



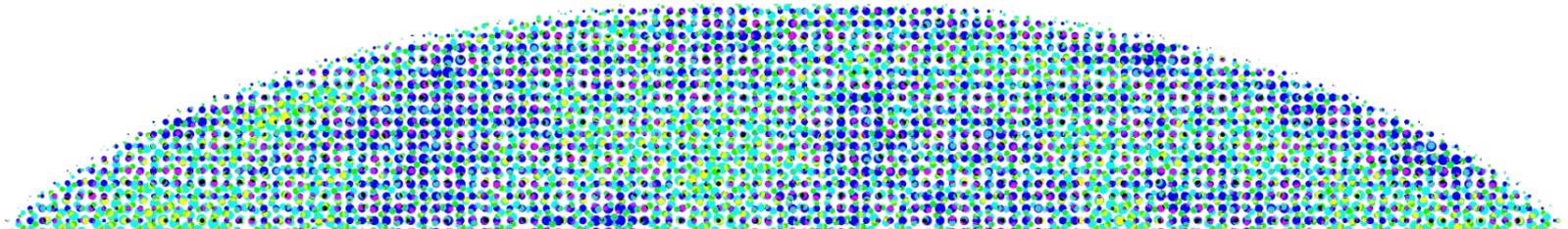
Project Report- Status and Path Forward

2024 Summer Collaboration Meeting

July 31, 2024

Jim Strait (he/him)– Project Director

John Carlstrom (he/him) – Project Scientist, NSF PI



Re-cap of the situation: The new reality

- On May 7, NSF publicly announced that they have decided “not to move the CMB-S4 project in its current form into the NSF Major Facility Design Stage at this time,” since NSF “must prioritize the recapitalization of critical infrastructure at the South Pole.”
- NSF has told us privately that it is likely that the South Pole will be closed to new experiments for at least 10 years.
- They have told us in no uncertain terms that any proposal from CMB-S4 that has a South Pole component will be rejected at this time.
- Given this guidance, we must develop a plan that does not include the South Pole.
- The science case for CMB-S4 remains one the most compelling in physics, cosmology and astrophysics. The mission need described in the DOE CD-0 statement remains valid.
- Our Analysis of Alternatives determined that although configurations utilizing the South Pole are preferred, an all-Chile version “could offer a way to make the measurements, if CMB-S4 is unable to access the Pole.”
- With the South Pole not available, this is the best way to get at this fabulous science.

CMB-S4 Project Planning

- Alternative 3 was developed for the AoA only to the extent necessary to make the comparative analysis. Now we must optimize its configuration with the objective to meet the CMB-S4 Science Goals for a reasonable cost, in a reasonable observing time, and with acceptable risk.
- In order to choose a revised configuration that we can confidently develop toward a full conceptual design, we must first do a rapid study of the design space for CMB-S4 in Chile, including:
 - Numbers and types of telescopes, frequency bands and focal plane detector designs;
 - Survey strategies;
 - Site layout options and constraints.
- In addition, we need to ensure that the design of CMB-S4 takes account of the potential results of other experiments that will be running between now and when CMB-S4 will begin observations.
- We have set up a Coordination Group to oversee the rapid study of the design space to optimize the design concept for an all-Chile configuration for CMB-S4.
- We have also established an internal Working Group to collect and evaluate information regarding the plans and capabilities of current CMB experiments that are able to address one or more of the CMB-S4 Science Goals.

Interactions with the Funding Agencies

- We have been working with our official contacts with DOE and NSF to understand their positions regarding the future of CMB-S4.
- Most important was a meeting on July 18 with the CMB-S4 Joint Oversight Group (JOG), which combines people from both DOE and NSF, first meeting together and then with us. The JOG meeting included both Gina Rameika, the head of DOE HEP and Denise Caldwell, the acting head of NSF MPS, as well as others from both agencies.
 - We reported on plans to conduct a rapid study of the design space for CMB-S4 in Chile in order to choose a configuration that can be confidently developed toward a full conceptual design.
 - We also said that we were considering establishing an internal Project Working Group to collect and evaluate information regarding the plans and capabilities of current CMB experiments that are able to contribute to one or more of the CMB-S4 Science Goals, with the objective of determining the most efficient way to reach the CMB-S4 goals by building on what will be accomplished by other experiments.
 - *DOE and NSF expressed support for CMB-S4 to conduct the studies described above.*

Interactions with the Funding Agencies

- NSF and DOE also asked for additional information regarding:
 - Further details of the plans for the two studies;
 - Plans and timescale for moving to CDR and CD-1;
 - International collaboration.
- We provided the requested information and got a positive reply from Denise Caldwell.
- The material we provided to the JOG is contained in the rest of this presentation.
- ~~The next JOG meeting is tomorrow, at which we will present further details of our plans and hope for continued positive feedback.~~ (Meeting canceled.)

Funding

- The President's Budget Request for CMB-S4 in FY 2025 is \$4.5M from DOE. We have recently been told by DOE to plan on funding at this level. Funding for HEP in the House E&W Committee report supports this level.
- We have been told by NSF to plan on essentially flat funding of \$4.0M for the 2nd year of the Continuing Design Cooperative Agreement, which starts July 31, 2024
- We have not been given any longer-term funding profiles with which to plan the Project.
- This funding is sufficient to support the replanning of CMB-S4 via the two working groups.
- But the progress that CMB-S4 can make beyond that will be limited, especially on the DOE side.
- The Project Office and engineering effort at LBNL will be significantly reduced from previous years. Similarly the effort at other DOE labs and partner institutions must be substantially reduced.
- We are working with the management of LBNL and the partner institutions to try to ensure that when more funding becomes available, we will be able to recover the expertise and facilities that are currently working on CMB-S4.

Working with other Collaborations

- With CMB-S4 now focusing on observing from Chile, working closely with SO to understand systematics in measuring r from Chile is of great importance. We need to leverage the considerable overlap between the CMB-S4 and SO collaborations.
- The CMB-S4 leadership has engaged with the leadership of SO and are exploring mechanisms to share information about instrumentation performance in the field in Chile to help in the design of the all-Chile S4 configuration.
- Initial ideas have been floated for joint work on instrumentation related to SATs and LATs that could incorporate CMB-S4 design features with lessons learned from SO.
- Additional ideas were discussed in the outskirts of the SO Collaboration meeting last week.
- There is already significant joint effort on DAQ and Data Management between CMB-S4 and SO, involving many of the same people on both sides. This will naturally grow.
- There is also considerable overlap between CMB-S4, SPT and BICEP collaborations and continued engagement with SPO is important. For example, there are ideas for ways to compare the performance of aggressive SAT designs with the well-understood BICEP SATs.

CMB-S4 Project Coordination Group: Optimize an all-Chile CMB-S4 Configuration – Draft Charge

Purpose

- The purpose of the Chile-Optimization Coordination Group is to coordinate studies to optimize the design concept for an all-Chile configuration of CMB-S4 that will form the basis for developing a full conceptual design and project plan.
- The Coordination Group is led by and reports to the CMB-S4 Project Director and to the NSF PI / Project Scientist.

Membership

- The Coordination Group consists of the leaders of working groups on each of the four key topics listed 2 slides below, which represent respectively the inflation science simulation and forecasting group, and the Project L2 organizations for SATs, LATs and the Chile Site, Additional members may be chosen by the Project Director and Project Scientist.
- The working groups will draw upon the expertise of the entire CMB-S4 Collaboration and Project to obtain and develop information needed to do their work.

CMB-S4 Project Coordination Group:

Optimize an all-Chile CMB-S4 Configuration – Draft Charge

Charge

- Starting from the point design represented by Alternative 3 in the Analysis of Alternatives that was reported to the Funding Agencies in December 2022 and to the Director's Review in November 2023, develop a more optimized configuration of CMB-S4 with all telescopes located in the high Atacama desert in Chile.
- The all-Chile configuration should address all of the CMB-S4 science goals, and be optimized to meet the inflation science goal of $\sigma(r) \leq 5 \times 10^{-4}$ within a reasonable survey duration ($\lesssim 10$ years), for a reasonable total project construction cost (DOE TPC + NSF MREFC \lesssim \$1B), with an acceptable level of scientific risk.

CMB-S4 Project Coordination Group:

Optimize an all-Chile CMB-S4 Configuration – Draft Charge

Charge (continued)

- The work of optimizing the all-Chile configuration will focus on four main topics:
 - Science simulations and forecasting, including: numbers and types of telescopes; optimal frequency bands and survey strategies; foregrounds; delensing strategies; systematic errors for different telescope designs and configurations.
 - SAT design options for Chile conditions.
 - LAT design options to address both the wide-deep survey and de-lensing requirements.
 - Site design development and constraints
- Areas where additional information is needed to advance the design should be identified and the means to obtain the information (e.g. focused R&D or data provided by other experiments such as the Simons Observatory) should be specified, together with a rough timeline for when sufficient information would be available.

CMB-S4 Project Coordination Group: Optimize an all-Chile CMB-S4 Configuration – Draft Charge

Reporting

- The Chile-Optimization Coordination Group should provide regular reports to the CMB-S4 Collaboration and Project, including progress reports to the CMB-S4 Level 1 Team on August 28 and September 25.
- A preliminary written report should be delivered by October 31, 2024 and
- A final written report should be delivered by December 20, 2024.

CMB-S4 Project Working Group: Survey of Current CMB Experiments – Draft Charge



Purpose

- The purpose of the Current Experiments Working Group is to collect and evaluate information regarding the plans and capabilities of current CMB experiments that are expected to take data in the next 10 years and are able to address one or more of the CMB-S4 Science Goals, in order to inform CMB-S4 Project Management in planning the revised configuration of CMB-S4.
- The working group reports to the CMB-S4 Project Director and to the NSF PI / Project Scientist.

Membership

- The Current Experiments Working Group membership is mainly drawn from members of the CMB-S4 Collaboration and Project and includes members who are knowledgeable about each of the relevant experiments.
- The working group will draw upon the expertise of the entire CMB-S4 Collaboration and Project and that of the full CMB community.

CMB-S4 Project Working Group: Survey of Current CMB Experiments – Draft Charge



Charge

- The Current Experiments Working Group is charged to collect and evaluate information regarding the plans and capabilities of current CMB experiments that are expected to take data in the next 10 years and to be able to address one or more of the CMB-S4 Science Goals.
- Include experiments that are in operation, under construction, and realistically planned.
- Based on this information, provide projections regarding the expected science reach as a function of time for each experiment using relevant metrics for each science goal that can be used to compare the capabilities of each experiment relative to the CMB-S4 Science Goals. These projections should be based on those made by the proponents of each experiment.
- If the assumptions made by an experiment in making their projections differ significantly from those made by CMB-S4, provide an evaluation as to how the projections would differ if they were based on CMB-S4-like assumptions.
- Also, provide an evaluation of the risk regarding each experiment's ultimate capabilities.
- Identify and quantify gaps between the combined sensitivity of the experiments considered and the Science Goals of CMB-S4.

CMB-S4 Project Working Group: Survey of Current CMB Experiments – Draft Charge

Charge (continued)

- Experiments to be considered include:
 - South Pole Observatory (BICEP + SPT)
 - Simons Observatory
 - CLASS
 - CCAT-prime
 - LiteBIRD
 - AliCPT
 - Other experiments that the working group may identify in the course of its work

Reporting

- The Current Experiments Working Group should provide regular reports to the CMB-S4 Collaboration and Project.
- It is asked to provide progress reports to the CMB-S4 Level-1 Team on Aug. 14, Sep. 18, and to submit a preliminary report by Oct. 15, 2024, for discussion at the L1 meeting on Oct. 18.
- A final report should be submitted by December 16, 2024.

Status of the Working Groups

- Co-Chairs of the Working Groups have been selected.
 - Survey Working Group: Charles Lawrence (JPL) and Nils Halverson (Colorado)
 - Chile Optimization Working Group: Jim Strait (LBNL), John Carlstrom (Chicago)
- Charges are being finalized, working with the Co-Chairs and the CMB-S4 Project L1 Team
- The Working Groups have been formed, with membership that is broadly representative of the CMB-S4 Project and Collaboration.
 - The Chile Optimization Coordination Group include experts in simulations and forecasting, small- and large-aperture telescopes, and the Atacama site in Chile. Its work will be supported by all of the expertise within CMB-S4.
 - The Current Experiments Working Group includes people active in most of the relevant experiments to be evaluated.
- CMB-S4 Collaboration Meeting (July 31 - August 2) is addressing the key topics of these two working groups.

Collaboration Meeting: Input From Other Experiments

WEDNESDAY, 31 JULY

11:15 → 13:00 **Plenary: Updates from the CMB Community - Ground Based Experiments**

Convener: Prof. Colin Bischoff (University of Cincinnati)

11:15 **Atacama Cosmology Telescope**

11:32 **South Pole Telescope**

Speaker: Srinivasan Raghunathan (NCSA)

11:49 **Cosmology Large Angular Scale Surveyor (CLASS)**

Speaker: Joseph Eimer (Johns Hopkins University)

12:06 **BICEP / Keck**

Speaker: Dr Marion Dierickx (Center for Astrophysics | Harvard & Smithsonian)

12:23 **Simons Observatory**

Speaker: Katie Harrington (Argonne National Laboratory, University of Chicago)

14:00 → 14:40 **Plenary: Updates from the CMB Community - Space Based Experiments**

Convener: Lindsey Bleem (Argonne National Laboratory & KICP)

14:00 **LiteBIRD**

Speaker: Carlo Baccigalupi (SISSA/IFPU)

14:17 **Future Satellite Missions**

Speaker: Charles Lawrence (JPL)

14:40 → 15:25 **Plenary: Discussion of CMB-S4 strategy in context**

Conveners: Jim Strait (Lawrence Berkeley National Laboratory), John Carlstrom (University of Chicago, Argonne National Laboratory)

Collaboration Meeting: Developing the Chile Configuration of CMB-S4

WEDNESDAY, 31 JULY

15:55 → 17:45 **Plenary: Overview of Chile-only Instrument and r-forecasting**

Conveners: John Carlstrom (University of Chicago/Argonne National Laboratory), John Ruhl (Case Western Reserve University)

15:55 **Overview [John Carlstrom]**

- Strategy
- Update from AoA Study for Alt 3 from July revision
- Overview of plan for tomorrow's parallel sessions

Speaker: John Carlstrom (University of Chicago/Argonne National Laboratory)

16:05 **SAT & LAT Designs and Considerations [John Ruhl]**

- Overview of "aggressive" SAT optical design
- List of potential SAT systematics and studies to address them
- LAT design choices, pros and cons
- Plan for and items to work on at tomorrow's parallel session

Speaker: John Ruhl (Case Western Reserve University)

16:20 **Efficacy of rotating 1/2 wave plates in Chile [Adrian Lee]**

- Lessons from prior deployments
- Simons Observatory Design and experience to date
- Items for tomorrow's parallel session #1

Speaker: Adrian Lee (UC Berkeley/Lawrence Berkeley National Laboratory)

16:30 **Efficacy of Variable-delay Polarization Modulator in Chile [Yunyang Li]**

- Overview
- Lessons learned from CLASS
- Potential for CMB-S4, other methods?

Speaker: Dr Yunyang Li (Johns Hopkins University)

16:40 **Temperature and Polarization Anisotropy of the Atmosphere [Anna Coerver]**

- Characterization and mitigation strategies
- Site comparisons

Speaker: Anna Coerver (UC Berkeley)

16:55 **Chile r-forecasting: Foregrounds models [Susan Clark and Brandon Hensley]**

- Review of the three foreground models

Speakers: Brandon Hensley (Princeton University), Susan Clark (Stanford University)

17:05 **Chile r-forecasting: Sky area selection and scan strategy [Sara Simon]**

- CMB-S4 plans; S0 plans; Overlap with BICEP/Keck

Speaker: Dr Sara Simon (Fermilab)

17:15 **Chile r-forecasting: Delensing and map based validation [Raphael Flauger]**

- Delensing forecasts; map validation; freq band allocation

Speaker: Raphael Flauger (UC San Diego)

17:25 **Chile r-forecasting: r-forecasting and map based validation [Colin Bischoff]**

- Overview of methodologies, current results
- Work needed
- Plan for tomorrow's r-forecasting parallel session

Speaker: Prof. Colin Bischoff (University of Cincinnati)

THURSDAY, 1 AUGUST

Breakouts: Chile-only configuration



11:45 **Chile r-forecasting: How to Improve & validate r-forecasts [Conveners Jacques Delabrouille and Clem Pryke]**

- De-lensing validation
- Map based validation
- Optimizing band allocation on SATs and delensing LATs
- Inclusion of potential systematics

Speakers: Prof. Clem Pryke (University of Minnesota), Jacques Delabrouille (AstroParticle & Cosmology Laboratory)

13:30 **Chile SAT Design and Considerations [Conveners: John Kovac and Jeff McMahon]**

- Beating the Systematics
 - Potential SAT systematics and studies to address them
- Beating the atmosphere
 - atmospheric "sky" noise mitigation
 - polarized atmosphere mitigation impact on design, site studies

Speakers: Jeff McMahon (University of Chicago; FNAL), John Kovac (Harvard University; Center for Astrophysics | Harvard & Smithsonian)

FRIDAY, 2 AUGUST

Breakouts: Chile-only Configuration



10:00 **Discussion / Follow-up from previous breakouts [Conveners: John Ruhl / John Carlstrom]**

- Plans for next steps

Speakers: John Carlstrom (University of Chicago/Argonne National Laboratory), John Ruhl (Case Western Reserve University)

Steps Following the Conclusion of the Two Working Groups: Defining the Revised Configuration

- The combined results of the two working groups will be used to define a revised configuration that, building on the expected results of current experiments, allows CMB-S4 to achieve the goals set out in Astro2020, the 2023 P5 Report, and the CMB-S4 Program-Level Requirements.
- The process for converging on a revised CMB-S4 configuration is under development and is currently expected to include the following elements:
 - The Project and Collaboration leadership, working closely with the Project L1 Team and the Collaboration Science Council, will propose a revised configuration.
 - A draft document describing the revised configuration, its science capabilities, risks, cost, and the rationale for choosing it will be made available to the full Collaboration.
 - A special collaboration meeting will be convened to discuss the revised configuration.
 - The final document will be revised, if necessary, following the collaboration discussion.
- CMB-S4 will ask to brief the JOG on the conclusions of the studies and the proposed configuration and seek concurrence for development of a complete conceptual design based on it.

Steps Following the Conclusion of the Two Working Groups: Value Engineering

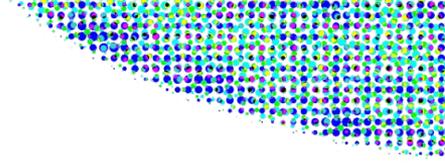
- The Project will conduct value-engineering studies to minimize estimated project costs within the constraints of the science and measurement requirements. The elements of this study will be developed in parallel with the activities of the two working groups, but are likely to include:
 - Review of key technical decisions in light of technical developments since they were made, e.g., readout or detector technology.
 - Possible reduction in detector type variants vs. sensitivity.
 - Optimization of the number of SAT optics tubes per SAT mount for Chile conditions.
 - Possible increased SAT aperture by increased size of polarization modulators or by eliminating them.
 - Optimal placement of telescopes on the Cerro Toco plateau or adjacent sites.
 - Optimization of LAT optics and detectors.
 - Developing collaboration with Simons Observatory or other experiments to evaluate potential collaborative use of instruments to complement or as potential components of CMS-S4.
 - Opportunities for Increased operational efficiency.
 - Optimized scan strategies or analysis techniques for higher efficiency .

Some of these may require collaboration with other experiments or modest hardware R&D to adequately evaluate.

Steps Following the Conclusion of the Two Working Groups: Laying the Foundation for the Revised Conceptual Design

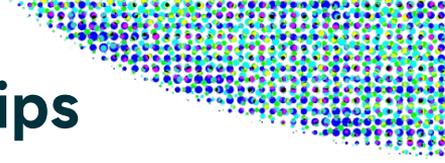
- Continued engineering development in key technical areas is needed to support the optimization of the revised configuration, including value engineering studies and cost estimating.
- This development will help to maintain engagement by key technical personnel and facilities that will be needed for development of the revised conceptual design, once funding permits.
- Development of the revised conceptual design will build on the extensive work done already by CMB-S4.
- Given the advanced state of readiness of CMB-S4 prior to the NSF decision regarding the South Pole, we could develop the revised configuration to a level ready for NSF CDR and DOE CD-1 by the end of FY 2026, if adequate funding is available.

Timeline



- FY24 Q4 - FY25 Q1: Complete studies by the two Working Groups
- FY25 Q2: Analyze results and conclude on the revised configuration of CMB-S4
- March 2025: Brief the CMB-S4 JOG on the revised configuration and seek concurrence
- FY25 Q3-Q4: Value engineering studies to optimize the revised configuration for cost while maintaining scientific capability
- FY26: Develop the conceptual design to readiness for CDR and CD-1, to the extent that funding permits

We continue to develop international partnerships



- Active discussions are in process with representatives of several countries, including Australia, Canada, Chile, France, Germany, Italy, Japan, Spain and the UK.
- A draft agreement has been reached to provide mutual benefits to CMB-S4 and the Universidad de Chile during the construction and operations of CMB-S4 and discussions continue toward eventual recognition of CMB-S4 by the Republic of Chile.
- Agreements are in place or in the final approval process with the French agencies CEA and IN2P3 for specific deliverables to the R&D program. Funding of 505 k€ has recently been granted.
- A consortium of Canadian groups (UBC, SFU, Toronto and McGill) is in the process of applying for funding for CMB-S4 from the Canadian Foundation for Innovation. UVic is planning to fabricate prototype coupling wafers.
- A high-level MOU is in place with INFN, and similar MOUs are in final stages or being negotiated with institutes or consortia in the other countries, in consultation with their respective funding agencies.
- It is intended that these will be developed into legally binding commitments for specific deliverables required by the Project prior to baselining at DOE CD-2 and NSF PDR.
- These agreements are being developed in close cooperation with DOE and NSF.

Conclusions and Outlook



- The next phase of CMB-S4 is the development of a cost-effective configuration in Chile that can achieve our science goals in a reasonable time and with acceptable scientific risk.
We must do a comparison of the capabilities and costs of potential designs of CMB-S4 with what can be realistically achieved. We need to convince ourselves and others that a ground-based CMB-S4 can be done.
- The funding agencies support us in taking this next step. Success in developing the new configuration is a prerequisite for CMB-S4 to proceed into full project design and toward construction.
- The expertise, creativity – and work – from the full CMB-S4 Collaboration needs to be brought to bear to allow us to move forward.
- The science remains among the most compelling in physics, cosmology and astrophysics, and we have support of the full scientific community .
- Let do it!