National Science Foundation
WHERE DISCOVERIES BEGIN

High Luminosity Large Hadron Collider (HL-LHC)

ATLAS Upgrade

Earned Value Management System (EVMS) Surveillance

September 30, 2021

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1 Executive Summary

The National Science Foundation (NSF) accepted the HL-LHC ATLAS Earned Value Management System (EVMS) in March 2020 based on a compliance assessment conducted by an independent review team. The review team determined that the ATLAS met both the intent of EIA-748 guidelines and NSF requirements. Section 5.1 of this report discusses ATLAS' responses to the recommendations from the compliance assessment.

This 2021 surveillance was conducted virtually from August 17-20, 2021 and determined that the ATLAS EVMS continues to meet the intent of EIA-748 guidelines and NSF requirements and that the ATLAS Project Team appropriately uses the associated tools and processes. This 2021 surveillance review identified no findings and the following recommendations, with detailed explanations of each in Section 5.3. Recommendations are improvement opportunities (IO) and are to enhance ATLAS' EVMS implementation. Recommendations need not be tracked for closure except for the recommendations with an asterisk (*).

A. Document the Risk Adjusted Estimate at Completion (RAEAC) value in the NSF Monthly Report to comply with the NSF Major Facilities Guide (MFG) for reporting risk exposure. Include a summary of the risk analysis results with data tables and distribution curves whenever the risk exposure (RAEAC) is updated.* (Guidelines 25 and 27)

B. Perform a comprehensive Estimate at Completion (EAC) in conjunction with the annual RAEAC analysis (as indicated by the MFG) and as a precursor to the re-baseline.* (Guideline 27)

C. In Variance Analysis Reports (VARs) with multiple drivers, quantify the cost and schedule impacts with each identified driver, especially for VARs with both COVID and non-COVID related variances.* (Guideline 23)

D. Include both positive and negative cost and schedule variance analysis reports in the NSF Monthly Reports per the MFG.* (Guideline 25)

E. Document the process for calculating total project risk exposure from the aggregation of multiple independent WBS Level 2 Monte Carlo simulations in either the Project Execution Plan (PEP), as a supplement to the Risk Management Plan, or in a risk analysis report. (Guideline 27)

2 Scope of EVMS Surveillance

The EVMS surveillance review of the ATLAS project management control system (PMCS) was conducted virtually from August 17-20, 2021 in accordance with the ATLAS EVMS Surveillance Plan, Appendix A. The EVMS surveillance was performed concurrently with the virtual ATLAS Annual Progress Review (held August 18, 2021). Appendix B provides the agenda used for the EVMS surveillance review. The surveillance review team consisted of NSF LFO Representatives and two consultants from MPR Associates with extensive background in EVMS, project controls

and scheduling. The team was led by an NSF LFO Representative certified in EVM. Appendix C contains the biographical sketches of the review team members.

This surveillance consisted of review of project documentation; interviews with the Assistant Project Manager for Project Finances & Controls, Deputy Project Manager for Project Development, Administrator & Financial Manager and select Control Account Managers (CAMs); as well as independent data traces. The review team also observed the Annual Progress Review presentations on August 18, 2021. Project documentation was made available electronically in advance and at the review for data tracing.

The 2021 ATLAS EVMS surveillance review pursued four goals:

- Review ATLAS's response to 2020 verification review recommendations and trace actual costs from a cost performance report (CPR) to the monthly accruals and the subaward invoice data in Columbia's financial system.
- Review effectiveness of the processes for assessing and forecasting COVID-19 impacts versus other cost and schedule variances.
- Review ATLAS project team's adherence to their EVMS processes and procedures in accordance with the ATLAS project controls documentation.
- Review the timeliness and reliability of project performance data provided by ATLAS.

Four of the five EVM process categories from EIA-748 guidelines were considered during this surveillance review with a focus on Analysis and Management Reports and Revisions and Data Maintenance. The ATLAS EVMS Surveillance Plan, Appendix A, lists the specific EIA 748-C guidelines included in this review. Section 6, EVMS Guideline Summary, provides the assessment results of review guidelines. This review surveyed the following in-progress control accounts (CAs) and work packages. These accounts were selected based on the progress and variances reported in recent NSF monthly progress reports.

1. 6.04.01 Liquid Argon (LAr) Front End (FE) Electronics
2. 6.06.01 Muon Small diameter MDT chambers (sMDT)
3. 6.08.03 Trigger Global Event Processor (GEP)

3 EVMS Surveillance Summary

The ATLAS Project has an established and complete EVM system, with an integrated master schedule (IMS) maintained in Primavera P6 and EVM processing in Deltek Cobra. Processes for collecting, analyzing, and reporting EVM data are documented in the ATLAS Project Execution Plan dated August 8, 2021, Brookhaven National Laboratory (BNL) Earned Value Management System Program Description dated December 6, 2019, and the NSF Accrual Reconciliation Procedures.

NSF scope for the overall ATLAS project is delineated in unique elements at Level 2 (L2) of the combined DOE/NSF project Work Breakdown Structure (WBS) for each major detector component (e.g. 6.06 LAr, 6.06 Muon) and is overseen by an NSF L2 Manager. L2 elements are further subdivided into Level 3 (L3) control accounts for each subcomponent (e.g., 6.04.01 LAr

FE Electronics, 6.06.01 Muon sMDT) and overseen by CAMs, typically residing at the institution primarily responsible for the sub-component. Control account scope is further subdivided at Level 4 (L4) for each institution performing scope in that L3 control account with unique cost accounts.

The Project performs monthly EVM status updates in accordance with NSF guidance. On the 20th or 21st of each month, Project Controls posts a spreadsheet in google docs for CAMs to enter schedule activity status, including actual starts/finishes, activity percent complete, and expected finish date for in-progress activities. CAMs may also update the activity resource loading if they forecast an effort to complete different from the remaining budget. CAMs are given five days to complete the schedule status update. Project Controls then integrates the updates into the IMS and issues validation reports to the CAMs on the 2nd of the new month; CAMs have 48 hours to validate the results of the update.

The Financial Manager uses google docs to collect accruals from each performing institution at WBS L4. Reports are open from the 1st through the 6th of each month, and are returned to the Project Office by the 8th. The Project reconciles accruals with invoices and Project Controls completes Cobra integration by the 10th. Project controls data are uploaded to the Integrated Project Database (IPD), a database developed at BNL for project management purposes. CAMs complete variance analysis in reporting (VARs) in IPD by the 23rd of the month.

3.1 Overall Assessment of the CAM Interview Information

The CAMs for the three control accounts identified in Section 2 were interviewed by the review team. The areas of focus for the interviews were: the method of progressing the work, the relationship of the control account scope to the project critical path, the basis for the significant variances, estimates to complete the associated work, and changes to the baseline.

During the interviews, it was evident that the CAMs are well versed in and understand the EVM data provided by Project Controls. The information received during the interviews aligned with the project controls documentation. The review team did not identify any material inconsistencies between the information obtained during the CAM interviews and the information presented in the project controls documentation or heard at the annual construction progress review. The details of each CAM interview are included in Section 4 of this report.

One systemic item is that the CAMs indicated the recently implemented COVID Baseline Change Proposal (BCP) NSF-038 satisfied the requirement in the Cost Estimating Plan (CEP) to perform an annual bottom-up EAC. As discussed in greater detail in Section 3.2, the review team notes that this BCP focused on the near-term activities in accordance with NSF guidance, but it isn't comprehensive and wouldn't assess non-COVID aspects.

COVID-19 Cost Impacts

The ATLAS Project is tracking and reporting the cost impacts of COVID-19 in accordance with NSF LFO guidance. As part of the monthly accruals process, each institution reports the

fraction of monthly costs that are due to COVID-19. These costs are mostly due to labor inefficiency and are included in the Project actual costs (ACWP). The CAMs review this data and assess for reasonableness. Exhibit 1 shows a snapshot for the Project's COVID tracking by month for each WBS L4 (by institution) and total to date by WBS L3. The Project has attributed $685K of ACWP to COVID inefficiencies through June 2021. The review team notes that 17 of the 36 WBS L4 are reporting incurred COVID impact costs in ACWP; however, in the CPR report, only five of these WBS L4 are reporting a negative cumulative cost variance (CV). Overall the Project is reporting a positive $1.1M cumulative CV through June 2021, with COVID-related savings of $438K from unfilled staff positions and $100K from travel limitations. Columbia should consider having each institution perform a reasonableness check of the COVID costs in the ACWP as part of the "true-up" discussions or the COVID basis of estimates (BOEs) planned for the fall.

Monthly Tracking by WBS L4 (Institution)

	Total	$103,346.37	$19,807.72	$50,396.50	$86,949.41
		Columbia	UT Austin	SMU	Columbia
Total By Month		6.4.1.1	6.4.1.2	6.4.1.3	6.4.2.1
$36,850.33	Apr-20	$25,285.16	$0.00	$0.00	$4,823.28
$59,382.40	May-20	$11,355.07	$6,633.46	$2,900.60	$6,386.48
$56,764.74	Jun-20	$9,116.23	$3,195.30	$3,173.80	$9,821.73
$38,787.25	Jul-20	$6,089.94	$1,263.52	$2,900.60	$342.64
$60,589.27	Aug-20	$11,077.00	$2,632.33	$4,959.80	$10,445.28
$41,235.92	Sep-20	$4,341.62	$621.31	$4,959.80	$3,247.01
$56,653.86	Oct-20	$9,400.37	$32.40	$2,741.40	$12,586.64
$38,996.11	Nov-20	$7,508.48	$621.31	$2,615.10	$8,555.32
$38,921.35	Dec-20	$4,000.91	$1,242.75	$4,099.40	$6,718.66
$31,209.31	Jan-21	$1,289.48	$621.31	$6,380.80	$2,416.12
$39,132.08	Feb-21	$4,511.01	$1,242.63	$6,380.80	$6,723.29
$44,045.38	Mar-21	$2,893.03	$24.40	$6,380.80	$4,570.55
$47,676.16	Apr-21	$2,893.03	$465.99	$2,903.60	$4,570.55
$51,746.20	May-21	$1,446.52	$310.66	$0.00	$2,285.28
$43,077.99	Jun-21	$2,138.52	$900.35	$0.00	$3,456.58
$685,068.35					

WBS L3 Summary

COVID ACTUALS BY L3			
System	Total	Apr-20 – Oct-20	Nov-20 – Jun-21
6.04 LAr	**361,107**	**224,039**	**137,068**
6.04.01 FEE	173,551	112,680	60,871
6.04.02 FEB2	86,949	47,653	39,296
6.04.03 BEE	100,607	63,706	36,901
6.05 Tile	**72,547**	**21,891**	**50,656**
6.05.01 MB	47,068	7,995	39,073
6.05.03 ELMB	0	0	0
6.05.04 LV	25,479	13,896	11,583
6.06 Muon	**240,875**	**100,749**	**140,126**
6.06.01 sMDT	52,927	14,859	38,067
6.06.03 TDC	23,731	8,469	15,262
6.06.04 CSM	44,241	21,699	22,542
6.06.05 L0MDT	119,976	55,722	64,254
6.08 Trigger	**10,539**	**3,585**	**6,954**
6.08.01 L0Calo	0	0	0
6.08.02 HWTT	0	0	0
6.08.03 Global	10,539	3,585	6,954
NSF TOTAL	**685,068**	**350,264**	**334,805**

Exhibit 1. ATLAS Project COVID Impact Tracking Spreadsheets by Institution (L4) & Control Account (L3)

The Project has processed two BCPs for COVID, NSF-033 for the period from March – November 2020 adding $497K to the Project BAC, and NSF-038 for November 2020 – April 2021 adding $834K to the BAC. In accordance with NSF guidance, COVID BCPs are tracked separately in the Project contingency log and are not funded by contingency.

These BCPs were implemented as retroactive changes to reschedule scope with baseline dates in the past. This is allowable per NSF LFO guidance as it improves visibility of variances for "in-progress" activities and maintains a reliable schedule to manage the project. Historical Cost Performance Index (CPI)/CV and Schedule Performance Index (SPI)/SV data are being maintained in the trend charts in the Monthly Report as a record of past performance. Exhibit 2 illustrates how the COVID BCP's improved the cumulative SV, while maintaining a historical record of the SV trend before the retroactive change.

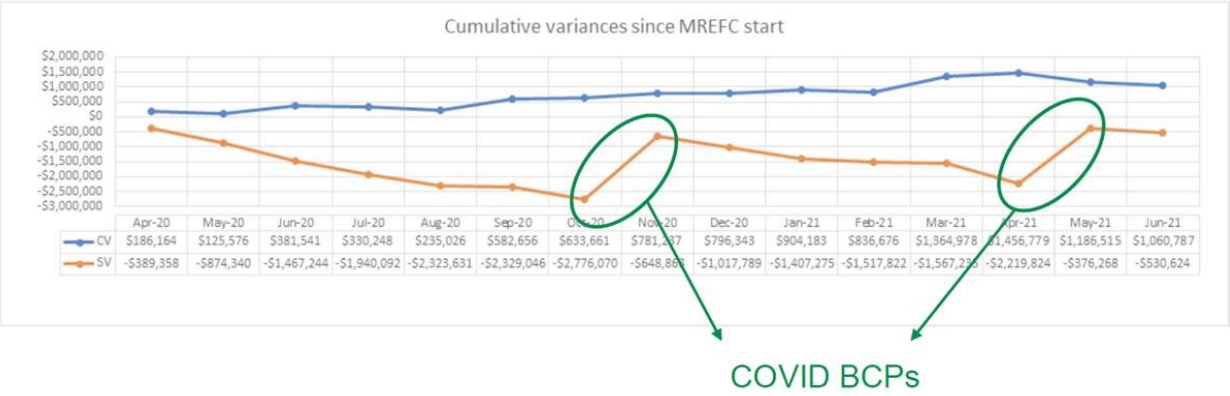


Exhibit 2. ATLAS Schedule Variance Trend

Exhibit 3 shows before/after BAC data from BCP NSF-033. $294K is a result of escalation with higher labor rates and markups applied to activities that were rescheduled due to COVID. The BCP also includes a $168K increase in direct costs as a result of additional resources (primarily labor hours) added to existing schedule activities. The review team confirmed that activities with direct cost increases were scheduled to start 02-Nov-2020, the BCP cut-off date. This is allowable per NSF COVID guidance, which states that effort for not-started activities may be changed for activities scheduled to be completed in the near term (three-six months).

WBS (3)	(All)				
Work Package.FUNI	NSF.MREFC				
Sum of Value	Column Lab				
WBS	DIRECT	FRINGE	OVERHEAD	ESC	Grand Total
After	**38,631,857**	**3,042,094**	**4,247,389**	**3,361,979**	**49,283,319**
6.04 LAr	15,909,592	1,241,805	958,556	1,409,134	19,519,087
6.05 Tile	3,914,916	123,055	294,094	263,185	4,595,250
6.06 Muon	9,283,826	1,001,048	1,460,520	783,757	12,529,151
6.08 Trigger	9,523,523	676,185	1,534,219	905,903	12,639,830
Before	**38,464,171**	**3,006,251**	**4,248,133**	**3,067,712**	**48,786,267**
6.04 LAr	15,786,264	1,209,037	950,235	1,273,813	19,219,349
6.05 Tile	3,858,838	121,698	291,733	217,384	4,489,653
6.06 Muon	9,285,200	1,001,035	1,461,222	698,450	12,445,907
6.08 Trigger	9,533,869	674,480	1,544,942	878,066	12,631,358
Diff	167,686	35,843	(744)	294,267	497,052
6.04 LAr	123,328	32,768	8,321	135,321	299,738
6.05 Tile	56,078	1,357	2,361	45,801	105,597
6.06 Muon	(1,374)	13	(702)	85,307	83,245
6.08 Trigger	(10,345)	1,705	(10,723)	27,837	8,473

Exhibit 3. BCP NSF-033 Before/After BAC Comparison

Planning Packages

The Project Office maintains a spreadsheet to track planning package activities in the IMS, with a worksheet for each WBS L2. The spreadsheet shows eight activities identified as planning packages for 6.04 LAr, four activities for 6.05 Tile, three activities for 6.06 Muon, and 67 activities for 6.08 Trigger. The Project is not using any coding in the IMS to identify these as planning package activities. Additionally there is no process for tracking to ensure

conversion of these activities to work packages prior to the start of the work. Some of the listed planning package activities are scheduled to start on July 1, 2021.

Upon further discussion with the Project it was evident that these activities are tracked on the spreadsheet solely based on their duration in excess of 60 days, and not based on activity scope/complexity or level of planning. The review team concludes that many of these activities do not warrant any additional detailed planning, and that overall planning packages are not used extensively. The review team suggests that the Project consider determining which activities are planning packages based on the need for earned value fidelity in addition to activity duration, and consider coding activities in the IMS (EVT = "K") to promote visibility and ensure earned value is not inadvertently accrued. These suggestions are not being tracked as formal improvement opportunities.

3.2 Earned Value Data Reliability

ATLAS' EVMS processes are established and mature ensuring a high degree of confidence in reported values. Key project milestones in the NSF monthly report (Tier 4 and higher) are traceable to the baseline and forecast dates in the IMS. Individual activities in the IMS are of reasonable duration and CAMs use objective measurement techniques to assess activity progress, including pre-defined activity earning rules for longer duration activities. Traces of accounting data showed that ACWP stored in Cobra reconciles with invoices and accruals stored in the Columbia financial system, and that CAMs are effectively working with the Performing Institutions to accrue estimated actual costs for any un-invoiced effort.

Estimate at Completion

The Project is currently calculating EAC for the monthly reporting as the cumulative ACWP to date plus the budgeted value of the remaining scope (remaining Budget at Completion, or BAC). This results in a Variance at Completion (VAC) equal to the current CV for each control account, with small differences a result of escalation applied in Cobra due to difference between an activity's forecasted dates and the dates in the baseline schedule. This is judged to be acceptable at this relatively early stage of MREFC scope (14% complete) where sufficient performance data are not yet available to warrant significant changes to the budget for remaining scope. The Project has the capability to manually adjust Estimates to Complete (ETC) if this becomes necessary at some point in the future.

The PEP and Cost Estimating Plan (CEP) indicate that comprehensive bottom-up cost estimates of cost-to-go (CTG) are performed annually. The Project has not performed a comprehensive bottom-up EAC since the start of the construction award. The recent COVID BCP NSF-038 focused on the near-term activities in accordance with NSF guidance, but it isn't comprehensive and wouldn't assess non-COVID aspects. The review team notes, however, that there is little value in performing a comprehensive bottom-up EAC now due to the planned re-baseline in the future. The Project should perform the next comprehensive EAC in conjunction with the annual RAEAC analysis (as indicated by the NSF Major Facilities Guide) and as a precursor to the re-baseline.

Risk Adjusted Estimate at Completion

The Project performed an updated risk analysis in June 2021. The methodology and results were included in an August 2021 presentation for the NSF Annual Progress Review, but have not yet been formally documented in a risk analysis report. The ATLAS risk analysis methodology is unique in that it combines the results of separate Monte Carlos simulations for each Level 2 sub-project into composite results for the entire Project. Additionally it appears that the Project used the baseline resource loaded schedule as input to the Monte Carlo simulation, such that the deterministic costs (pre-risk) represent the BAC; the review team notes that it is more typical for projects to use a forecast schedule with ACWP to date and ETC to go, such that the deterministic costs represent the current EAC. The unique complexities for the ATLAS project warrant formal documentation of the analysis methodology, either as a supplement to the Risk Management Plan, in the NSF PEP, or in a standalone risk analysis report. The review team notes that the Project provided a document from July 2019 describing the simulation methodology used at that time; however, the document did not specifically address the aggregation of multiple simulations to develop curves for confidence level versus cost for the entire project.

The June 2021 NSF Monthly Report presents the new calculated cost and schedule risk exposure at the 85% confidence level, but does not include any further documentation of the analysis outputs such as tables showing risk exposure at various confidence levels or distribution curves. The LFO expectation is that a summary of the risk results, including data tables and distribution curves, is included in the NSF Monthly Report whenever the risk input to the RAEAC is updated.

The ATLAS NSF Monthly Reports are not fully consistent with the expectations of the NSF MFG for reporting RAEAC. The MFG guidance is that remaining available contingency should always equate to the difference between the total project cost minus the EAC and any liens, where the sum of the EAC and liens should include variances (backward looking actuals) and updated estimates (forward looking forecasting) in the current plan, not the target baseline BAC. The ATLAS monthly report documents risk exposure at the 85% confidence level but does not report RAEAC for comparison to Total Project Cost (TPC). In summary, while the data appears to be available to calculate RAEAC in accordance with MFG expectations, the Project is not currently doing so. The Project should follow-up with the NSF LFO Liaison to clarify expectations for RAEAC reporting in future monthly reports.

4 CAM Interviews

This section identifies the independent data traces and document research accomplished in support of this surveillance following each individual CAM interview. It discusses the research and data trace objectives in the context of the surveillance review scope.

4.1 WBS 6.04.01 Liquid Argon (LAr) Front End (FE) Electronics – T. Andeen (CAM)

This control account covers the final prototyping and production of new Application Specific Integrated Circuits (ASICs) for the frontend electronics for the LAr calorimeter readout

electronics upgrade. Work is performed by Columbia University, University of Texas (UT) Austin, and Southern Methodist University (SMU). Columbia and UT Austin are collaborating on the custom Analog-to-Digital Converter (ADC) chip. Columbia is also responsible for the overall integration of the ADC chip. SMU is responsible for the data transmission and control link circuits and acquisition of the lpGBT serializers.

The CAM used project controls tools and the IPD to show control account parameters such as overall BAC at $6.7M with progress at 13% complete through June 2021, and described the monthly statusing and accruals process consistent with Project procedures and other presentations from the Project Office. In discussing control account performance trends he noted large variability in SPI due to COVID with large adjustments from the COVID BCPs, and positive CPI driven by SMU labor with a combination of lower effort to complete deliverables and lower labor rates than originally planned. The Project is currently evaluating if the positive CPI trend is expected to continue. Exhibit 4 illustrates the SPI/CPI trends for this control account.

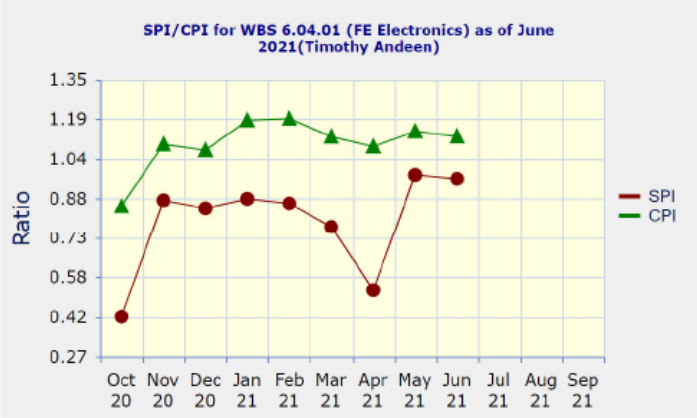
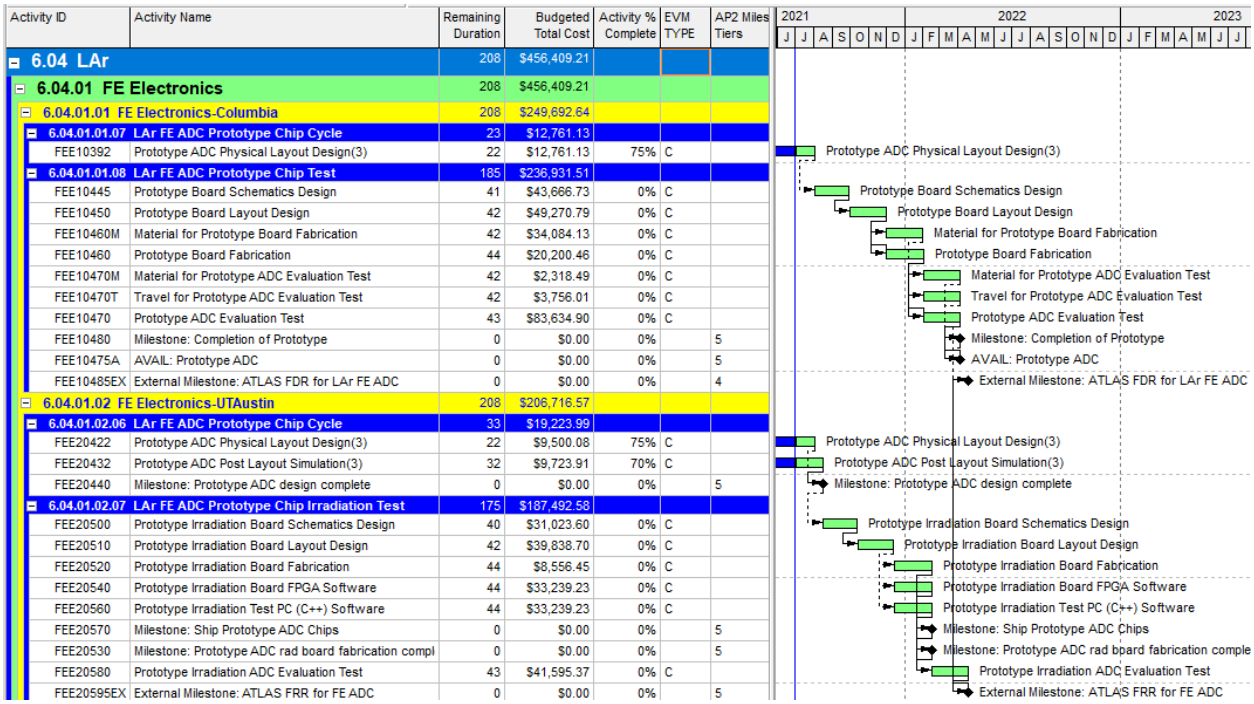


Exhibit 4. SPI/CPI Trends for 6.04.01

The CAM stated that the control account schedule was developed to ensure short duration tasks that can be objectively assessed on a weekly/bi-weekly basis, with % complete used as primary basis for task measurement and phased milestones to capture key events such as 25%, 50%, 75%, etc. completion for the overall lots. Exhibit 5 validates this, showing in-progress and near term activities from two institutions, Columbia and UT Austin, to complete a prototype ADC. The schedule illustrates use of the % complete earned value methodology (EVM Type = C) for objective performance measurement. Key milestones are coded with the appropriate tier, with T4 milestones included in the NSF Monthly Reports.



Activity ID	Activity Name	Remaining Duration	Budgeted Total Cost	Activity % Complete	EVM TYPE	AP2 Miles Tiers
6.04 LAr		208	$456,409.21			
6.04.01 FE Electronics		208	$456,409.21			
6.04.01.01 FE Electronics-Columbia		208	$249,692.64			
6.04.01.01.07 LAr FE ADC Prototype Chip Cycle		23	$12,761.13			
FEE10392	Prototype ADC Physical Layout Design(3)	22	$12,761.13	75%	C	
6.04.01.01.08 LAr FE ADC Prototype Chip Test		185	$236,931.51			
FEE10445	Prototype Board Schematics Design	41	$43,666.73	0%	C	
FEE10450	Prototype Board Layout Design	42	$49,270.79	0%	C	
FEE10460M	Material for Prototype Board Fabrication	42	$34,084.13	0%	C	
FEE10460	Prototype Board Fabrication	44	$20,200.46	0%	C	
FEE10470M	Material for Prototype ADC Evaluation Test	42	$2,318.49	0%	C	
FEE10470T	Travel for Prototype ADC Evaluation Test	42	$3,756.01	0%	C	
FEE10470	Prototype ADC Evaluation Test	43	$83,634.90	0%	C	
FEE10480	Milestone: Completion of Prototype	0	$0.00	0%		5
FEE10475A	AVAIL: Prototype ADC	0	$0.00	0%		5
FEE10485EX	External Milestone: ATLAS FDR for LAr FE ADC	0	$0.00	0%		4
6.04.01.02 FE Electronics-UTAustin		208	$206,716.57			
6.04.01.02.06 LAr FE ADC Prototype Chip Cycle		33	$19,223.99			
FEE20422	Prototype ADC Physical Layout Design(3)	22	$9,500.08	75%	C	
FEE20432	Prototype ADC Post Layout Simulation(3)	32	$9,723.91	70%	C	
FEE20440	Milestone: Prototype ADC design complete	0	$0.00	0%		5
6.04.01.02.07 LAr FE ADC Prototype Chip Irradiation Test		175	$187,492.58			
FEE20500	Prototype Irradiation Board Schematics Design	40	$31,023.60	0%	C	
FEE20510	Prototype Irradiation Board Layout Design	42	$39,838.70	0%	C	
FEE20520	Prototype Irradiation Board Fabrication	44	$8,556.45	0%	C	
FEE20540	Prototype Irradiation Board FPGA Software	44	$33,239.23	0%	C	
FEE20560	Prototype Irradiation Test PC (C++) Software	44	$33,239.23	0%	C	
FEE20570	Milestone: Ship Prototype ADC Chips	0	$0.00	0%		5
FEE20530	Milestone: Prototype ADC rad board fabrication compl	0	$0.00	0%		5
FEE20580	Prototype Irradiation ADC Evaluation Test	43	$41,595.37	0%	C	
FEE20595EX	External Milestone: ATLAS FRR for FE ADC	0	$0.00	0%		5

Exhibit 5. Schedule Activities for 6.04.01 ADC Prototype at Columbia/UT Austin

4.2 WBS 6.06.01 Muon Small diameter MDT chambers (sMDT) – R. Schwienhorst (CAM)

This control account covers the construction and test of drift tubes by Michigan State University (MSU) which are assembled into small-tube MDT (sMDT) chambers by the University of Michigan (UM) for the ATLAS Muon Spectrometer barrel inner station. This work includes equipping the sMDT chambers with on chamber gas system, and HV and RO distribution boards covered with Faraday Covers. In total, 98 chambers, corresponding to 52,000 tubes are needed, with the project providing half of these.

The BAC for this control account is $5.5M. The CAM reported the control account at 25% complete with no variances in excess of 10% and CPI/SPI near 1.0; this is consistent with June 2021 performance data which shows a cumulative CV of +$64K and a cumulative SV of -$24K. The CAM also reported COVID inefficiency costs consistent with data in the Project tracking spreadsheet ($53K to date for this control account).

The CAM reported that the last bottom-up EAC for this control account was performed as part of COVID BCF NSF-038, and that the account is maintaining the initial activity cost estimates for to-go scope. As discussed in Section 3.2, the review team does not consider this BCP as satisfying the requirement for an annual bottom-up EAC as it would mainly focus on near-term COVID impacts.

The CAM showed a strong knowledge of the scope, cost and schedule for this control account and was able to accurately explain trends in the EVM curves, shown in Exhibit 6.

The drop in ACWP from February to March 2021 was a result of a data entry error in the accounting accrual spreadsheet. This anomaly was explained in a variance report (triggered by a +$364K CV) included in the Aril 2021 NSF Monthly Report and was corrected in the May 2021 financial period. This demonstrates that the Project is not performing retroactive changes but rather making adjustments/corrections in the current period. The large increase in BCWS from August to September 2021 is due to a planned large material purchase by UM. Material is typically purchased in 25% increments, and earned value is claimed when the material is delivered to CERN.

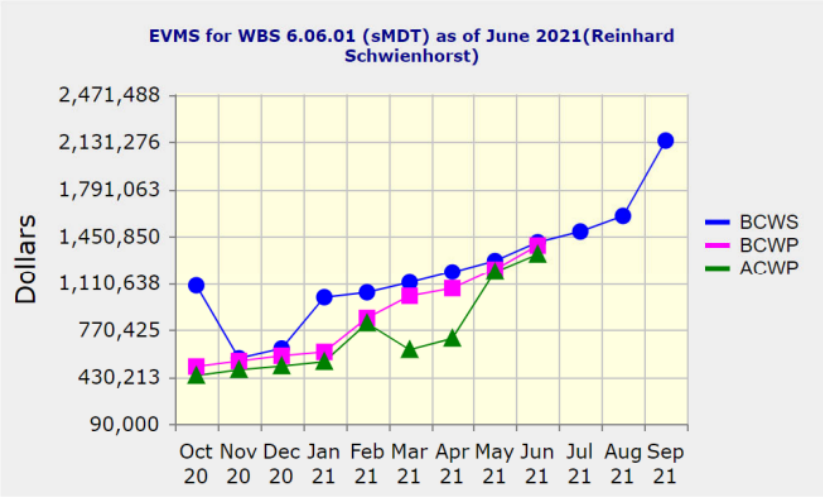


Exhibit 6. Earned Value Data for 6.06.01

The review team performed a data trace of invoices and accruals for work by MSU in WBS 6.06.01.02. Exhibit 7 shows the Project Office accrual tracking spreadsheet. The cumulative invoiced amount of $202.5K accurately reconciles to a full list of invoices from the Columbia accounting system, and the cumulative accrued value of $241.8K reconciles to the ACWP reported in the June 2021 NSF Monthly Status Report.

WBS	WBS Name	Institute	CAM	Columbia contract	Work Package		Cumulative Invoice	Cumulative Accruals	Cumulative ACWP
6.05.03.01	ELMB-MSU	MSU	Huston	G14488	6050301c	ACT_c_AP2	$11,969.97	$18,891.35	$18,891.35
6.05.04.01	LVPS-UTA	UTA	Hadavand	G14503	6050401c	ACT_c_AP2	$226,806.46	$235,199.28	$235,990.04
6.05.04.02	LVPS-NIU	NIU	Chakraborty	G14492	6050402c	ACT_c_AP2	$0.00	$9,463.11	$9,463.11
6.06.01.01	sMDT_Michigan	UM	Zhou	G14485	6060101c	ACT_c_AP2	$818,838.45	$1,078,284.26	$1,078,284.26
6.06.01.02	sMDT_MSU	MSU	Schwienhorst	G14489	6060102c	ACT_c_AP2	$202,507.19	$241,779.20	$241,779.20
6.06.03.01	TDC_Michigan	UM	Zhu	G14486	6060301c	ACT_c_AP2	$83,367.20	$115,649.21	$115,649.21
6.06.04.01	CSM Michigan	UM	Schwarz	G14487	6060401c	ACT_c_AP2	$161,051.18	$157,853.59	$160,599.10
6.06.05.01	L0MDT_BU	BU	Butler	G14478	6060501c	ACT_c_AP2	$100,927.80	$141,203.17	$141,203.17
6.06.05.02	L0MDT_UMASS	UMass	Martinez-Outschoor	G14501	6060502c	ACT_c_AP2	$147,378.82	$205,464.00	$205,464.00

Exhibit 7. Accruals and Invoice Tracking for 6.06.01.02

4.3 WBS 6.08.03 Trigger Global Event Processor (GEP) – Wade Fisher (CAM)

This control account covers the production of the GEP trigger firmware. This includes the trigger framework (MSU) and five algorithms: topological clustering (MSU and Oregon), jet-finding (Indiana), hadronic global event quantity reconstruction (Chicago), pileup suppression (Pitt), and tau identification (Oregon), as well as coordination of integration of the framework and algorithms into firmware (Oregon). The CAM described the algorithms being developed by different institutions as mostly independent from each other with no need for inter-institution collaboration.

The CAM was fluent in the use of project controls tools to show control account status, including BAC ($4.3M) and current percent complete (21%). The control account budget is dominated by engineering labor, with a small amount of material costs for each institution to purchase licenses and development kits to test the firmware. The CAM used a three-month look-ahead schedule view provided by Project Controls to illustrate activities, linkages and near-term milestones for one of the L4 institutions.

The CAM described the use of a rubric to define earning rules for longer duration activities (>2-3 months). Exhibit 8 illustrates the earning rules for several of these long duration activities, including both near term tasks that were split as a result of the COVID BCP as well as future tasks. This demonstrates objective, pre-defined criteria for earning value and provides confidence in the reliability of the data reported to NSF.

Long Duration Tasks % Complete Methodology - June 2021								
WBS	Activity ID	Activity Name	Percent Complete	Current Duration	Start	Finish	EVM TYPE	%Complete Methodology
Trigger								
Tasks that were split and extended for the 2nd COVID BCP								
6.08 Status.03.01	GEPTF1261	V1-Preliminary Firmware Testing on GEP Prototype V1 2	40%	84	04-May-21 A	31-Aug-21	C	Task broken into five distinct parts, each incrementing 20% when complete: Synthesize FW, Validate synthesis, Generate constraints, Build bitfile, Deploy
6.08 Status.03.05	GPHER5142	Assess and Optimize Resource Utilization 3	15%	62	04-May-21 A	30-Jul-21	C	Task broken into five distinct parts, the first 4 are 15% increments and the last is 40%: Synthesize FW, Validate synthesis, Analyze resource usage, Form optimization strategies, implement optimization
6.08 Status.03.06	GEPPSA6171	R&D: Develop Advanced Technique to Compute cut-Based Quantities 2	65%	87	04-May-21 A	3-Sep-21	C	Task broken into five distinct parts, increments of 15%, 20% and 25%: Propose algorithm variations, evaluate candidate performance, evaluate candidate resources, evaluate candidate latency, downselect
Long-Duration Future tasks								
6.08 Status.03.05	GPHER5280	Assess and Optimize Resource Utilization of v1 Hadronic Reco	0%	65	28-Jul-22	28-Oct-22	C	Task broken into five distinct parts, each incrementing 20% when complete: Synthesize FW, Validate synthesis, Analyze resource usage, Form optimization strategies, implement optimization
6.08 Status.03.06	GEPPSA6181	R&D: Develop Advanced Technique to Compute Multi-Dim. Quantities 2	0%	186	7-Sep-21	1-Jun-22	C	Task broken into five distinct parts, increments of 15%, 20% and 25%: Propose algorithm variations, evaluate candidate performance, evaluate candidate resources, evaluate candidate latency, downselect
6.08 Status.03.07	GEPTIA7280	Integrate v2 Tau ID Algorithm Firmware with Framework Firmware	0%	65	27-Sep-23	29-Dec-23	C	This task has a long duration due to uncertainty of when review will take place. Status as 100% once travel period is complete.

Exhibit 8. Earned Value Criteria for Long Duration Activities in 6.08.03

In discussing risks to achieving technical, schedule or cost goals, the CAM noted a concern that delayed algorithm inputs from international partners to the US project could present challenges to the control account schedule, and that this has been added to the risk register. Exhibit 9 shows this risk highlighted in the June 2021 NSF Monthly Status Report (as well as another high-ranking risk for loss of key personnel for the firmware effort).

WBS	Risk-ID	Expected Expiration	Title	Probability Post-Mitig.	Schedule Impact (months) Low	Schedule Impact (months) High	Risk Rank	Task Affected for simulation	Probability Weighted Schedule Exposure (months)
6.8 Trigger (NSF)									
6.8.3 Global	RN-06-08-03-008	1-Jul-25	Loss of key personnel in firmware effort	36%	6.0	9.0	210	all firmware writing tasks; e.g., insert delay at GEPJF4360	2.7
6.8.3 Global	RN-06-08-03-009	1-Jul-25	International algorithm partner delay.	36%	3.0	6.0	90	repeat v3 alg integration tasks: GEPTF1840 (only) up to GEPTF1840-GEPTF1870T	1.6

Exhibit 9. Schedule Risks Impacting 6.08.03

5 Surveillance Results

5.1 Status of Previous Findings and Recommendations

The March 2020 verification review identified no findings requiring corrective action. The 2020 review team identified one improvement opportunity to update project documentation to reflect the following EVM processes and procedures as follows:

A. Document the revised process for accrual collection and reconciliation (Guideline 16)

Closed. The process for accrual collection and reconciliation is documented in Section 3.5.3.1 of the CEP.

B. Identify the report elements required by the Major Facilities Guide including reporting milestones and the WBS level for variance reports in the PEP (Guideline 25)

Closed. The PEP has been updated in Section 14.1 to address the current monthly reporting for the construction stage. See Section 5.3 below for new Improvement Opportunity A. related to reporting RAEAC.

C. ETC, EAC, and risk-adjusted EAC calculation procedures are not documented (Guideline 27)

In process. Section 3.5.4 of the CEP describes the process for calculating ETC/EAC, including provisions for the CAMs to adjust the remaining units of schedule activities in

case more/less effort is needed to complete the work (adjusted ETC). This section also defines requirements for an annual bottom-up EAC.

Section 3.6 of the CEP discusses how contingency is calculated using quantitative risk analysis, but does not fully describe how the multiple analyses for each WBS L2 are combined together to create the confidence level for the entire project. Additionally the process for explicitly calculating RAEAC in accordance with MFG guidance is not defined. This item will be tracked through new improvement opportunities A. and E. described in Section 5.3.

D. Change control thresholds and associated approval authorities are not documented (Guideline 32)

Closed. Section 10.2 of the PEP was updated to include the NSF change control thresholds.

5.2 Corrective Action Requests (CAR)

Based on the interviews with the project team and review of the project documentation, the review team identified no findings requiring corrective actions.

5.3 Improvement Opportunity (IO)

Based on the interviews with the ATLAS project team and review of the project documentation, the review team identified the following recommendations. As noted in the Surveillance Plan, Appendix A, recommendations are EVMS implementation enhancements and need not be tracked for closure except recommendations with an asterisk (*).

A. Document the RAEAC value in the NSF Monthly Report to comply with the MFG for reporting risk exposure. Include a summary of the risk analysis results with data tables and distribution curves whenever the risk exposure (RAEAC) is updated.* (Guidelines 25 and 27)

The ATLAS monthly report documents risk exposure at the 85% confidence level but does not report RAEAC for comparison to TPC per the MFG. While the data appear to be available in the monthly report to calculate the RAEAC in accordance with MFG expectations, the Project is not currently doing so. Nor does the monthly report include a summary of the risk analysis.

B. Perform a comprehensive EAC in conjunction with the annual RAEAC analysis (as indicated by the NSF MFG) and as a precursor to the re-baseline.* (Guideline 27)

The Project has not performed a comprehensive (bottom-up) EAC since initiation of the construction award in April 2020. The CEP indicates that a bottom-up EAC will be performed annually. The Project identified a recent COVID BCP as the annual EAC. But, this COVID BCP focused on the near-term activities in accordance with NSF guidance, and it isn't comprehensive nor would it assess non-COVID aspects. The review team

notes that there is little value in performing a bottom-up EAC now due to the re-baseline in the future.

C. In VARs with multiple drivers, quantify the cost and schedule impacts with each identified driver, especially for VARs with both COVID and non-COVID related variances.* (Guideline 23)

Monthly VARs document total variances at the control account level and include generalized issue descriptions. However, in instances where multiple variance drivers exist, the VARs lack traceability to the relative contribution of each issue to the overall variance total.

D. Include both positive and negative cost and schedule variance analysis reports in the NSF Monthly Reports per the MFG.* (Guideline 25)

The August 2021 update to the PEP (Section 14.2) states that Monthly Reports will include VARs at the deliverable (WBS 3) level for only negative variances with an SV larger than $100k AND an SPI below 0.9. MFG Section 4.6.2 requirements are to report both positive and negative variances (>±10%).

E. Document the process for calculating total Project risk exposure from the aggregation of multiple independent WBS L2 Monte Carlo simulations in either the PEP, as a supplement to the Risk Management Plan, or in a risk analysis report. (Guideline 27)

The CEP and the Risk Management Plan describe the quantitative risk analysis methodology using Monte Carlo simulation, but do not discuss how the results of the independent simulations are combined to generate the range of cost/schedule contingency versus confidence level for the entire Project. The unique complexities of the ATLAS methodology warrant additional explanation in a formal project document.

6 EVMS Guideline Summary

Guideline EIA-748-C	NSF-Adjusted Guideline Description	Intent Met? High Medium Low	References Project Procedure/ Document/ Interview	Comments/Findings/Recommendations
Planning, Scheduling and Budgeting				
2.2b Set Measurement Indicators	7. Identify physical products, milestones, technical performance goals, or other indicators that will be used to measure progress.	High	• Integrated Master Schedule (IMS) • CPRs for April, May, June 2021 • US ALAS HL-LHC Cost Estimating Plan (CEP) • BNL EVMS System Description • CAM Interviews • Planning Package tracking spreadsheet • Earned value rubric for Trigger 6.08.03	Baseline and forecast dates for key milestones tracked in the NSF Monthly Report (Tier 4 and higher) are traceable to the baseline/forecast IMS. WBS L3 Control accounts are subdivided into WBS L4 cost accounts for each performing institution working in the L3. CPRs show performance by institution to facilitate effective oversight and management by the CAMs. Activities are generally of reasonable duration to promote accurate performance measurements, and are coded with the appropriate earned value technique for integration with Cobra (wither % complete or level of effort). For longer duration activities the Project uses rubrics with pre-defined earning rules in discrete increments. The Project maintains a spreadsheet tracking planning package activities based on activity duration >60 days. There are no activities coded as planning packages in the IMS. **Consideration (not tracked as an IO):** The Project should consider determining which activities are planning packages based on the need for earned value fidelity in addition to activity duration, and consider coding activities in the IMS (EVT = "K") to promote visibility and ensure earned value is not inadvertently accrued.

Guideline EIA-748-C	NSF-Adjusted Guideline Description	Intent Met? High Medium Low	References Project Procedure/ Document/ Interview	Comments/Findings/Recommendations
Accounting Considerations				
2.3a Record Direct Costs	16. Record direct costs in a manner consistent with the budgets in a formal system controlled by the general books of account.	High	• CPRs for April, May, June 2021 • June 2021 Monthly Performance Report • Cost Estimating Plan (CEP) • BNL EVMS System Description • Sponsored Project Financial Report - Detail-May-2021.xls. • 0-NSF Reconciliation_Review_6-17-21.xlsx • CAM & Project Controls Interviews	The process for reporting ACWP and accruals is well documented in the CEP. The record of invoices for each institution at WBS L4 exported from the accounting system (Sponsored Project Financial Report - Detail-May-2021.xls) reconciles to the ACWP reported in the CPRs (with adjustments for accruals for un-invoiced work). Accruals are tracked at WBS L4 (0-NSF Reconciliation_Review_6-17-21.xlsx). In verifying that ACWP in the CPR reconciles with Columbia's financials, the review team found some instances where the accruals were continuing to be used for the ACWP in lieu of the invoice amounts from the Columbia financial system (negligible, conservative deltas in ACWP). Columbia is considering a step to "true-up" the accruals with the invoices with each institution in conjunction with future incremental funding awards. The review team endorses adding the "true-up" step in the reconciliation process. As part of the monthly accrual collections, each institution identifies the incurred COVID costs at WBS L4 by identifying labor inefficiencies due to COVID for that month. 17 of the 36 WBS L4 are reporting incurred COVID impact costs in ACWP. In the CPR report, only five of these WBS Level 4 are reporting a negative cumulative cost variance. **Consideration (not tracked as an IO):** Columbia should consider having each institution perform a reasonableness check of the COVID costs in the ACWP as part of the "true-up" discussion or the COVID BOEs planned for the fall.

Guideline EIA-748-C	NSF-Adjusted Guideline Description	Intent Met? High Medium Low	References Project Procedure/ Document/ Interview	Comments/Findings/Recommendations
2.3f *Track and Report Costs and Quantities*	21. *For EVMS, the accounting system will provide for:* *(1) Accurate cost accumulation and assignment of costs to control accounts in a manner consistent with the budgets using recognized, acceptable, costing techniques.* *(2) Cost recorded for accomplishing work performed in the same period that earned value is measured and at the point in time most suitable for the cost category involved (i.e., for material no earlier than the time of actual receipt or for subawards/subcontracts alignment with the payment terms). Estimated actuals used when necessary and significant and reconcile with the accounting system. (MFG Sections 4.2.3 and 4.3.4)* *(3) Full accountability of all material purchased for the project including the residual inventory.*	High	•CPRs for April, May, June 2021 •Cost Estimating Plan (CEP) •BNL EVMS System Description •Sponsored Project Financial Report - Detail-May-2021.xls. •0-NSF Reconciliation_Review_6-17-21.xlsx •CAM & Project Controls Interviews	Material costs are budgeted and planned in the IMS in increments based on the intended ordering sequence, generally in increments (25% at a time) of the total order. Earned value for material is claimed when the material has been delivered to CERN. ACWP by cost category (labor, materials, travel, etc.) is not available in Cobra. The performing institutions enter accruals by category, but only the total cumulative accrual for the institution is reported back to the Project Office. The review team suggests that a future surveillance evaluate if the CAMs have adequate visibility into how different cost categories are driving variances. See Guideline 16 for discussion on accruals process for estimating actuals for un-invoiced work performed.

Guideline EIA-748-C	NSF-Adjusted Guideline Description	Intent Met? High Medium Low	References Project Procedure/ Document/ Interview	Comments/Findings/Recommendations
Analysis and Management Reports				
2.4a Analysis and Management Reports	22. On a monthly basis, generate EVM reports including the following information at the control account and other levels as necessary for management control using actual cost data from, or reconcilable with, the accounting system: (1) Comparison of the amount of planned budget and the amount of budget earned for work accomplished. This comparison provides the schedule variance. (2) Comparison of the amount of the budget earned and the actual (applied where appropriate) direct costs for the same work. This comparison provides the cost variance.	High	• CPRs for Apr, May, Jun 2021 • Jun 2021 Monthly Progress Report • VARs for 6.04.01, 6.06.01, 6.08.03 • PEP Sections 4.10.2 and 10.2 • BNL EVMSD Section 2.3 • Interviews	Cost and schedule performance data are recorded per PEP/EVMSD procedures, with variances reported out in the monthly CPR. Variances are calculated at L4 and analyzed/reported at L3 (control account). Monthly variance analysis reports for each L3 control account are also issued to document performance metrics in the given reporting period (e.g., BCWS, BCWP, ACWP, SV, CV, SPI, CPI, and BAC), thresholds exceeded, variance description, impact, and identified corrective actions. Variance analysis is performed and reported by the responsible CAM for any cumulative schedule or cost variance that exceeds the dollar thresholds defined in Section 10.2 of the PEP as well as >= 10% variance.

Guideline EIA-748-C	NSF-Adjusted Guideline Description	Intent Met? High Medium Low	References Project Procedure/ Document/ Interview	Comments/Findings/Recommendations
2.4b Identify Significant Variances for Analysis	23. Identify, on a monthly basis, the significant differences between both planned and actual schedule performance and planned and actual cost performance, and provide the reasons for the variances in the detail needed by project management. Provide plans for remediation.	Medium	• CPRs for Apr, May, Jun 2021 • Jun 2021 Monthly Progress Report • VARs for 6.04.01, 6.06.01, 6.08.03 • Google Docs Spreadsheet • PEP Sections 4.10.2 and 10.2 • BNL EVMSD Section 2.3 • Interviews	Variances exceeding CPI/SPI thresholds are highlighted in monthly CPRs. Cost variances associated with COVID related labor inefficiencies are documented in a separate data tab within the Google Docs Spreadsheet. Monthly variance analysis reports (VARs) document total variances at the control account level and include generalized issue descriptions. However, in instances where multiple variance drivers exist, the VARs lack traceability to the relative contribution of each issue to the overall variance total. The project appears to have the data detail to be able to assign the cost and schedule impacts for the different drivers including COVID and non-COVID. The project is planning to develop documentation (BOEs) detailing the basis of cost and schedule impacts for COVID-related variances starting Fall 2021. **Recommendation**: In VARs with multiple drivers, quantify the cost and schedule impacts with each identified driver, especially for VARs with both COVID and non-COVID related variances.*

Guideline EIA-748-C	NSF-Adjusted Guideline Description	Intent Met? High Medium Low	References Project Procedure/ Document/ Interview	Comments/Findings/Recommendations
2.4d Summarize Information for Management	25. Summarize the data elements and associated variances through the project organization and/or work breakdown structure to support management needs and any customer reporting specified in the project.	High	•BNL EVMS System Description •PEP dated August 8, 2021 •PEP dated March 21, 2020 •NSF Monthly Reports, June, May, and April 2021 •CPRs for Apr, May, Jun 2021 •Cooperative Agreement 1948993	BNL EVMS System Description indicates variance analysis is conducted at the control account level, if any cumulative SPI or CPI is less than 0.9 or greater than 1.10, unless alternate thresholds are defined in the PEP/PMP. August 2021 PEP, Section 14.2 states Monthly Reports will include VARs at the deliverable (WBS 3) level for only negative variances with an SV larger than $100k AND an SPI below 0.9. March 2020 PEP Section 14.2 states Monthly Reports will include VARs at the WBS Level as agreed upon with NSF for all cost and schedule variances > ±10%. This is as required by the MFG. The NSF Monthly Reports include variance analyses (VARs) per the monthly Cost Performance Report (CPR) and the thresholds in the current PEP and the Cooperative Agreement. June Monthly Report states the risk exposure from the June 2021 risk analysis is $18.7M with 85% confidence level. The outputs from the risk analysis were not included in the Risk Management section of the report. See Guideline 27 for recommendations for documenting RAEAC and analysis results in the Monthly Report. **Recommendation**: Include both positive and negative cost and schedule variance analysis reports in the NSF Monthly Reports per the MFG.*

Guideline EIA-748-C	NSF-Adjusted Guideline Description	Intent Met? High Medium Low	References Project Procedure/ Document/ Interview	Comments/Findings/Recommendations
2.4e* Implement Corrective Actions	26. Implement managerial actions taken as the result of earned value information. *Total project cost and schedule variances greater than ±10% require submission to NSF of a recovery plan with timeline for accomplishment. (MFG Section 4.6.4)*	High	• CPRs for Apr, May, Jun 2021 • Jun 2021 Monthly Progress Report • VARs for 6.04.01, 6.06.01, 6.08.03 • BCP Reports • PEP Sections 4.10.2 and 10.2 • BNL EVMSD Section 2.3 • Interviews	BCP data and sample VARs indicate that corrective actions correlating to identify variances are assessed on a monthly basis. The cause of a large positive cost variance in 6.08.03 in March 2021 was identified as a data entry error in the accrual spreadsheet for University of Michigan, and was corrected in the May 2021 monthly report.

2.4f* Revise Estimate at Completion (EAC)	27. Periodically develop revised estimates of cost at completion based on performance to date, commitment values for material, and estimates of future conditions. Compare this information with the performance measurement baseline, integrated master schedule, estimated risk exposure, and cost and schedule contingency amounts to identify variances at completion important to company management and any applicable customer reporting requirements including statements of funding requirements. *(MFG 4.2.5.8 & 6.2.11.4 - periodic updates of ETC, EAC, and risk exposure)*	Medium	• Project Execution Plan • Cost Estimating Plan • Interviews • June 2021 NSF Monthly Report • ATLAS Presentation at NSF Annual Progress Review, "Cost and Schedule COVID Tracking and Estimates"	The Project has not performed an annual bottom-up EAC according to the PEP/CEP. The recent COVID BCP-1038 focused on the near-term activities in accordance with NSF guidance, but it isn't comprehensive and wouldn't assess non-COVID aspects. The process for determining RAEAC is not well documented. The unique complexities for the ATLAS project (combining multiple Level 2 analyses) warrant formal documentation of the analysis methodology. The risk analysis was performed using BAC not EAC and does not account for CV or the forecasted ETC. Liens and difference between BAC/EAC should be included as part of the RAEAC value. The NSF June 2021 Monthly Report includes the confidence level in the TPC as a result of the risk analysis, but it did not include a summary of the analysis and did not identify the RAEAC value in accordance with MFG guidance. Follow up with the NSF LFO Liaison to ensure a clear understanding of the MFG guidance. **Recommendations**: • Document the RAEAC value in the NSF Monthly Report to comply with the MFG for reporting risk exposure. Include a summary of the risk analysis results with data tables and distribution curves whenever the risk exposure (RAEAC) is updated.* • Perform a comprehensive EAC in conjunction with the annual RAEAC analysis (as indicated by the NSF MFG) and as a precursor to the re-baseline.* • Document the process for calculating total Project risk exposure from the aggregation of multiple independent WBS L2 Monte Carlo simulations in either the PEP, as a supplement to the Risk Management Plan, or in a risk analysis report.

Guideline EIA-748-C	NSF-Adjusted Guideline Description	Intent Met? High Medium Low	References Project Procedure/ Document/ Interview	Comments/Findings/Recommendations
Revisions and Data Maintenance				
2.5a* Incorporate Changes in Timely Manner	28. Incorporate changes in a timely manner, *as authorized per the award instrument and MFG Sections 4.2.5.5 and 6.2.11.2*, recording the effects of such changes in budgets and schedules. In the directed effort prior to negotiation of a change, base such revisions on the amount estimated and budgeted to the project organizations.	High	•PEP dated August 8, 2021 •Contingency Tracking NSF_MREFC •BCPs 1027, 1029, 1031, 1033, and 1038 •CPR for Jun 2021 •Liens List in NSF Monthly Reports	PEP Section 8.2 describes the baseline change control process. Sampled BCPs were approved and implemented in 1-2 months. Contingency Tracking log records the impacts to the budget contingency, the BAC at WBS Level 2 and 3, the PMB End Date, and COVID cost. BCPs identified the realized risks for each of the non-COVID BCPs. Liens List in the Monthly Reports identifies pending and future BCP estimates.
2.5b Reconcile Current to Prior Budgets	29. Reconcile current budgets to prior budgets in terms of changes to the authorized work and internal re-planning in the detail needed by management for effective control.	High	•Contingency Log •BCP NSF-033 and NSF-038 •IMS •CPR	The contingency log tracks changes in BAC from each BCP at WBS L3 (control account) and the rolled up value for the entire PMB. The current BAC value in the contingency log reconciles to the June 2021 CPR and NSF Monthly Report. BCPs NSF-033 and NSF-038 were traced for integration into P6 and Cobra at the activity level. Direct costs are traceable with appropriate markups in Cobra for the change in schedule as a result of COVID. BCP data in P6 and Cobra reconcile to BCP approved values.

Guideline EIA-748-C	NSF-Adjusted Guideline Description	Intent Met? High Medium Low	References Project Procedure/ Document/ Interview	Comments/Findings/Recommendations
2.5c Control Retroactive Changes	30. Control retroactive changes to records pertaining to work performed that would change previously reported amounts for actual costs, earned value, or budgets. Adjustments should be made only for correction of errors, routine accounting adjustments, effects of customer or management directed changes, or to improve the baseline integrity and accuracy of performance measurement data.	High	•CPRs for Apr, May, Jun 2021 •NSF Monthly Reports, June, May, and April 2021 •BCP-1038 •NSF Guidance on Construction Project Re-baselining due to COVID-19 Impacts dated Nov 12, 2020	Per the Cost Performance Reports (CPRs), the May $BCWS_{CUM}$ is lower than the April $BCWS_{CUM}$ but the May current BCWS is positive. • April BCWScum = $9,290,223. • May BCWScum = $7,983,777. • May BCWScur = $1,006,837. The implemented COVID BCPs are changing previous months' BCWS values. The CPI/CV and SPI/SV data are being maintained in the trend charts in the Monthly Reports. CPRs have no negative BCWScur, BCWPcur, or ACWPcur at the control account levels except one minor negative ACWP. Due to COVID-19 replanning efforts, retroactive changes have been implemented in accordance with NSF guidance and to improve visibility of variances for "in-progress" activities and maintain a reliable schedule to manage the project.
2.5d Prevent Unauthorized Changes	31. Prevent revisions to the project budget except for authorized changes.	High	•PEP dated August 8, 2021 •Contingency Tracking NSF_MREFC •BCPs 1027, 1029, 1031, 1033, and 1038 •CPR for Jun 2021	PEP Section 8.2 describes the baseline change control process. Level 3 Tab of the Contingency Tracking identifies the BAC change of each Control Account with each Baseline Change Proposal (BCP). The budget changes from BCP-1038 for the select Control Accounts reconciles with the BACs reported in the June 2021 CPR. Contingency Tracking Log and BCPs identify the realized risk. COVID BCPs identify COVID in Block 11, Change in Response Identification, of the BCP Form. Contingency Tracking form identifies approval dates for each BCP. One of the five BCPs reviewed matches the approval dates on the BCP Forms. Each of the other four BCPs implemented in the baseline were subsequently approved.

Guideline EIA-748-C	NSF-Adjusted Guideline Description	Intent Met? High Medium Low	References Project Procedure/ Document/ Interview	Comments/Findings/Recommendations
2.5e* Document Performance Measurement Baseline (PMB) Changes	32. Document change requests and the resultant changes to the performance measurement baseline. *Maintain a change log and provide all change requests to NSF with contingency allocations. (MFG Section 4.2.5)*	High	•BCPs 1027, 1029, 1031, 1033, and 1038 •Contingency Tracking NSF_MREFC •NSF Monthly Reports	BCPs identify the cost impacts at the Control Account levels. Contingency Tracking log records the impacts to the BAC changes at WBS Level 2 and 3. Monthly Report includes a log BCP and budget & schedule contingency usage.

APPENDIX A: ATLAS Earned Value Management System (EVMS) Surveillance Plan without Appendices

Large Hadron Collider (LHC) High Luminosity (HL) Upgrade Program
A Toroidal LHC Apparatus (ATLAS) Detector Project
Columbia University, Cooperative Agreement 1948993

Earned Value Management System (EVMS) Surveillance Plan
August 2021

PURPOSE

NSF accepted the ATLAS EVMS in March 2020 based on a compliance assessment conducted by an independent review team. The review team determined that the HL-LHC ATLAS EVMS meets both the intent of EIA-748 guidelines and NSF requirements and will provide reliable project performance data during the Construction Stage.

The purpose of NSF's EVMS surveillance reviews during project execution is to ensure that the accepted EVMS is being maintained and followed and provides reliable EVM project performance data. Typically, NSF conducts EVMS surveillance as part of the project annual reviews.

SURVEILLANCE OVERVIEW AND SCOPE

Surveillance is the process of reviewing the implementation and use of the accepted EVMS processes and procedures to the project. The scope of a surveillance review may be inclusive of all 32 EIA-748 guidelines or can concentrate on specific guidelines or interests. An effective surveillance process reinforces and maintains the EVMS process throughout the project construction stage through assessment, training, and mentoring of the EVMS process elements.

This ATLAS EVMS surveillance review will focus on the responses to the 2020 verification review recommendations and sample the following in-progress control accounts.

- 6.04.01 Liquid Argon (LAr) Front End (FE) Electronics
- 6.06.01 Muon Small diameter MDT chambers (sMDT)
- 6.08.03 Trigger Global Event Processor (GEP)

The 2021 Surveillance Review seeks to accomplish three goals:

- Review ATLAS's response to 2020 verification review recommendations and trace actual costs from a cost performance report (CPR) to the monthly accruals and the subaward invoice data in Columbia's financial system.
- Review effectiveness of the processes for assessing and forecasting COVID-19 impacts versus other cost and schedule variances.
- Review ATLAS project team's adherence to their EVMS processes and procedures in accordance with the ATLAS project controls documentation.

- Review the timeliness and reliability of project performance data provided by ATLAS.

Four of the five of the EVM process categories will be considered during this system surveillance with a focus on (1) Analysis and Management Reports and (2) Revisions and Data Maintenance. This EVMS surveillance will be based upon the remaining work and content that is specific to the guidelines being reviewed. Appendix A is a summary of the March 2020 ATLAS EVMS verification review results.

SURVEILLANCE MEMBERSHIP

Membership of the surveillance review team consists of both internal NSF individuals and external experts, providing knowledge and experience with NSF requirements and EVMS processes and implementation while retaining an independent viewpoint.

Surveillance Team Reviewers

- Rebecca Yasky (Team Leader), NSF Large Facilities Office, HL-LHC LFO Liaison
- Rick Farnsworth, NSF Large Facilities Office
- Sam Steiman – MPR Associates, Inc.
- Josh Wargo – MPR Associates, Inc.

EVMS Surveillance Team Assignments

Lead Team Member	Responsible Area	Guidelines
Steiman	Planning, Scheduling and Budgeting	7
Steiman	Accounting Considerations	16, 21
Wargo	Analysis & Management Reports	22, 23, 26
Yasky	Analysis & Management Reports	25
Steiman	Analysis & Management Reports	27
Farnsworth	Revisions & Data Maintenance	28, 29, 32
Yasky	Revisions & Data Maintenance	30, 31

This surveillance execution will be organized to provide a structured setting to assess the approach to EVM process implementation and its consistency across the project. This will be facilitated by:

- A clear code of conduct
- Understanding of how results will be used
- Open discussions of potential findings before a report are generated
- A clearly defined format for reporting findings and recommendations

SURVEILLANCE REVIEW - CODE OF CONDUCT

Responsibilities

The surveillance team will provide advanced notification of the documentation and processes that will be reviewed. It is also the intent of this surveillance to not interfere with on-going work to the extent possible including the Annual Construction Review. The surveillance team will not require extensive presentations or preparations, and it can review and interpret data provided in the project's native formats. The review will be conducted in a professional manner and in a spirit of constructive assessment and discovery. The surveillance team leader is responsible for the final determination of findings and recommendations and ensuring that the results are communicated to the NSF Program Officer and the LFO Liaison.

Project personnel should be prepared to demonstrate through objective project information that they are complying with applicable policies and procedures. The ATLAS project team should coordinate with the surveillance team to ensure that Control Account Managers (CAMs) responsible for areas of specific interest are available for discussions and interviews. The project personnel should also ensure that adequate data and project policies are available to the surveillance team sufficiently in advance of the review to allow for meaningful analysis.

The surveillance team leader will ensure that the review focuses on system compliance and does not become involved with non-EVM system-related issues.

Project Information

Successful surveillance is predicated upon demonstration of compliance with the Project Controls and Financial Reporting processes and procedures through explanations and illustrations using objective project information consisting of documents, computer files, working papers, notes, or other forms of data and communication which demonstrate compliance/non-compliance with a policy, procedure, or process. Objective project information is created in the normal conduct of business and is not prepared solely for the review of a surveillance team. Appendix B is a list of project information to be posted by the ATLAS project team to a website accessible by the Surveillance Review members at least two weeks prior to the virtual on-site portion of the EVMS Surveillance Review. Additional project documentation may be requested during the virtual on-site review.

Data Gathering

The surveillance review will be conducted through reviewing of project performance data, interviewing CAMs and project staff, and verifying the integrity of objective project information. The Surveillance Review Lead will provide a preliminary agenda coordinated with the Annual Review agenda. Typically, the Annual Review agenda will take precedence. The ATLAS project team will coordinate the scheduling of these interviews. The surveillance team lead will adjust the agenda as necessary during the virtual on-site review. Based on surveillance results, if additional interviews are desired, the ATLAS project team will schedule them with CAM(s) that have completed the project work.

Interviews will generally be conducted in a manner which facilitates ease of access to objective project information. The surveillance review will be thorough and structured. This involves

developing a list of subject areas to facilitate scheduled interviews, ensuring that discussions address the complete scope of the EVMS surveillance.

CAM interviews are a key component of EVMS surveillance because CAMs are the source of much of the EVMS information. CAM interviews are supplemented with data integrity tests performed independently. All interviews will incorporate common attributes based on the National Defense Industrial Association (NDIA) Program Management Systems Committee (PMSC) Intent Guide. The purpose of the interviews is to assess the Project's implementation of the following subjects and the scope of the surveillance review. Additional interviewees may include the project manager, the project controls manager and line management.

1. Planning, Scheduling and Budgeting
    a. Verify that objective completion criteria are used as basis to determine progress (Guideline 7 Intent Guide).
    b. Verify that CAM updates schedule status (Guideline 7 Intent Guide).

2. Accounting Considerations
    a. Verify that Actual Cost of Work Performed (ACWP) in the CPR reconcile with books of record (Guideline 16 Intent Guide).
    b. Verify that an established process exists for reporting subaward costs and material actual costs and use of estimated actuals (accruals) when necessary and significant. (Guideline 21 Intent Guide).

3. Analysis and Management Reports
    a. Verify that variance analysis is performed to the project thresholds as required (Guideline 22 Intent Guide).
    b. Verify that variance analysis contains cause, impacts, and corrective action as appropriate (Guideline 22/23 Intent Guide).
    c. Verify that corrective actions are assessed and closed in a timely manner (Guideline 23/26 Intent Guide).
    d. Verify that variance analysis as reported to NSF reconciles with the analysis at the control account level (Guideline 25 Intent Guide).
    e. Verify Estimate to Complete (ETC)/Estimate at Complete (EAC) (Guideline 27 Intent Guide)
        i. Verify that EACs are updated per requirements and take into account past performance.
        ii. Verify that CAMs review achievability of control account EAC.
        iii. Verify that time-phased ETC reconciles with the EAC as reported externally.
    f. Verify risk-adjusted Estimate at Complete (RAEAC) (Major Facilities Guide & Guideline 27 Intent Guide)
        i. Verify that CAMs provide input to updated risks and opportunities.
        ii. Verify that current risks and opportunities are used to establish the risk-adjusted estimate at completion (RAEAC) and for comparison with BAC, cost/schedule contingency amounts, and TPC.

4. Revisions and Data Maintenance
   a. Verify that work authorization plus any baseline change documentation equal current control account budget (Guideline 28/29 Intent Guide).
   b. Trace a change proposal authorized. Verify schedule and cost integration at control account level and that the WBS dictionary is updated as appropriate (Guideline 28/29 Intent Guide).
   c. Verify that change logs reconcile and contain justification including identification of realized risk (Guideline 28/29/32 Intent Guide).
   d. Verify that retroactive changes are made only for correction of errors, accounting adjustments, effects of management directed changes to improve accuracy of data. If any have been made, verify that they are consistent with disclosed EVMS policy (Guideline 30 Intent Guide).
   e. Verify, in at least one control account, that last month's changes as reported to NSF and this month's PMB reconcile to entries in the baseline log (Guideline 30/32 Intent Guide).
   f. Verify that negative earned value status, if any, has been adequately explained (Guideline 31/32 Intent Guide).
   g. Verify that all baseline changes within a month reconcile to baseline control requests or the equivalent (Guideline 31/32 Intent Guide).

SURVEILLANCE RESULTS

Concerns Identified During the Surveillance

The surveillance team will gather data by reviewing documentation and interviewing members of the ATLAS project team. A key component of surveillance is communicating timely, pertinent, and candid feedback. Surveillance team members and project personnel should seek clarification to fully understand questions asked, the data sought, and the responses provided. If, after fully understanding the information provided, a surveillance team member believes that there may be a question of compliance; the surveillance team will discuss the observation. If the surveillance team agrees that observation is still a question of compliance, the ATLAS project controls representative will be notified by the surveillance team of the concern. This gives the project the opportunity to supply the surveillance team additional information to clarify the observation. This may result in the concern of the observation being resolved, or may result in a Recommendation, or could be a Finding of non-compliance. Findings and Recommendations are defined as:

> *Findings (Corrective Actions)* – Findings are catalogued as Corrective Action Requests (CAR) and fall into two broad categories: 1) non-compliance with the accepted EVMS description or procedures and 2) non-compliance with the EIA-748-C EVMS guidelines. Failure to resolve findings reduces confidence in the ability of project management to effectively use the EVMS process to achieve project goals and objectives of the stakeholders. A Corrective Action Plan is required for each finding.
>
> Findings should be communicated to the ATLAS project team as part of the virtual on-site Out-Brief. If the corrective action to a finding is implemented by the project during the review, the finding (CAR) will be downgraded to an IO* (Improvement

Opportunity*). The asterisk indicates it was downgraded from a CAR due to being implemented during the surveillance review.

Recommendations (Improvement Opportunities) – Recommendations are continuous Improvement Opportunities (OI). The surveillance team members may recommend EVM implementation enhancements such as sharing of successful practices, tools, or other items that come to their attention. Recommendations are not the same as findings and, therefore, need not be tracked for closure. However, should a recommendation have an asterisk (*), the surveillance team members have elected that this practice is considered important enough to require tracking to closure.

Surveillance Out-Brief

The surveillance team will evaluate what they have observed, and the information received during the interviews from the ATLAS project team to come to a consensus if any Findings or Recommendations should be issued. The surveillance team may also identify if the observations are systemic or isolated issues. Any preliminary Findings and Recommendations are presented by the surveillance team to the ATLAS project team at an informal out-brief. The ATLAS project team and project controls representative may provide additional feedback in a reasonable timeframe.

Final Report

The surveillance team will take into consideration any feedback received when developing the final report. The final report will be issued to the NSF Program Officer. Dates for report delivery will be agreed to by the team at the virtual on-site out-brief. The NSF Program Officer will provide the report to the ATLAS project team.

Corrective Action Plan

The ATLAS project team will develop a corrective action plan (CAP) to address any Findings or Recommendations identified in the Final Report from the surveillance team. The CAP should include a schedule with realistic dates for when the corrective actions are to be completed. The NSF Program Officer, Grants and Agreements Officer, and LFO Liaison will receive a copy of the CAP for information only unless it is determined by NSF that further actions are required by the surveillance team – such as a follow-on review.

Surveillance Review Close-out

The ATLAS project team is to ensure that the CAP has been acceptably completed. Close-out of the CAP should be documented and retained for future EVMS surveillances. The LFO Liaison will track resolution of any Findings. The ATLAS project team should notify NSF when the CAP is complete.

APPENDIX B: ATLAS EVMS Review Agenda

Earned Value Management System Surveillance Review
HL-LHC ATLAS Detector Upgrade – CA 1948993
Virtual Review - August 17-20, 2021

PURPOSE:
This will be a surveillance review of the ATLAS Earned Value Management System (EVMS) in conjunction with the annual External Panel Review. Discussions will occur, and interviews will be performed to determine if the accepted EVMS is being maintained and followed and provides reliable EVM project performance data. The outcome of this review will be a formal assessment of ATLAS EVMS by an independent review team, including possible corrective actions and improvement opportunities.

AGENDA:

Time (EDT)	***Subject***	***Lead/ Interviewee***
Tuesday, August 17, 2021		
9:00-10:30	Overview of Project Controls & EVMS Reporting Tool Project Responses to 2020 EVMS Review Recommendations Overview of Tracking Methods for COVID Impacts	Brooijmans Novakova Garwood
10:30-11:30	Trace Accounting Data – ACWP & Estimated Actuals	Novakova Garwood
11:30-12:30	*Break*	
12:30-2:00	CAM Interview – 6.08.03 Trigger Global Event Processor (GEP)	Wade Fisher
2:00-2:30	EVM Review Team Interview Discussion	Executive Session
2:30-3:00	*Break*	
3:00-4:30	CAM Interview – 6.06.01 Muon Small Diameter MDT Chambers	R. Schwienhorst
4:30-5:00	EVM Review Team Interview Discussion, Identify Open Items	Executive Session
Wednesday, August 18, 2021		
11:00-4:45	Annual Progress Review*	
Thursday, August 19, 2021		
8:30-10:00	CAM Interview – 6.04.01 LAr Front End (FE) Electronics	T. Andeen
10:00-10:30	EVM Review Team Interview Discussion	Executive Session
10:30-11:00	*Break*	
11:00-12:30	Schedule (P6) and Cobra Data discussions with Project Controls	Steiman/Wargo
12:30-2:00	Additional Discussions with Project Team	
2:00-3:00	*Break*	
3:00-5:00	EVM Review Team – Guideline Assessments	Executive Session
Friday, August 20, 2021		
8:30–9:30	EVM Review Team – Guideline Assessments/Recommendations	Executive Session
9:30–10:30	Discussions with NSF Program Officer	Yasky-Coles
10:30-11:30	Out-brief to Project Team	Yasky
** EVM Review Team observes Annual Progress Review to inform EVMS Surveillance Review*		

APPENDIX C: Review Team Biographies

Rebecca Yasky, PE, PMP, EVP, CCM – NSF LFO Liaison to ATLAS Project and Review Lead
Ms. Yasky is a Large Facilities Advisor in NSF's Large Facilities Office (LFO) providing project management assistance and assurance to assigned major scientific facilities and is LFO's lead for earned value management. She previously worked 16 years for DOE's Thomas Jefferson National Accelerator Facility (Jefferson Lab) as a Project Manager and Engineering Manager. At Jefferson Lab, Ms. Yasky was responsible for the planning, design, and construction of the conventional facilities to support the accelerator upgrade from 6 GeV to 12 GeV along with a new experimental hall and for completion of facilities to support R&D on superconducting radiofrequency cavities. She also has served as a panelist with technical and project management expertise for several DOE independent project reviews. She received her B.S. in Civil Engineering from University of Wisconsin-Platteville and her M.S. in Construction Engineering and Management from Stanford University. She is a licensed Professional Engineer and certified Project Management Professional, Earned Value Professional, and Construction Manager.

Richard Farnsworth – NSF LFO Representative
Dr. Farnsworth is a Large Facilities Advisor in NSF's Large Facilities Office (LFO) providing project management assistance and assurance to assigned large scientific facilities. He has worked as a Scientific Program/Project Manager for over 15 years and was the PI for the Biology Directorate's only MREFC infrastructure project (NEON) before coming to NSF. He has managed numerous technical projects with EVM for both DoD and NSF, and also has served as a panelist with technical and project management expertise for several DOE independent project reviews. He received his B.S. in Zoology from the University of California-Davis, his Ph.D. in Biology from the University of California- Santa Cruz and his M.S. in Strategy from the US Army War College. He has been a certified Project Management Professional since 2008.

Samuel Steiman, PE, MPR Associates, Inc. – Schedule, PCMS and Risk Subject Matter Expert
Mr. Steiman has worked on a broad variety of projects in the disciplines of mechanical, electrical, controls and nuclear engineering, developing particular expertise in project controls/project management and quantitative cost and schedule risk analysis for large capital projects. His diverse experience includes: five years in the construction, operation and maintenance of shipboard systems on a nuclear-powered submarine; three years of process validation and project management experience at a medical device manufacturing plant; and approximately 21 years of engineering and project management/project controls consulting experience in projects for the United States Department of Energy and the nuclear power and medical device/pharmaceutical industries. Mr. Steiman holds a Bachelor of Science degree in Mechanical Engineering from the University of Michigan and is a licensed Professional Engineer in the state of Virginia.

Josh Wargo, CCP, PMP, MPR Associates, Inc. – Schedule and Risk Subject Matter Expert
Mr. Wargo has worked on a variety of projects with significant involvement in project controls efforts for the commercial fossil fuel, nuclear, and renewable energy industries, as well as the US Department of Energy, the National Nuclear Security Administration and the National Science Foundation. His experience includes extensive work in schedule, cost, and risk analysis for major power plant and energy system engineering, construction, procurement, and modification projects. He is extremely proficient in the use of Primavera P6, Polaris, Acumen Fuse, @RISK, and MS Project software packages. Mr. Wargo is a licensed Project Management Professional (PMP) and Certified Cost Professional (CCP). He holds a Bachelor of Science Degree in Engineering Science and Mechanics, and a Master of Science Degree in Engineering Mechanics from the Virginia Polytechnic Institute and State University.