1.08.01 DAQ & Control Management (CAM Talk)

Gregg Thayer

CMB-S4 DAQ Conceptual Design Review
July 24, 2023

Who Am I

Gregg Thayer

CMB-S4: 1.08 DAQ and Controls CAM

- Over 25 years of experience designing and implementing DAQ and Controls systems (19 years at SLAC)

Most recently:

- LSST Camera DAQ Lead
- LSST Camera DAQ Deputy CAM

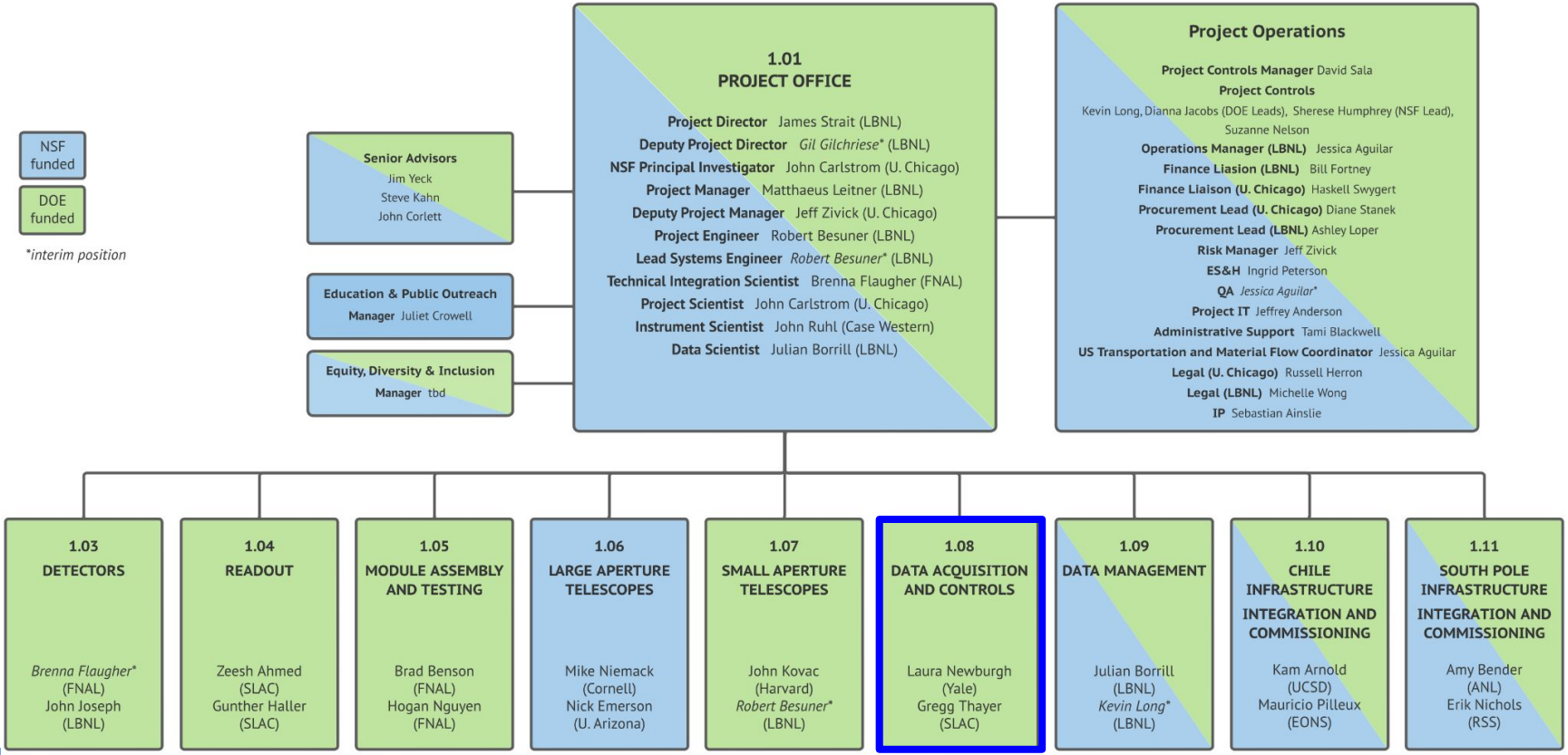
Further Back:

- RCE Platform (Generic DAQ Platform)
- GLAST/Fermi Gamma-Ray Space Telescope
- CLEO III

Outline

- Team
- Since the 2021 CDR
- Responses to Recommendations
- WBS system scope
- System design maturity
- Requirements and Interfaces
- Schedule
- Cost profile slides
- Basis of estimates
- Risks
- Safety (table of hazards)
- Quality assurance plans
- Next steps towards CD-1
- Summary

Work Breakdown Structure



Experienced DAQ Team, Efficient Use Of Funds

1.08
DATA ACQUISITION AND CONTROLS

Laura Newburgh (Yale)
Gregg Thayer (SLAC)

1.08.01
DAQ Management
Gregg Thayer (SLAC)

1.08.02
Observatory Control System
Brian Koopman (Yale)

1.08.03
Observatory DAQ
Nathan Whitehorn (MSU)

1.08.04
Monitoring and Alarms
Cosmin Deaconu (U. Chicago)

1.08.05
Lab Subsystem Development and Support
Abigail Crites (Cornell)

Since the 2021 CDR

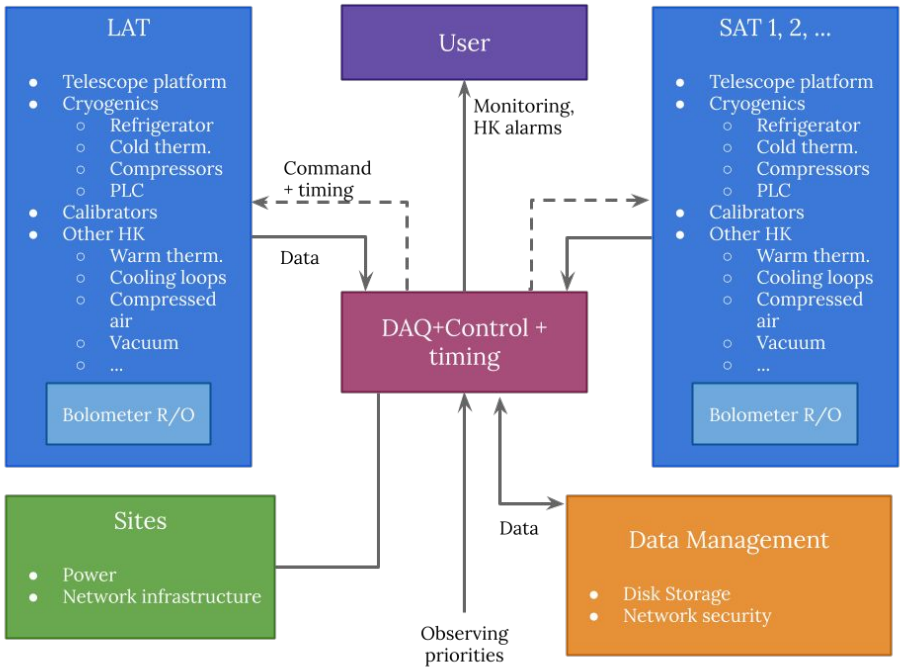
- Reviews
  - November 2021 Director's Review
- WBS
  - Finalized the WBS organization
  - All L2 and L3 positions filled
- Requirements
  - Requirements reorganized
  - Verification methods specified
- Interfaces
  - All Project level ICDs revised and ready or nearly ready for configuration control
- Schedule
  - Regenerated from the bottom up
  - Handoffs to other L2s rationalized
- Risks
  - Cost and Schedule Impact has been estimated
  - Some risks retired or deprecated
- Funding
  - Initially focused on DAQ Bolometer Prototype to support Readout development
  - FY23 includes support for Lab Support

Review Recommendations From 2021 CDR

- RT-134 Staffing
  - Justify that a group size of 7 FTE is adequate for the CMB-S4 DAQ project. Address how conflicts with current projects, e.g. SO, can be avoided.
  - DAQ has completed its first iteration of a bottom up schedule which, when resource loaded and reviewed, will provide this justification. This is happening in preparation for the Fall 2023 Director's Review
- RT-135 Staffing
  - Develop a detailed plan and timeline describing how you intend to hire or train qualified DAQ personnel.
  - As part of the resource loading and leveling process, we will address the need to plan for staffing levels
- RT-136 Trade Study Presentation
  - (see Laura's slides)
- RT-137 Budget
  - Complete the initial budget for this WBS.
  - This is on track for completion prior to the Fall 2023 Directors Review
- RT-138 Project Management (Funding)
  - Fund the DAQ project at sufficient levels to avoid delays in project completion.
  - L1 is aware of the crucial role played by DAQ and Controls in the early stages of the project, particularly DAQ to work with Readout development and Lab Support to leverage expertise in other L2s to work on OCS integration. DAQ has been funded since FY22, and DAQ and Lab Support have identified funding for FY23/FY24.
- RT-139 QA
  - Develop details and examples to clearly demonstrate that QA is sufficiently integrated into the design.
  - Lab Support will be developing automated testing as part of the build/release system. We will investigate the possibility of using Continuous Integration methods to implement this.

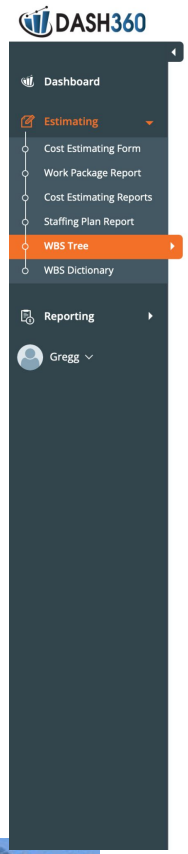
System Scope And Deliverables Are Well Defined

- Provide control framework of observatory, including telescope drive systems, readout boards, and other on-telescope hardware
- Acquire and aggregate high-speed data from detectors (400 Hz per detector, ~ 10 Gbit/s total) and hand off to data management
- Acquisition of housekeeping and other low-rate data streams into specified format
- Browser-based live and historical monitoring of ‘housekeeping’ data and metadata
- Hierarchical, **non-safety** alarms system based on housekeeping data
- Provide observatory-wide timing and frequency references to readout and telescope control hardware
- Provide support for running DAQ and Controls systems in development labs



(Example from the South Pole configuration)

WBS Tree And Dictionary Captured In The Dash360 Tool

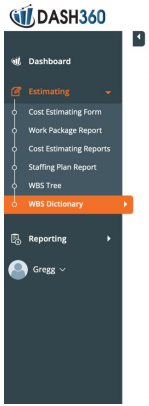


WBS Tree

Estimating / WBS Tree

Project: CMB-S4 CONST **WBS:** 1.08

- Work Breakdown Structure: CMB-S4 CONST
  - 1.08 - Observatory Control and Data Acquisition System (DAQ)
    - 1.08.01 - DAQ Management
      - 1.08.01.01 - DAQ Management
      - 1.08.01.02 - DAQ System Design Engineering
      - 1.08.01.03 - DAQ Reviews
      - 1.08.01.04 - Interface Documentation
    - 1.08.02 - Observatory Control System
      - 1.08.02.01 - Bolometer Readout Control
      - 1.08.02.02 - Telescope Platform Control - SP, Chile, LAT, SAT
      - 1.08.02.03 - Cryogenic Control
      - 1.08.02.04 - Housekeeping Control
      - 1.08.02.05 - Observatory Subsystem Control
      - 1.08.02.06 - Observation Scheduling
      - 1.08.02.07 - Control Framework
    - 1.08.03 - Observatory Data Acquisition
      - 1.08.03.01 - Bolometer Readout
      - 1.08.03.02 - Telescope Readout Data Acquisition
      - 1.08.03.03 - Housekeeping Data Acquisition
      - 1.08.03.04 - Observatory DAQ Network Design
      - 1.08.03.05 - Hardware Procurement
      - 1.08.03.06 - Timing
      - 1.08.03.07 - DAQ Build/Distribution
      - 1.08.03.08 - File Format Specification
    - 1.08.04 - Monitoring and Alarms
      - 1.08.04.01 - Remote Monitoring Capability of Telescope, Housekeeping Subsystems
      - 1.08.04.02 - Remote Monitoring and Real-Time Statistics Gathering
      - 1.08.04.03 - Non-Critical Alarms based on Bolometer + HK Monitors
      - 1.08.04.04 - Personnel and Equipment Protection Interfaces Propagated to Alarms
    - 1.08.05 - (Lab) Subsystem Development and Support
      - 1.08.05.01 - (Lab) Subsystem Development and Support



WBS Dictionary

Estimating / Work Breakdown Structure Report

Project: CMB-S4 CONST **WBS:** 1.08.02 Observatory Control System **WBS Level:** 1 Show Empty WBS Elements

1.08.02 Observatory Control System

Sponsor
DOE
DOE

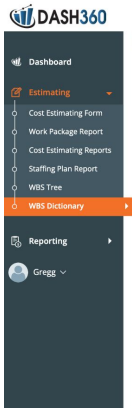
Responsible Manager
Joseph_J

Summary/Description
The Observatory Control System is a facility where each site manages the control and data taking of each site's set of Telescope Systems. It is the site operations center for distribution/coordination of each telescope's observation schedule, configuration, and monitoring data databases. The facility houses the operator's console and support computers. Telescope Systems housekeeping data are monitoring and available for display. Observation planning is provided by Data Management (DM) and execution commands are issued to the Telescope Systems. Telescope Systems science data are aggregated, converted from native format to "commodity" format, and passed to DM. Real time quality monitoring of science data is performed and near real time quality monitoring is provided by DM. Task costs are largely labor for design and implementation of software. Hardware costs are for computers, network equipment, and various site-global clocks and their distribution.

Development and implementation of the Observatory Control System computing hardware at the sites (Chile and SP) and software applications for the CMB-S4 project.

Acceptance Criteria
Delivery of the Observatory Control System computing hardware and software applications to all CMB-S4 Telescope Sites. Effort includes: (*) Specification and procurement of computing nodes capable of supporting the system control computing requirements of all CMB-S4 SAT and LAT sites; (*) Development, testing, and implementation of a control framework for all site-based auxilliary hardware (telescope pointing, thermometry, etc).

Final Product
(*) Control system computing hardware, network equipment, and site specific global time base clock generators and distribution, (*) Computing software applications to provide experiment control and configuration, site operations monitoring and telescope specific graphical user interfaces



WBS Dictionary

Estimating / Work Breakdown Structure Report

Project: CMB-S4 CONST **WBS:** 1.08.03 Observatory Data Acquisition **WBS Level:** 1 Show Empty WBS Elements

1.08.03 Observatory Data Acquisition

Sponsor
DOE
DOE

Responsible Manager
Joseph_J

Summary/Description
Development and implementation of the Observatory Data Acquistion computing hardware at the sites (Chile and SP) and software applications for the CMB-S4 project.

Engineering effort to provide software infrastructure hooks and hardware to collect data from the bolometer readout crates and send to the Observatory Control System in the specified format.

Acceptance Criteria
Delivery of the Observatory Data Acquistion computing hardware and software applications. Effort includes: (*) Specification and procurement of computing nodes capable of supporting the DAQ computing requirements for all CMB-S4 SAT and LAT sites, (*) Development and implementation of data receiver and event building software applications capable of providing full DAQ support for all SAT and LAT sites, (*) Development and implemetation of data transport protocol required to move data and events from each telescope to the Data Management systems.

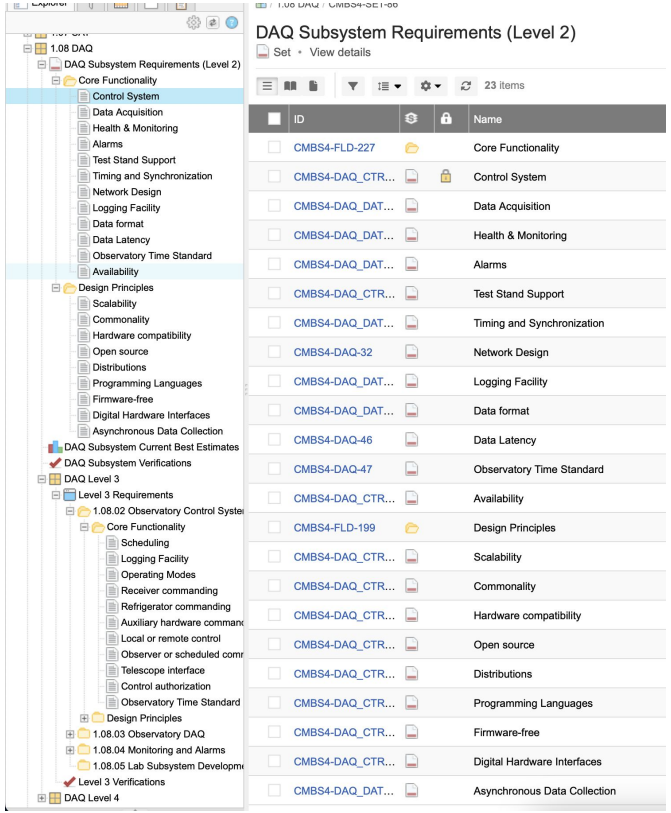
Final Product
(*) Bolometer readout data receiver computing hardware, (*) Event builder computing hardware, (*) Data acquisition and event building software, (*) Data transport software for interface to Data Management

DAQ Is At Or Beyond Conceptual Design Maturity

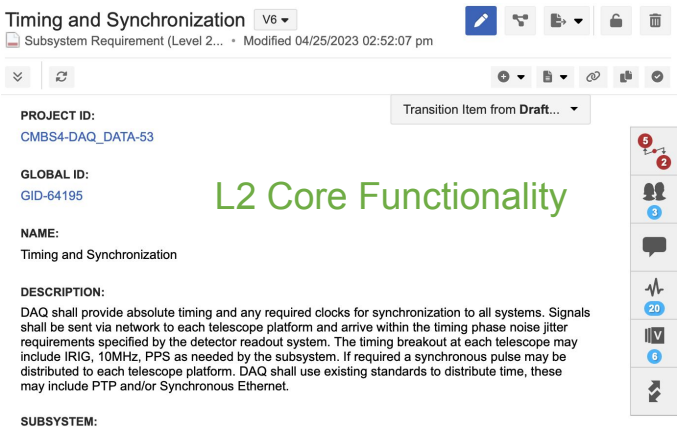
- Successful Previous Conceptual Design Review held Sept 28, 2021
  - Predominantly external reviewers
  - Review Panel Report posted at CMBS4-doc-751
  - 7 Recommendations, about half at the project level (more staffing required)
- Successful Director's Review held in November 2021
  - Review Panel Report posted at CMBS4-doc-796
  - 1 Recommendation for DAQ
- Framework based on heritage (Simons Observatory)
  - 1.08.02 - Observatory Control System
    - Primary updates are scale testing, simulations, QA, adaptation to S4 hardware
  - 1.08.03 - Observatory DAQ
    - Detector readout remains main early focus
  - 1.08.04 - Monitoring & Alarms
    - R&D ongoing for other feature requests, in particular handling fast detector data
  - 1.08.05 - Lab Subsystem Development and Support
    - Primary point of contact with labs and their needs, including data interrogation
    - Being funded for FY23-FY24

Subsystem Requirements Are Being Managed

- Jama Connect Tool
  - Tracks requirements across entire project
  - Will be used for verification
  - Details added as project matures
- Two types of Requirements
  - Core Functionality
    - Describe basic functionality of components
  - Design Principles
    - Describe practical qualities of the components
- Flowed down from Level 2 to Level 3
  - Level 2
    - High level functionality
    - Major system components
  - Level 3
    - Specific quantifiable requirements
    - Enumerate the functionality provided by each L3
- Exported to CMBS4-doc-783 and found in supporting documentation



Requirement Examples



Timing and Synchronization V6

Subsystem Requirement (Level 2... • Modified 04/25/2023 02:52:07 pm

Transition Item from **Draft**...

PROJECT ID:
CMBS4-DAQ_DATA-53

GLOBAL ID:
GID-64195

L2 Core Functionality

NAME:
Timing and Synchronization

DESCRIPTION:
DAQ shall provide absolute timing and any required clocks for synchronization to all systems. Signals shall be sent via network to each telescope platform and arrive within the timing phase noise jitter requirements specified by the detector readout system. The timing breakout at each telescope may include IRIG, 10MHz, PPS as needed by the subsystem. If required a synchronous pulse may be distributed to each telescope platform. DAQ shall use existing standards to distribute time, these may include PTP and/or Synchronous Ethernet.

SUBSYSTEM:
DAQ

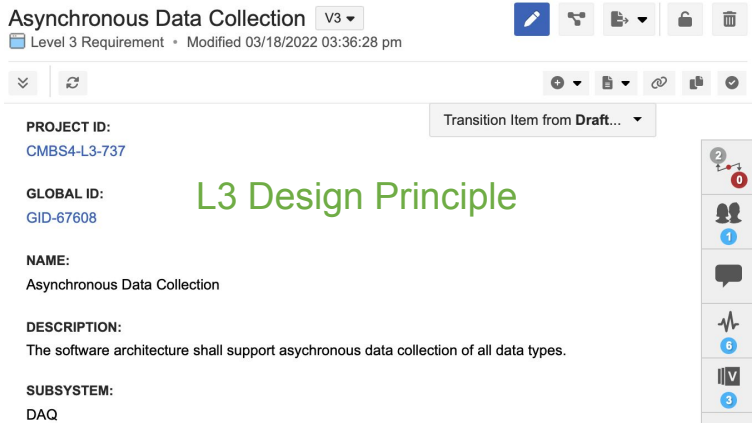
STATUS:
Draft

VERIFICATION METHOD:
Test

VERIFICATION DESCRIPTION:
To verify this requirement, we should set up a test with representative cable lengths, switches, and/or fan-outs and show that we provide an absolute timestamp within specification and meet the phase jitter requirements at a representative endpoint.

BASIS / RATIONALE:
All data acquired asynchronously will require absolute timestamps and systems may need to be be clocked synchronously for noise or other considerations. The specific requirements will need to come from ICDs with other subsystems or L1 requirements.

EXTERNAL ID:
DAQ-0040



Asynchronous Data Collection V3

Level 3 Requirement • Modified 03/18/2022 03:36:28 pm

Transition Item from **Draft**...

PROJECT ID:
CMBS4-L3-737

GLOBAL ID:
GID-67608

L3 Design Principle

NAME:
Asynchronous Data Collection

DESCRIPTION:
The software architecture shall support asychronous data collection of all data types.

SUBSYSTEM:
DAQ

STATUS:
Draft

VERIFICATION METHOD:
Demonstration

VERIFICATION DESCRIPTION:
Verification of this requirement will take the form of a demonstration of multiple components operating asynchronously.

BASIS / RATIONALE:
There should be no assumption that data provided to OCS occurs synchronously or that data from one source implies the presence of data from another source. This will allow the most flexibility for components to operate in isolation and in various modes.

EXTERNAL ID:

Project-Level Interfaces Are Identified

CMBS4-doc-469-v10: N-squared interface matrix

WBS 1.04 Readout	WBS 1.05 Module Assembly & Testing	WBS 1.06 Large Aperture Telescopes	WBS 1.07 Small Aperture Telescopes	WBS 1.08 Data Acquisition & Control	WBS 1.09 Data Management	WBS 1.10 Chile Site Infrastructure/I&C	WBS1.11 South Pole Site Infrastructure/I&C	← L2 Elements ↓
E (339)	M, E, T (several)	X	X	X	X	X	X	WBS 1.03 Detectors
	M, E, T (321)	M, E, T (318)	M, E, T (354)	E (324)	X	M, E, T (718)	M, E, T (719)	WBS 1.04 Readout
		M, T, O (345)	M, T, O (342)	X	X	M, E (721)	M, E (720)	WBS 1.05 Module Assembly & Testing
			X	M, E, T (333)	X	M, E, T (336)	M, E, T (330)	WBS 1.06 Large Aperture Telescopes
				M, E (351)	X	X	M, E, T (348)	WBS 1.07 Small Aperture Telescopes
					E (327)	M, E, T (417)	M, E, T (423)	WBS 1.08 Data Acquisition & Control
						M, E, T (426)	M, E, T (432)	WBS 1.09 Data Management
							X	WBS 1.10 Chile Site Infrastructure/I&C

(XXX) in cell indicates docdb number

Interface type key

M	mechanical
E	electrical, data, control, telem
T	thermal
O	optical

ICD maturity phase color coding

X	no interface exists, no ICD req'd
	doc drafted, general xface params named
	more specific naming of xface params & boundaries
	most scope, boundaries, responsibilities defined
Phase 1	scope, boundaries, responsibilities defined
Phase 2	design-driven refinements
Phase 3	ICD complete

DAQ contains interfaces to six WBS areas

- 1.04 Readout
- 1.06 LAT
- 1.07 SAT
- 1.09 Data Management (DM)
- 1.10 Chile Site Infrastructure
- 1.11 South Pole Site Infrastructure

Much progress has been made since the 2021 CDR

When ICDs are complete they are being ingested into Jama Connect for tracking and change control

DAQ ICDs have begun this migration and will complete this summer

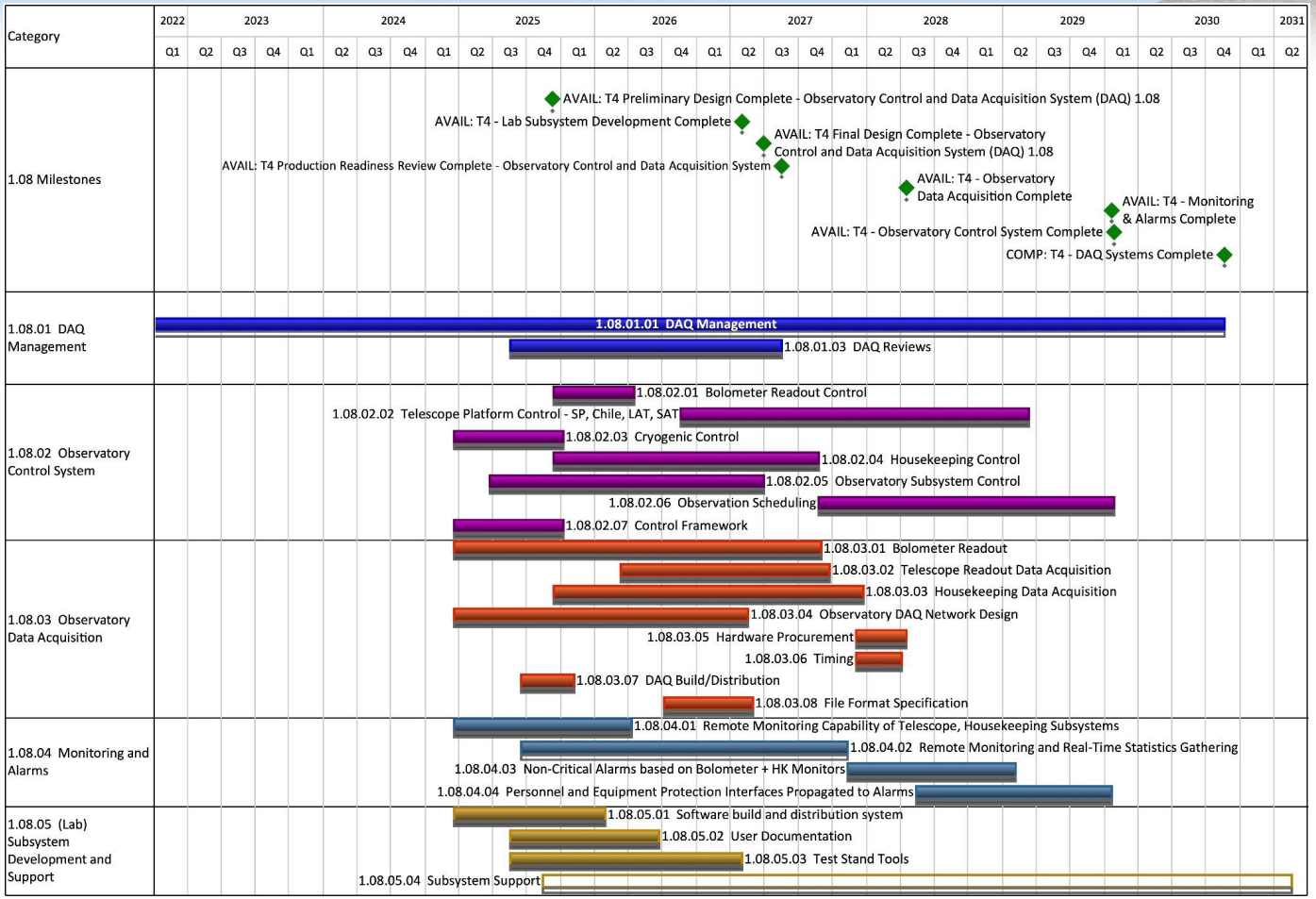
Interfaces Within The Subsystem Are Identified And Being Developed

- Main interfaces are code/data/database hand-offs:
  - Data from DAQ to monitoring
  - Control framework backbone also used to route slow data to DAQ
  - Eg Scheduler enters information into a database that gets sent with the data

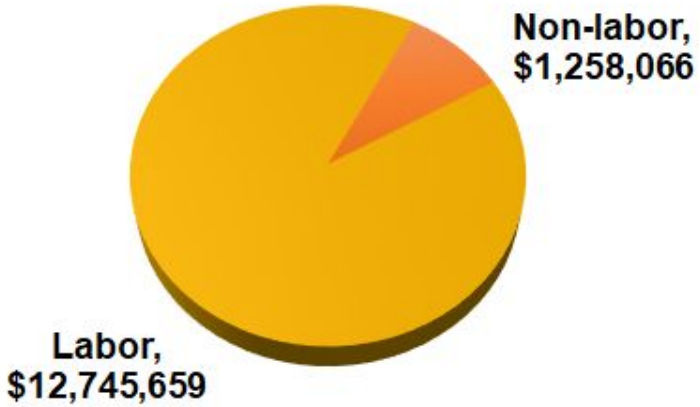
DAQ Schedule and Budget

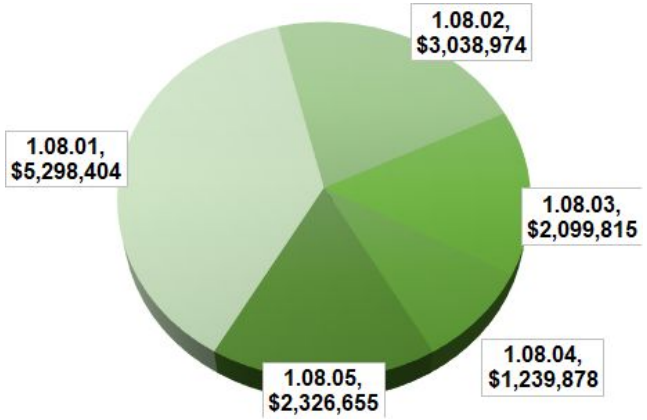
- Regenerated from bottom up
  - Presenting an snapshot today, but this is under active development
  - Work will be completed by Directors' Review
- Key Handoffs
  - Readout
    - Early support for test stands
  - Modules and Test
    - High Throughput Cryostat
  - LAT and SAT
    - Prototype testing
    - Integration and Test
  - Sites
    - Compute, network, and timing hardware
    - Staff transition to Integration and Commissioning (not included yet, still under development)
- Next Steps
  - Refine handoff timing by breaking up long duration activities
    - Including activities tied to releases after initial handoff to other subsystems
  - Define how support of released code is represented in schedule
    - Adding an activity to integrate feedback into a final release after handoff
  - Resource loading
    - Leveling effort over course of project has not been done yet with new schedule
    - Application of proper resources to activities is in progress

DAQ Schedule



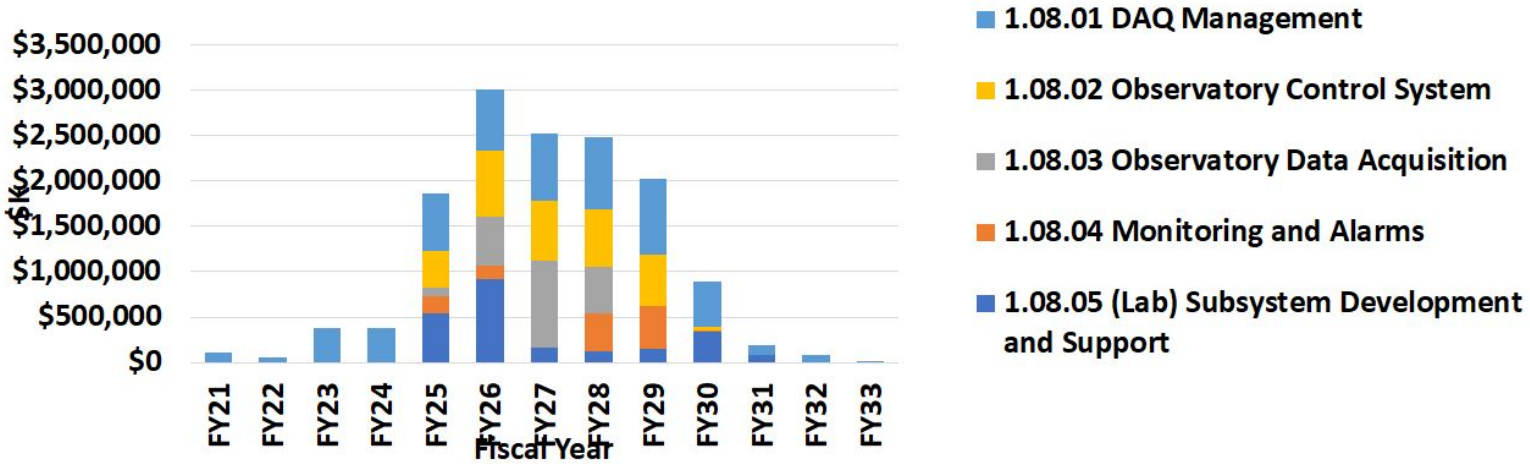
WBS Cost Summary





	Hours	NonLabor Direct $K	Total Burdened $K
1.08.01 DAQ Management	22,756	$658,822	$5,298,404
1.08.02 Observatory Control System	17,744	$0	$3,038,974
1.08.03 Observatory Data Acquisition	10,720	$325,159	$2,099,815
1.08.04 Monitoring and Alarms	12,464	$0	$1,239,878
1.08.05 (Lab) Subsystem Development and Support	12,355	$0	$2,326,655
Grand Total	**76,039**	**$983,981**	**$14,003,725**

Cost Summary – Time-Phased

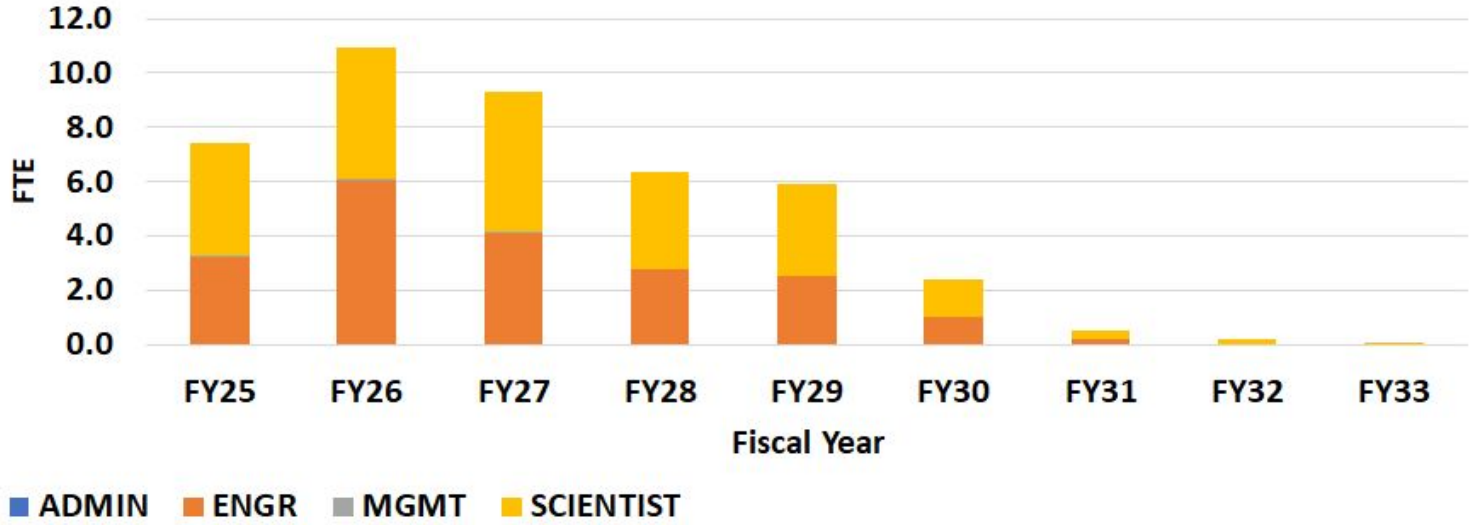


	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32	FY33	Grand Total $K
1.08.01 DAQ Management	$113,373	$55,636	$376,522	$381,610	$625,113	$684,622	$744,976	$798,643	$825,841	$496,838	$105,264	$77,174	$12,793	$5,298,404
1.08.02 Observatory Control System					$415,055	$722,713	$661,653	$636,414	$568,342	$34,797				$3,038,974
1.08.03 Observatory Data Acquisition					$88,277	$541,825	$952,417	$517,296						$2,099,815
1.08.04 Monitoring and Alarms					$188,406	$146,245	$0	$409,925	$472,926	$22,375				$1,239,878
1.08.05 (Lab) Subsystem Development and Support					$541,399	$920,048	$168,854	$125,603	$152,128	$332,837	$85,787			$2,326,655
Grand Total $K	$113,373	$55,636	$376,522	$381,610	$1,858,250	$3,015,453	$2,527,900	$2,487,880	$2,019,237	$886,847	$191,051	$77,174	$12,793	$14,003,725

NOTE: Incorrect resource type result in $0 cost, discovered too late for inclusion in time for review

Labor Profile

	Sum of Value
ADMIN	0.0
ENGR	19.9
MGMT	0.2
SCIENTIST	23.1
Grand Total	43.2



NOTE: Integrating transition to I&C and Support Activities intended to resolve hard rolloff.

Basis Of Estimate

- BOE is based on experience, particularly on SPT-3G and SO, Labor dominated
  - Control framework: code review, simulations, unit tests, integration tests, documentation, repository maintenance
  - Control: Detector readout design, telescope platforms, cryogenic control
  - DAQ: High-speed detector readout, metadata, and slow data (‘housekeeping’)
  - Monitoring and Alarms: feature updates based on requests (including fast time-stream data from detectors); adapting alarms system to two sites
  - Lab: data reading scripts, handling new users who are also DAQ contributors

BOE to be updated this summer in preparation for Director’s Review in Fall

Data Acquisition & Controls Risk Summary

Key	T	WBS L2	Summary	Cost Impact	Schedule Impact	Probability	Risk Score Value	Risk Ranking
RISK-283		1.08 - DAQ	Insufficient Expert Developer Staff	High - >= 1M and < 6M	Critical - SS > 6mo	Likely 25-67%	18	High
RISK-281		1.08 - DAQ	Controls Hardware/Simulator Availability	Moderate - >= 250K and < 1M	Critical - SS > 6mo	Likely 25-67%	16	High
RISK-280		1.08 - DAQ	Observatory Control System Test Stand Availability	High - >= 1M and < 6M	High - SS < 6mo	Likely 25-67%	16	High
RISK-277		1.08 - DAQ	Observatory DAQ Test Stand Availability	Moderate - >= 250K and < 1M	Critical - SS > 6mo	Likely 25-67%	16	High
RISK-282		1.08 - DAQ	Hardware Emulators Availability	Moderate - >= 250K and < 1M	High - SS < 6mo	Likely 25-67%	14	Moderate
RISK-484		1.08 - DAQ	Incomplete or Undocumented South Pole Site Interface Definition	Moderate - >= 250K and < 1M	Critical - SS > 6mo	Possible 10-25%	12	Moderate
RISK-483		1.08 - DAQ	Incomplete or Undocumented Chile Site Interface Definition	Moderate - >= 250K and < 1M	Critical - SS > 6mo	Possible 10-25%	12	Moderate
RISK-482		1.08 - DAQ	Incomplete or Undocumented Data Management Interface Definition	Moderate - >= 250K and < 1M	Critical - SS > 6mo	Possible 10-25%	12	Moderate
RISK-481		1.08 - DAQ	Incomplete or Undocumented Large Aperture Telescope Interface Definition	Moderate - >= 250K and < 1M	Critical - SS > 6mo	Possible 10-25%	12	Moderate
RISK-480		1.08 - DAQ	Incomplete or Undocumented Small Aperture Telescope Interface Definition	Moderate - >= 250K and < 1M	Critical - SS > 6mo	Possible 10-25%	12	Moderate
RISK-278		1.08 - DAQ	Incomplete or Undocumented Readout Interface Definitions	Moderate - >= 250K and < 1M	Critical - SS > 6mo	Possible 10-25%	12	Moderate
RISK-288		1.08 - DAQ	Insufficient End-to-End Testing Resources	Moderate - >= 250K and < 1M	Minor - SS < 1mo	Possible 10-25%	8	Minor
RISK-286		1.08 - DAQ	Early R&D DAQ Test Stand Availability	Minor - >= 50K and < 250K	Insignificant - SS level no impact	Likely 25-67%	6	Minor

RISK-283 Insufficient Expert Developer Staff

Risk Description:	IF the DAQ WBS does not have sufficient staff to ramp up for the R&D and preproduction phases of the project AND users have to write ad hoc software, THEN complex software tasks will not be completed and tested on schedule. The delays will ripple into other WBS areas and cause completion delays in Readout and SAT & LAT Assembly.
Agency:	DOE
WBS L2:	1.08 - DAQ
Risk Approvers:	Matthaeus Leitner
Risk Owner:	Gregg Thayer
Risk Handling Strategy:	Mitigate
Risk Handling Strategy Plan & Required Resources:	To mitigate this risk in the R&D phase of the project, software written by the readout-specialists at the Readout Development sites may be used initially for detector testing. These scripts, which may not be common across test stands without the DAQ framework in place, would need to be included in the software framework build later adding cost and additional tasks into the DAQ WBS.
Risk Retirement Date:	Mar 14, 2028
P6 Activity ID:	DAQ_Risk-283
Probability:	Likely 25-67%
Cost Impact:	High - >= 1M and < 6M
Schedule Impact:	Critical - SS > 6mo
Risk Score Value:	18
Risk Ranking:	High

RISK-482 Incomplete or Undocumented Data Management Interface Definition

Risk Description:	IF the interface to the Data Management WBS is not well understood and documented AND testing or integration reveals new or previously unknown requirements, THEN the data acquired by the DAQ may not be properly available to Data Management for processing and analysis. During construction, this may prevent the timely completion of the Data Management system or the discovery of problems which require the analysis provided by Data Management.
Agency:	DOE
WBS L2:	1.08 - DAQ
Risk Approvers:	Matthaeus Leitner
Risk Owner:	Gregg Thayer
Risk Handling Strategy:	Mitigate
Risk Handling Strategy Plan & Required Resources:	The mitigation strategy for this risk is to develop and complete this interface control document early in the project, prior to CD-1 approval, and ensure that principals from the DAQ and DM WBS areas collaborate equally on the definitions and descriptions.
Risk Retirement Date:	Mar 14, 2028
P6 Activity ID:	DAQ_Risk-482
Probability:	Possible 10-25%
Cost Impact:	Moderate - >= 250K and < 1M
Schedule Impact:	Critical - SS > 6mo
Risk Score Value:	12
Risk Ranking:	Moderate

Safety / Hazards Analysis

- Hazards to personnel, the environment, and the equipment have been identified in coordination with L3 leads and the CMB-S4 Safety Coordinator, per the Project Hazard Analysis Process Document CMBS4-doc-711.
- Next steps are to analyze impacts and probabilities of identified safety risks and define mitigations and populate the WBS 1.08 table in the Hazard Identification/Analysis Workbook
- Ensure security/access plan consistent with Project network security plans

Hazard Type	Title	Hazard Description	Severity	Probability	Risk Value	Risk Category	Mitigation Strategy	Mitigation Description	Severity	Probability	Risk Value	Risk Category
Repetitive stress/ergonomics	Material Handling/Lifting	Lifting or carrying objects that weight 20lbs or more	3	C	11	Medium	Administrative Controls	Provide instruction and training on the proper technique for lifting and carrying heavy objects	3	E	17	Medium
Working at heights	Falls	There are times when individual will need to work on a ladder	3	D	14	Medium	Administrative Controls	Provide instruction and training on the proper techniques for working at heights	3	E	17	Medium
Lasers	Eye Hazard	The system configuration may require the use of Optical Fiber high speed data links that operate at wavelengths and power that can be hazardous to the eye	3	E	17	Medium	Administrative Controls	Provide training on the use of lower power lasers used for high speed data transmission.	4	E	20	Low
Repetitive stress/ergonomics	Prolonged Daily Computer Use	This hazard addresses the use of Computers for 4 or more hours per day.	3	C	11	Medium	Administrative, Good Ergonomic Practices	Provide work station and lab equipment to all developers that address individual ergonomic needs to prevent repetitive stress injuries	3	D	14	Medium

Quality Assurance Implementation

QA throughout the project is governed by the CMB-S4 Project QA Plan, CMBS4-doc-602

- Project QA Manager: Creates, maintains, and oversees implementation of the QA Plan
- L2 Manager: Executes and oversees CMB-S4 QA within their L2 subsystem, using a graded approach per the Project QA Plan
- DAQ-specific QA will come in the form of:
  - Unit tests and integration tests built as part of the software distribution
  - Simulations of control with emulators
  - Scale testing of both readout and aux equipment (DAQ)
  - Close integration with lab testing

CAM Next Steps To CD-1

- Complete bottom up schedule
  - Handoffs to other L2s
  - Resource loading
  - Resource leveling
- Update WBS Dictionary
- Update Basis of Estimate
- Continue refining Requirements
  - In particular develop L3 requirements for Lab Support
- Continue to reevaluate risks and update registry

Conclusion

- Experienced team in place.
  - Good progress made since 2021 CDR
- Scope well-defined and technically mature to support the preliminary cost and schedule estimates.
  - Project-level ICDs ready for configuration control
  - Major subsystem risks have been identified with mitigations.
  - Major procurements are being planned.
  - QA is incorporated.
- Cost and schedule estimates well-defined and mature to support a point cost estimate and to establish a preliminary cost range.
  - Major cost and schedule drivers are identified.
  - Handoffs to other L2s included in P6
- Environment, health, and safety addressed