DATA ACQUISITION SYSTEMS (DAQ) CDR REPORT

Document Number CMBS4-doc-751-v3

Review Chairperson: Klaus Honsheid

Review Manager: John Joseph

Review Date: Sept 28th, 2021

Design Review Report

Review Type: Conceptual Design Review

Work Breakdown Structure Code: 1.08

1. Reviewers

Reviewer	Institution
Klaus Honscheid (Chair)	Ohio State University
Ryan Herbst	SLAC
John Kelley	University of Wisconsin / IceCube
Denis Barkats	Harvard University

2. Distribution List

This report will be distributed to following CMB-S4 project members (and others, as applicable, e.g. institutional line management).

Name	Project Role	e-mail
Laura Newburgh	CMB-S4 DAQ L2 Lead	laura.newburgh@yale.edu
Nathan Whitehorn	CMB-S4 DAQ L2 Deputy Lead	nwhitehorn@pa.msu.edu
John Joseph	CMB-S4 DAQ L2 CAM	jmjoseph@lbl.gov

3. List of Materials Distributed to Review Panel

The following materials were distributed to the review committee members

Document Number	Rev.	Title
CMBS4-doc-750-v2	V2	CMB-S4 DAQ/Control Trade Study 2021
CMBS4-doc-0327-v1	v1	DAQ - DM INTERFACE CONTROL DOCUMENT
CMBS4-doc-0324-v1	1	READOUT -DAQ INTERFACE CONTROL DOCUMENT
CMBS4-doc-0351-v1	1	DAQ - SAT INTERFACE CONTROL DOCUMENT
CMBS4-doc-0333-v1	1	DAQ -LAT INTERFACE CONTROL DOCUMENT
CMBS4-doc-0417-v2	2	CHILE -DAQ INTERFACE CONTROL DOCUMENT
CMBS4-doc-0423-v2	2	SOUTH POLE -DAQ INTERFACE CONTROL DOCUMENT
CMBS4-doc-0469-v4	v4	N-squared Interface Matrix

N/A		DAQ SubSystem Requirements (Exported from JAMA)

4. Purpose of the Review

The purpose of this review is to evaluate the conceptual design of the Data Acquisition subsystem. Successful completion of this review will endorse advancing the presented design to the preliminary design stage.

5. Introduction

The CMB-S4 DAQ WBS element includes the development and commissioning of the Observatory Control System, the Observatory Data Acquisition System, Monitoring and Alarms and integration, test and deployment of DAQ hardware and software at both observatory sites. Additionally, the DAQ WBS will provide subsystem development and support of the CMB-S4 fabrication and test sites.

6. Outcome Summary of the Review

A review of the conceptual design of the DAQ system for the CMB-S4 experiment was performed on September 28, 2021. During this one-day review, the team presented the design and current status of the DAQ effort and responded to questions from the committee.

- Overall, the committee commends the team for developing a design that will meet the CMB-S4 requirements.
- No technical showstoppers were identified during the review.
- The committee notes that the DAQ effort has not yet received project funding. Given that, the team has done an admirable job. This, however, is not sustainable, and the committee strongly advises project management to start supporting the DAQ effort even if the overall funding level for CMB-S4 continues to fall short of expectations.
- Building up the DAQ workforce needs to start now in order to get ready for the upcoming reviews — and in particular to support the more formal project management aspects.

In summary, the CMB-S4 DAQ project is on track to be ready for a CD-1 review next year.

7. Response to Charge Questions

Technical Scope:

Are the requirements defined at a conceptual design level of maturity, and is the proposed design expected to meet them?

YES

Have the major interfaces been identified and appropriately incorporated into the design?

YES — all interfaces have been identified and ICDs are being drafted. However, these documents are not (sufficiently) complete yet.

Have alternatives been appropriately studied in developing the design?

YES — however, the study performed by the team was not to look for the best possible and most cost-effective solution but to demonstrate that the baseline design based on the Simons Observatory data acquisition system satisfies CMB-S4 requirements and that none of the other options investigated were obviously better.

Design Management:

Have the major subsystem risks been identified?

YES — though the staffing needs and ramp-up is not emphasized enough.

Are procurements being planned and prepared for appropriately?

Not applicable — this was not discussed/reviewed. The DAQ subsystem budget is primarily labor, and required computing components are off-the-shelf.

Have major cost and schedule drivers been identified?

YES — but the origin of the numbers behind the major costs were not very transparent.

Quality Assurance:

Is QA sufficiently incorporated into the design and execution planning?

YES, in the sense that the team is aware of the necessary steps, but details are lacking.

Are the necessary future QA documents identified and are plans at a level of maturity commensurate with a conceptual design?

YES, but see previous comment.

ES & H:

Is ES&H sufficiently incorporated into the planning and design?

YES — for the current stage of the project. Additional details need to be worked out on cyber security, data integrity measures and machine protection/fault monitoring before CD-1.

Miscellaneous:

Have all the previous review recommendations been addressed?

YES — but some of the work is still ongoing. (e.g. the ICDs).

Are there any other issues that have been identified that need to be addressed?

YES — see recommendations.

Overall Readiness:

Is the design maturity at a sufficient level for conceptual design review approval?

YES — for an internal conceptual design review. The team is not yet ready for CD-1 but is on track to be ready next year.

8. Findings

ID	Title	Findings
F.1	Project tools	The WBS tree is recorded in a software tool called Dash360. Risks are compiled into a JIRA risk registry.
F.2	Labor budget	Labor is estimated as 7 FTE/year for DAQ work, based on scaling from Stage 3 experiments.
F.3	DAQ baseline	Baseline DAQ framework is OCS based on a crossbar.io messaging layer.
F.4	Data rates	Data rates: 10k measurements/s for slow control system, and 10Gb/s for fast control system.
F.5	Data storage	4PB storage for 1 yr data at Pole
F.6	Subsystem scope	Scope includes on-telescope hardware, timing reference, computer hardware and control room but lab support/test stands are not included (shopping list only).
F.7	DAQ interfaces	DAQ interfaces are all digital. DAQ is software-only (as much as possible) and Ethernet based. Low Rate DAQ is based on SO design. Uses concepts of OCS Agent RPC and pub/sub messaging protocol. ICD with readout group including on wire protocol is ongoing. Timing requirements are at the microsecond level. Asynchronous interface to "widgets".
F.8	Interface documentation	Interfaces are being defined and ICDs are actively under development.
F.9	Test plan	Software test plan under development. Will include unit testing etc.
F.10	Distribution and configuration	Docker is used for software distribution and configuration.

F.11	Software agents	OCS agents operate at high level, leaving the low level software and firmware to the component teams.
F.12	Housekeeping data management	Metadata (housekeeping data) is archived in an influx database and a separate copy is stored on disk.
F.13	Emulator strategy	Software emulators will be written and used while the hardware is under development.
F.14	Fault tolerance	The DAQ system is designed to be tolerant of failure of individual sensors. Potential single points of failure in the DAQ subsystem include the OCS aggregator and the bolometer-data aggregator systems.
F.15	Recovery plan	The failure recovery plan is predicated on fast rebuilds of the machines rather than provisioning hot spares and fully-redundant systems such that our downtime is a subdominant component in the overall observing efficiency.
F.16	Recovery time	Insertion of a cold spare would take on order of an hour. Field site experience indicates that such failures might occur once every two years.
F.17	Hardware safety / site sensors	Sensors within the hardware subsystems and the sites are separate (in some cases, like South Pole, operated by USAP and not the Project), but may be monitored by DAQ for informational purposes.
F.18	De-scope options	The DAQ subsystem does not have any significant de-scope options that would not adversely impact overall system performance. Any reduction in funding for DAQ will result in delays within DAQ, likely leading to overall Project delays.
F.19	QA strategy	For DAQ, QA will include regular unit testing, scale testing, code reviews, and simulations. Unit tests will also be performed in lab test-stand institutions, allowing for verification of function with the hardware under in situ conditions.
F.20	DAQ “live look”	Detector metadata comes from readout that helps indicate function of detectors. This, plus some subset of live detector data, is the “live look” capability in DAQ scope.
F.21	Data quality checks	More complex quality checks (noise levels in range, etc.) are part of the Data Management Subsystem

		(DM, WBS 1.09) "quick look" capability. This follows on our data delivery, but using the full DM analysis pipeline with somewhat higher (15 minute to hour) latency and is not within DAQ Subsystem scope.
F.22	ES&H impact	ES&H impact is under development.

9. Comments

(THE COMMENTS ARE IN NO PARTICULAR ORDER)

ID	Title	Comments
C.1	Bandwidth for commissioning and calibration	Demonstrate that there is a plan/foresight for tests and calibration flexibility. For example, 100 Hz data rate is DAQ rate, but often during tests and commissioning there is a need for special DAQ modes (many kHz) with much much higher data rates on subset of detectors. How is this handled through the whole DAQ ?
C.2	Science requirements flowdown	For future reviews, in the introduction, show a clear path from the science requirements to the DAQ performance requirements (e.g. data rates, etc.).
C.3	Interface documentation	Interface documentation (ICDs) is critical at the CDR stage. Several examples were provided as part of the supplementary documentation. These are good for the current stage but further work will be required to complete at least the high level interface description for CD-1.
C.3a	Interface documentation II	• Completing the core ICDs is especially important as the DAQ is one of the earliest subsystems that needs to be available for the other subsystems to be tested.. • There needs to be in the ICD allowances for flexibility and unexpected needs. Though the DAQ needs to be ready ~9 months from now, its final implementation will be delivered 9-11 years from now. • More details are also needed on the observing priorities interface with Data Movement and

		any metadata / calibration / tuning interfaces needed with the high-rate detectors. ● One key interface that needs further investigation is between the DAQ and the data management side. ● There is potentially a significant amount of scope related to online data processing and visualization. The initial answers to questions related to this concern appear to push off a good chunk of this scope to the data management side. It is very likely that additional development will creep into the daq scope in order to support local detector validation and data qualification. The danger is that the DAQ structures will not be properly designed for this need up front, resulting in ad-hoc solutions which may burden the core daq.
C.4	Timing Interface	Complete the definition of the timing interface and get buy-in from all stakeholders.
C.5	Trade Study	The committee agrees with the conclusion of the trade study but feels the presentation would benefit from a change in strategy namely that the study evaluated the baseline solution based on the Simons Observatory DAQ and that none of the other options in the study provided clear advantages.
C.5a	Trade Study II	A lot of the scoring appears to come from either not fully understanding the alternatives and weighing these alternatives based on their comfort level and apparent ease of entry. The baseline solution is very familiar to the team and their survey may not adequately take into account the barrier to entry of unfamiliar developers. While they know the current system they have not yet fully deployed it at scale and may not yet be fully aware of its limitations.
C.5b	Trade Study III	For future reviews and presentations, fully evaluate all options presented rather than not scoring an

		alternative without clearly documenting why the option was disqualified from further consideration.
C.6	Network availability at South Pole	Network availability at the South Pole is a concern. The team should present a clear outline how CMB-S4 will handle this, including latency requirements for different DAQ data products and control interfaces.
C.7	Housekeeping data	How is housekeeping data monitored remotely? (The committee received conflicting answers from different team members.)
C.8	Staffing Plan	A group size of 7 FTE could be correct, but more details need to be presented about how the team arrived at this number. Labor is the main cost driver, more detail is needed on the effort required. The schedule as presented is top-down, but a staffing / ramp-up plan that satisfies this schedule should also be developed. It is not apparent that the DAQ effort is a true bottoms up estimate, rather than fitting the potentially available funds to a labor count.
C.9	Staffing ramp up	All experiments face difficulties hiring qualified DAQ personnel. More details need to be made available describing how the project plans to ramp up DAQ group staffing.
C.10	Budget	The committee did not review the budget in any detail. It is dominated by personnel. A cost estimate for the compute farms at both sites should also be included. The labor budgeted for this effort is a relatively large fraction of total cost compared to other subsystems. Cost savings due to the choice of using the SO DAQ architecture as baseline should be discussed. It would be very helpful to break the effort estimates into three major categories: 1. The core DAQ development; 2. the generic interface driver development (interfaces and drivers for the controlled elements, motor control. monitoring etc); and 3. the site-specific

		development which takes into account the structure differences between the telescopes being managed.
C.11	Computing hardware	The team plans to use off the shelf computer hardware. Some level of detail on the required performance (core count, CPU speed, memory) should be provided.
C.12	Crossbar.io server	The crossbar.io server is a single process running on a single computer hence representing a single point of failure. The team should address why this is not a problem or how it is mitigated.
C.13	Design	The committee commends the team for adopting design principles that stress commodity hardware and software (open source) and modularity.
C.14	Test stand support	There are clear advantages of using standard CMB-S4 DAQ software (and hardware) for lab work and test stands but the implications for the DAQ project (both schedule and workforce) need to be carefully understood.
C.15	Longevity and flexibility	The DAQ design needs to be functional soon (~9 months from now) and remain relevant when it's delivered in ~10 years. This is an extremely difficult goal to achieve, and the balance will need to be well placed and often re-evaluated between systematic planning of everything and allowance for some flexibility.
C.16	Project Management	So far the DAQ effort has received only limited funding support for the project. This should change immediately or the project risks schedule delays as DAQ support will be needed early for teststand and lab support.
C.17	Fault Monitor/Machine Protection	While machine protection and fault monitoring is outside the DAQ scope, it is still important to carefully delineate the responsibilities of DAQ vs. other subsystems when it comes to machine protection and machine safety. This should be developed further to consider how to isolate machine safety systems from

		DAQ and how to prevent potential conflicts on DAQ vs. safety alerts.
C.18	ICDs II	All ICDs should state up front that the DAQ system is not guaranteed to be online. Other developers may not fully consider this. It is one thing to define a system as “not 100% reliable” it is another to accept that it may go offline for hours at a time for upgrades and development purposes. This being indicated clearly in bold text will hopefully spur the necessary conversations needed to identify weaknesses in the machine and personal safety systems.
C.19	QA	CMB-S4 requires all components to have a focus on QA. The DAQ team is aware of the necessary steps but the presentations lacked the necessary details and examples to clearly demonstrate that QA is sufficiently integrated in the design.

10. Recommendations (Requests for Action)

ID	Title	Request for Action/Recommendation
R.1	Interface Documentation	Complete the ICDs [before CD-1].
R.2	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 [before CD-1].
R.3	Staffing II	Develop a detailed plan and timeline describing how you intend to hire or train qualified DAQ personnel [before CD-1].
R.4	Trade Study	Change how the trade study is presented. The study evaluated the baseline solution based on the Simons Observatory DAQ, found it to be adequate and that none of the other options in the study provided clear advantages [before CD-1].
R.5	Budget	Complete the initial budget for this WBS [before CD-1].
R.6	Project Management	Fund the DAQ project at sufficient levels to avoid delays in project completion. [before CD-1]

R.7	QA	Develop details and examples to clearly demonstrate that QA is sufficiently integrated into the design [before CD-1].

Appendix A: Agenda