relevant performance metrics, most significantly on the data taking efficiency, and impact on offline data processing capacity;
  - uniqueness to US, if it can be taken up by international partners;
  - critical mass within existing activity and if that workload can be effectively distributed with others;
  - an analysis of cost vs physics benefit, and an assessment of the increased risk to the program.
- US ATLAS Operations Program presented an R&D plan within the budget guidance for the development of software and computing models that will facilitate efficient and cost-effective processing of data during the High-Luminosity (HL)-LHC running period.

## Findings (3)

- The program presented planned FTE per year that is responsive to program goals and needs while adapting to budget and interface constraints.
- Under the [low] DOE -5% budget guidance, the US ATLAS operations program would not be able to sustain the current level of Tier-1 computing contributions in the planned manner. The mitigation strategy would be to request additional time at NERSC or other high-performance computing facilities that are not dedicated to the LHC program. There is currently no MOU, written arrangement, or other mechanisms in place.
- The end-of-the-year decision point regarding the first muon new Small Wheel (nSW) installation within the LS2 is critical.

## Comments (1)

- The US ATLAS Operations Program continues to be remarkably successful and productive.
- Management of this multifaceted and distributed set of efforts, with complicated constraints, is challenging, and the team is to be commended for their successes and planning.
- The management team is outstanding. Communication appears to be excellent and inclusive among all the levels, with clear and concise documentation and well-understood processes, such as the summer scrub.
- Implementation choices for reductions to the research program can have a significant impact on the operations program, so it is valuable for the agencies to make those choices in consultation with US ATLAS Operations to avoid unintended consequences.
- Committee members commend US ATLAS for starting to address Diversity, Equity, and Inclusion in a meaningful way. In particular, the collection of demographic data in a manner that respects privacy and confidentiality will assist in calculating metrics to track progress. The ~80% response rate is impressive, and the reminders from upper-management of the US ATLAS Operations Program send a powerful, positive message that these issues are important.

## Comments (2)

- The management reserve is appropriate, based on past performance and the ~\$3M unobligated reserve the program carries from one year to the next. However, marching-army costs and phasing uncertainties about possible further delays in the muon new Small Wheel (nSW) represent a substantial fraction of the total flexibility of the program.
- Management Reserve seems to represent liens, upscope options, and risk-based reserves. This can lead to misconceptions about how much “cash” the program is holding. For future reporting, consider labeling these items separately to present a clearer picture and minimize misunderstandings.
- Using the risk register to inform decisions related to the appropriate management reserve levels based on the timing of the risks is a good practice and should be continued. Early management reserve allocation with re-baselining yearly after the “summer scrub” provides time for planned smooth transitions, which is commendable.
- Adopting the same exchange rate for both US CMS and US ATLAS would improve the consistency of accounting.
- The extensive and detailed Level 1 milestone lists could be made even more useful if they were summarized into a subset of high level milestones for tracking and reporting purposes. The program may want to consider adding need-by dates for activities under time constraints (e.g., refurbishments within the Long-Shutdown window, I&C activities with need-by dates, S&C R&D progress milestones toward High-Luminosity data taking, etc.). The list would highlight high-priority and critical activities and facilitate management of priorities and resources.

## Comments (3)

- The personnel plan is well developed and realistic. However, the plan depends on resources outside of the operations program's control. This is a risk, as the reserves cannot cover impacts of loss of these personnel.
- The program uses metrics for M&O and S&C performance and tracks progress relative to milestones. These metrics are adequate and appropriate.
- Several documents posted for panel review were out of date with respect to the recent decision to change the baseline I&C plan to install only one nSW during LS2. In particular, the I&C Plan, milestone lists, and the risk register did not reflect the changes. If major events occur outside of the "summer scrub" period, updating project documents in a timely manner would be beneficial.
- The list of criteria used to prioritize the scope for the US ATLAS Operations Program seems reasonable, and the team is encouraged to present the "summer scrub" process and priorities including this information in future reviews.
- The Risk Management plan written in response to the previous operations review is appropriate and well-matched to program needs.
- Maintaining an integrated milestone list, FTE profile, budget, risk register, etc. for the operations program would facilitate analysis and understanding by reviewers.
- Providing information from previous years and plans for out years to illustrate the evolution of planning and adjustments to circumstances over time would help reviewers answer the charge.

## Recommendations

- Coordinate with the agencies on priorities for scientific research program-funded labor on at least an annual basis.
- Include a Diversity & Inclusion Committee representative on selection committees within the operations program and develop a plan by the end of calendar year 2019 for ensuring that those making appointment decisions at all levels have appropriate diversity and inclusion training.
- Perform a special “scrub” session to evaluate impacts of a possible delay in installation and commissioning of both wheels as soon as the international ATLAS plans are announced, especially if the [low] -5% scenario is realized.
- Work with the agencies, various scientific computing stakeholders, and US CMS when appropriate, to find a sustainable mechanism to secure the necessary S&C resources.

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## Findings (M&O)

- The ATLAS experiment was successfully operated and collected high-quality data with high efficiency during Run 2 at a higher-than-design LHC instantaneous luminosity.
- The program developed a detailed LS2 plan that includes both maintenance and Phase-1 upgrade of the detector components under US responsibility.
  - This plan includes cost and FTE needs.
  - The budget and FTE for this plan is still based on installing both muon new Small Wheels (nSW) during LS2, which is no longer a possibility. However, budget and FTE of this plan do include the refurbishment of one side of the muon CSC, as needed given that no more than one nSW can be installed in LS2.
- The 2017 review recommendations have been implemented.
  - An improved risk registry and list of milestones (baseline and actual/forecast) have been generated.
- A -5% budget scenario has been presented, which includes M&O scope reduction (Pixel and SCT readout) and some effort reduction (TDAQ and FCAL).



## Findings (I&C)

- Phase-1 I&C is being carried out under the M&O program, as planned.
- Phase-1 I&C work has started following detailed LS2 plan, which is mentioned in the M&O findings of this closeout report.
- US electronics production for Phase-1 upgrade of LAr calorimeter is nearing completion (i.e., expected completion of June 2019), and associated LS2 I&C work has started; the risks are modest.
- Despite some delays, the delivery to M&O of the US-built electronics for the Phase-1 upgrade of TDAQ is complete. The surface test is underway, and the overall I&C in the cavern is foreseen to be carried out as planned. The risks are moderate and mostly due to non-US deliverables.
- The delivery of US-built Phase-1 new Small Wheels (electronics and alignment system) are almost complete (some components to be completed June 2019).
- The assembly and installation schedule of the muon nSW has been delayed by approximately one year with respect to the schedule developed following the FY 2017 U.S. ATLAS Operations Program review due to chambers (non-US) and electronics production issues/delays.
- Due to chamber delays (non-US), the US Phase-1 DOE project scope was reduced (VMM ASIC and Front End Cards descoped). Following ATLAS authorization of restarting chamber production, production of the descoped components has now resumed.

## Comments

- We congratulate the US ATLAS teams on the successful detector operation and high-quality data-taking throughout Run 2.
- The management team is well qualified & has successfully set appropriate priorities.
- The US ATLAS team is capably navigating a challenging situation around the nSW following chamber production delays originating outside the US, and is adapting to the resulting uncertainties in the schedule.  
Consequently, the installation of one nSW in LS2 remains a possibility.
  - We strongly agree that a “go/no-go” decision for installing one nSW in LS2 has to be made by the end of 2019.
  - The uncertainty around nSW installation (i.e., one or zero wheel installed in LS2) will have considerable impact on M&O, in particular CSC refurbishment.
  - A strategy will be needed to prepare for Run 3 operations with zero or one nSW, including a mitigation strategy to cope with the trigger rates especially in the zero nSW case.
- The program should continue to develop the list of milestones for LS2 I&C, which includes activities start dates.
- It would be beneficial to work with international ATLAS to understand the feasibility of installing and commissioning both nSW in LS3 while other HL-LHC I&C-related activities are underway.

## **Recommendations**

- Develop detailed schedules, as well as a new FTE and budget plans, for the installation and commissioning for installing only one nSW in Long Shutdown 2, as well as the alternative zero wheel installation in LS2, in advance of the “go/no-go” decision anticipated in November 2019.



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## **Findings (1)**

- US ATLAS S&C program significantly engaged with its international partners and the larger HEP community in the HSF Community White Paper (CWP) process. The US LHC operations program continues to be engaged with the community via various funded projects towards addressing the challenges, and to perform R&D in the priority directions outlined in the CWP.
- An R&D path has been identified that decreases computing and disk needs projections for 2028 to only x2 above budget projections assuming flat funding. This development represents a x2.5 reduction in CPU, and a factor of more than 3 reduction in disk since 2017.
- Additional R&D opportunities for further reduction in computing needs have been identified, and are starting to be pursued.
- US ATLAS S&C program created an HL-LHC R&D program comprising ~6 FTEs in 2019, scaling out to ~12 FTEs in 2022. Initially, this program is focused on ~12 postdocs funded jointly between the operations and research programs. This effort is managed as a newly created WBS 2.4 element.



## Findings (2)

- US ATLAS is leading an Analysis Model Study group in global ATLAS that is charged with defining data models that reduce the event size by 30%. In addition, this group is looking at reducing the number of different DAOD versions in use by different physics groups within ATLAS.
- Global ATLAS is creating an HL-LHC strategy group that is charged with advancing the HL-LHC computing model. It is meant to produce an initial document by spring 2020 explaining the model used for estimating the HL-LHC computing needs.
- The US ATLAS facility program including Tier-1 and Tier-2 continues to make significant contributions to the global resources as follows:
  - Tier-1 provided ~23% of global Tier-1 resource consumption
  - Tier-2 provided ~33% of global Tier-2 resource consumption
- In 2018, 1.1B Geant 4 events were simulated on HPC systems in the US using a mix of competitive allocation, directors discretionary, and backfill. This is 24% of the total produced in the US. The US share of the total global is roughly  $\frac{1}{4}$ .
  - 7% directors discretionary at TACC.
  - 17% DOE HPC; 12% via allocation and 5% via backfill.



## **Findings (3)**

- US ATLAS is exploring a change in S&C service operations towards NoOps, leveraging developments by SLATE, a project funded by NSF independent of the operations program. This operations model is being implemented in collaboration with ESNNet to deploy caches funded by ESNNet in the ESNNet network backbone.
- US ATLAS leads the resource utilization metrics effort in global ATLAS.
- US ATLAS is leading an effort towards a multi-threaded framework that is expected to be used for simulation and reconstruction in Run 3.

## Comments

- We congratulate the operations program on the progress made in identifying R&D towards reducing computing needs such that they fit into funding scenarios consistent with the nominal budget guidance that was provided by the agencies, as well as focussing the university community's attention on some of this high priority R&D via the creation of a "postdoc program" and collaboration with IRIS-HEP.
- We support the philosophy of starting some high-risk high-reward R&D activities for HL-LHC S&C now, evaluating them on a regular basis, and transitioning the successful activities into production further down the road.
- We fully support the large ramp-up in HL-LHC R&D from slightly more than 1 FTE in 2018 to 6 FTEs in 2019 to 12 FTEs in 2022, and its organization in WBS 2.4.
- US ATLAS has developed appropriate metrics to assess the utilization of computing resources. It is an impressive effort that sets the international standard across the experiments at the LHC.
- Preparations for Run 3 are underway and well planned.
- While being behind schedule by 6-9 months, the multi-threaded framework deployment is making good progress towards production deployment in Run 3.



## Recommendations

- Accelerate the timescale for a document that describes the plan to meet HL-LHC computing needs within resource constraints so that it is available prior to the Final Design Review for the NSF MREFC in September 2019. Coordinate with the US CMS operations program on this document.
- Lead the development, jointly with US CMS, of an HL-LHC S&C R&D strategic plan by November 2019 with specific milestones for deliverables to the US LHC operations program.
  - Carry out a set of open workshops in coordination with US CMS, HEP-CCE, IRIS-HEP, Open Science Grid (OSG)-LHC, and WLCG.
  - Coordinate with the DOE and NSF a plan to sustain such an R&D activity for the next 3-5 years.
- Coordinate with the agencies on their HPC allocation processes to arrive at joint ATLAS and CMS programmatic, multi-year proposals by the end of calendar year 2019.



U.S. DEPARTMENT OF  
**ENERGY**



# End Closeout Report