Project Overview

John Corlett
(he, him)

CMB-S4 Collaboration Meeting
May 9-13, 2022

CMB-S4

Outline

- Recent events and project status
- Systems engineering; requirements and performance margin
- Recent accomplishment highlights
- Organization
- FY22 agency guidance and funding
- Analysis of Alternatives
- Key near-term project goals
- Summary

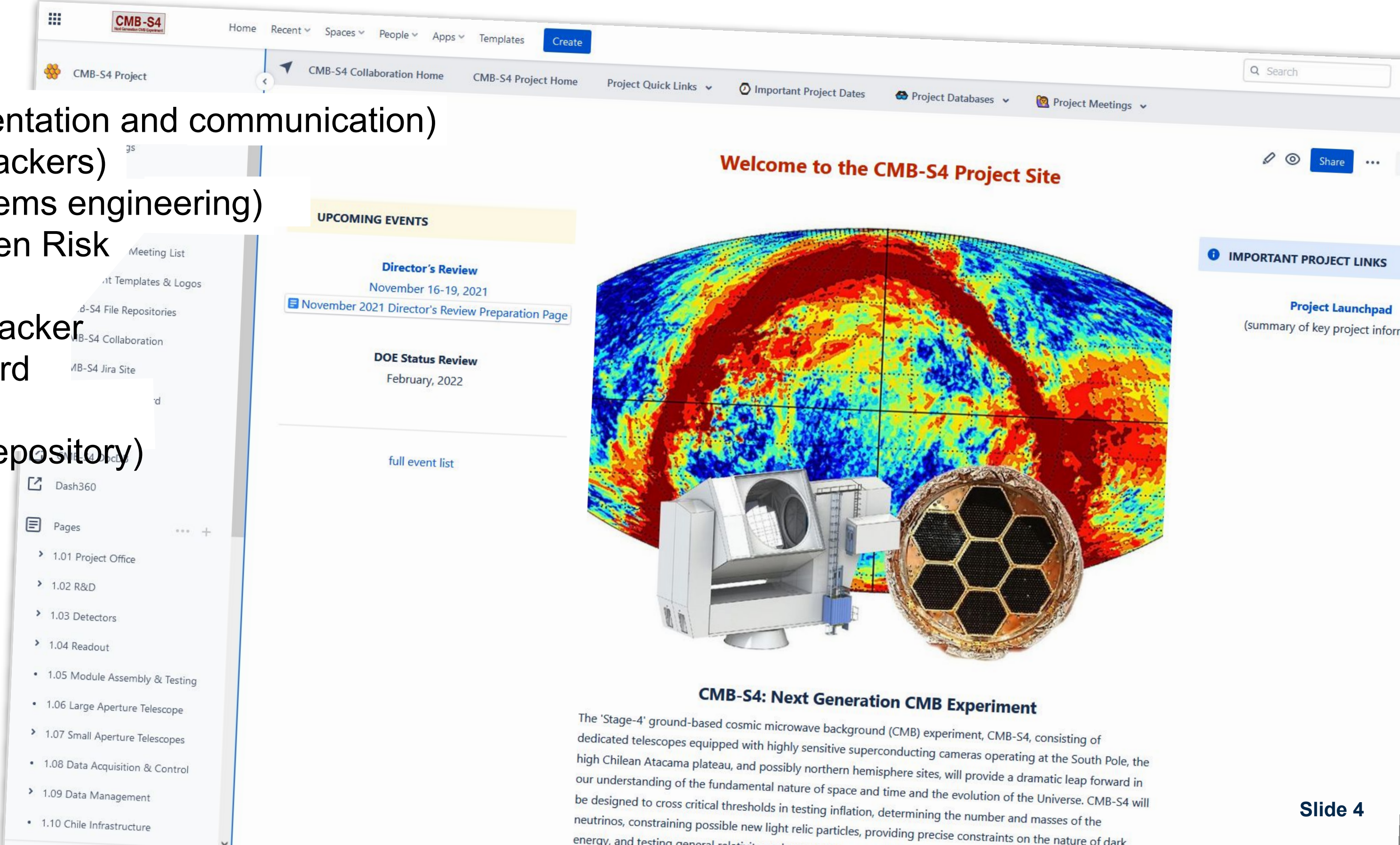
Project Recent Events and Status

- Project organization and infrastructure, technical development, and planning, has been developed in readiness for Conceptual Design Review (DOE) and Preliminary Design Review (NSF)
- Strong recommendation from Astro2020
- Director's Status Review held in November 2021
- Prepared for a DOE Office of Project Assessment (OPA) Status Review planned for February 2022
- DOE OPA Status Review was **postponed**
- Currently at an appropriate level of maturity in most aspects, however the scope of the project and in particular use of resources at the South Pole must be re-assessed
- Performing R&D commensurate with funding
- Developing potential in-kind contributions that could offset project costs
- Performing an Analysis of Alternatives to understand options, to inform and discuss with the agencies

A Suite Of Project Tools Has Been Implemented To Enable Efficient Project Execution

Matthaeus Leitner, Project Manager
Jeff Zivick, Deputy Project Manager

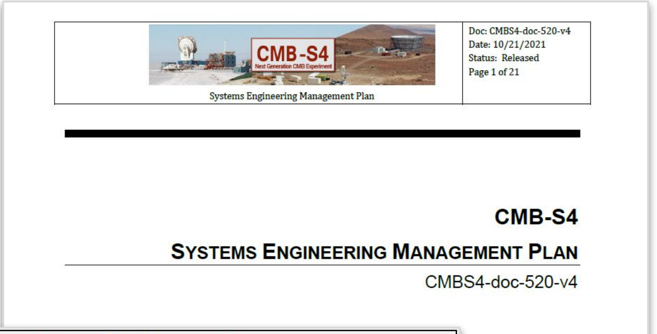
- Primavera
- Dash360
- Confluence (documentation and communication)
- Jira (for all project trackers)
- Jama Connect (systems engineering)
- Risk Registry, Acumen Risk
- Windchill
- Recommendation Tracker
- Change Control Board
- Decision Log
- DocDB (document repository)
- Milestone Tracker
- Statements of Work
- ...

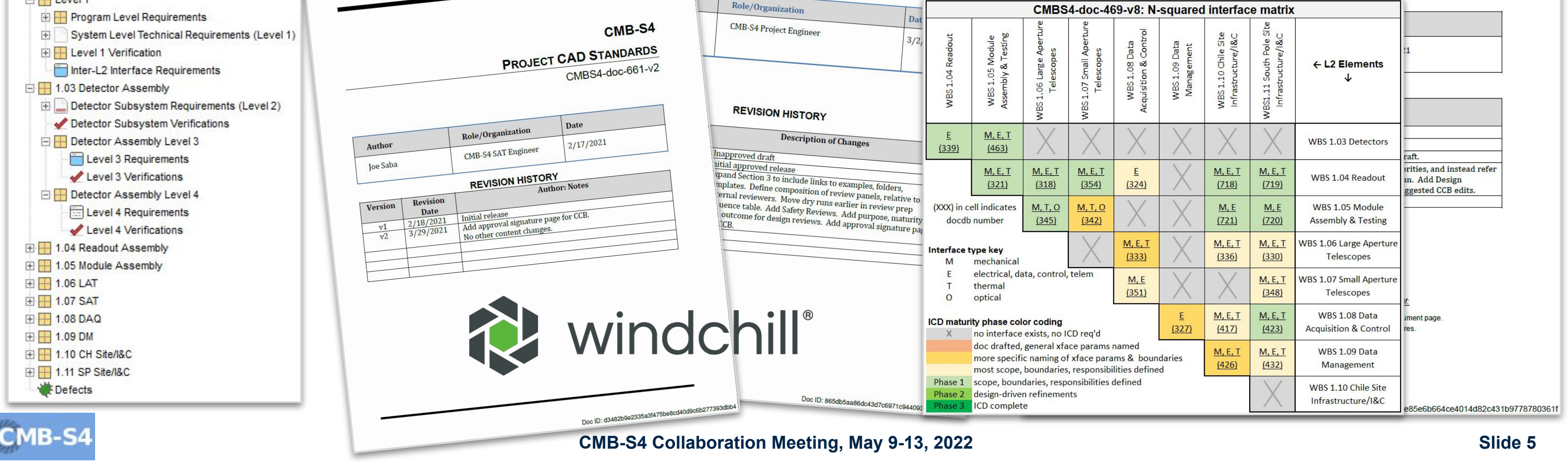


Project Design Maturation Is Coordinated By The Project Engineering And Systems Engineering Office

Matthaeus Leitner, Project Manager
Jeff Zivick, Deputy Project Manager
Bobby Besuner, Project Engineer

- Interfaces and requirements are captured and traced in a central project database
- CAD and document standards have been established

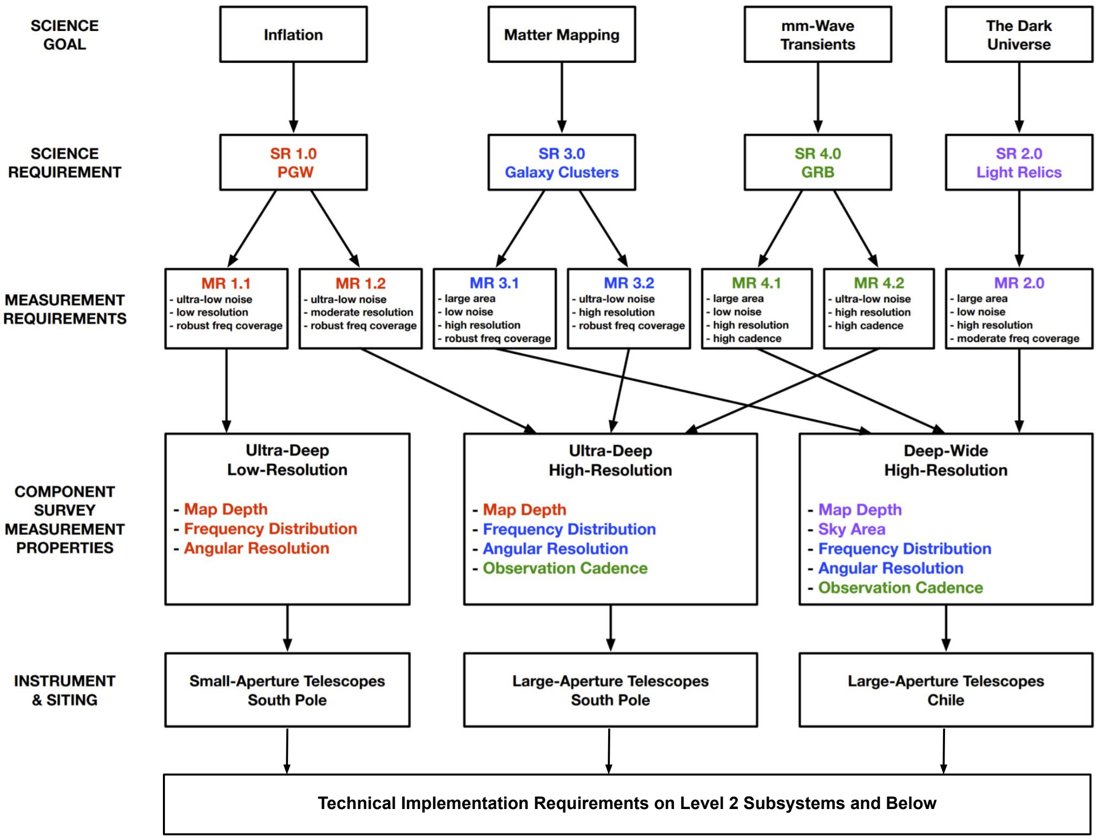




Systems Engineering - Requirements

Bobby Besuner, Project Engineer

- Requirements flow down from high-level science goals described in the preliminary baseline design report (PBDR, CMBS4-doc-716) and program level requirements (PLR, CMBS4-doc-671) to technical implementation requirements on the system, subsystems, and lower levels
- Successful requirements workshops and a recent internal requirements review have helped refine the technical requirements as captured in the project's Jama requirements management tool
- Refinement and further flow-down of requirements continues, along with detailing of system interfaces



Bobby Besuner, Project Engineer

Systems Engineering - Performance Margin

- Ongoing efforts are identifying areas where performance can be improved over the baseline configuration, to build performance margin
- Current areas of focus include
  - Observing efficiency (optimizing scan strategies and system up-time, Observing Strategy Group)
  - Fraction of deployed detectors that contribute to mapping (by rigorous detector fab process control and screening, DRM and QA teams)
  - Use of low-ell data from SPLAT (to augment mapping from SATs, Low-ell BB WG)

Observation Efficiency Summary

Last edit was made 4 days ago by Sara Simon

CHLAT	Numbers with potential margin that has not been quantified are highlighted in light blue					Numbers that r
			PBD	PBD Updates	Potential Factors	Derivation and
f_total (25 GHz)			0.31	0.31	0.38	
f_total (40 GHz)			0.31	0.31	0.38	
f_total (90 GHz)			0.31	0.31	0.38	
f_total (150 GHz)			0.31	0.31	0.38	
f_total (230 GHz)			0.28	0.28	0.34	
f_total (280 GHz)			0.28	0.28	0.34	
	f_year		0.6	0.6	0.675	
		f_season	0.75	0.75	0.75	Per [7], seasor conditions. Sea CMB-S4. There year. From hist 50% of the mor years), April (9
		f_uptime	0.8	0.8		In [7], a fudge f ACT data show is due to weath the telescope t
	f_scan		0.766	0.766		
		f_field	0.9	0.9		
		f_turnarounds	0.994	0.994		
		f_scanset	0.92308	0.92308		
		f_cal_maint	0.927	0.927		
	f_pass (25 GHz)		0.68	0.68		
	f_pass (40 GHz)		0.68	0.68		

Performance Margin Summary

Last edit was 1 hour ago

Current Best Estimates of Performance Margin relative to Preliminary Baseline Design

Not Freq-Dependent

Parameter	PBD value	CBE value	ratio	margin
Deployed Useful Detector Fraction	0.8	0.9	1.125	13%
Observing Efficiency, excluding f_pass	0.459	0.562	1.22	22%
TOTAL			1.38	38%

Freq-Dependent

			Band					
			LF_1	LF_2	MF_1	MF_2	HF_1	HF_2
PBD	f_pass		0.68	0.68	0.68	0.68	0.6	0.6
	Optical Efficiency (horn to detector)		0.7	0.7	0.7	0.7	0.7	0.7
	Optical Efficiency (telescope+optics tubes)		0.145	0.266	0.161	0.270	0.508	0.549
	Photon Loading from Instrument	[Watts/Hz]	2.12E-23	3.22E-23	2.40E-23	5.31E-23	1.44E-22	2.02E-22
	Detector Phonon Noise	[W/sqrt(Hz)]	2.85E-18	7.26E-18	8.40E-18	1.24E-17	2.63E-17	2.83E-17
	Readout Noise	[W/sqrt(Hz)]	1.37E-18	4.31E-18	5.38E-18	9.78E-18	2.88E-17	3.42E-17
	NumDetectors/wafer		96	96	864	864	864	864
CBE	f_pass		0.68	0.68	0.68	0.68	0.6	0.6
	Optical Efficiency (horn to detector)		0.7	0.7	0.7	0.7	0.7	0.7
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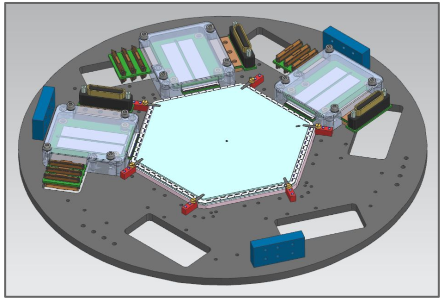
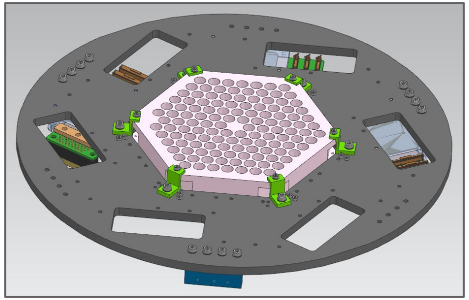
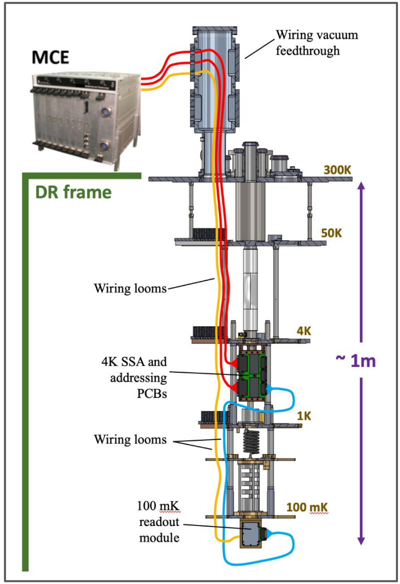
	NumDetectors/wafer		96	96	864	864	864	864
Ratio of CBE mapping speed to PBD mapping speed for freq-dependent factors			1.00	1.00	1.00	1.00	1.00	1.00
CBE Mapping speed margin for freq-dependent factors			0.00	0.00	0.00	0.00	0.00	0.00
CBE Mapping speed margin including freq-dependent and non-freq-dependent params			38%	38%	38%	38%	38%	38%

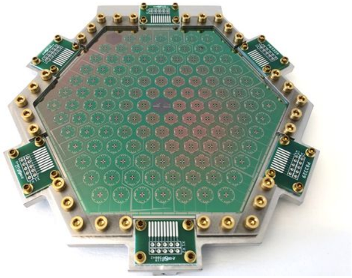
R&D Is On Track To Test Detector Arrays In Modules This Year

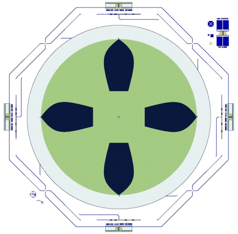
- “Flat” module and no flex cable to facilitate first tests of CDFG and CMB-S4 prototype detector wafers and early prototype readout (dark and optical tests)
- Feedhorn and coupling wafer prototype designs for optical tests
- Outfit 3 module test beds with readout and equipment to characterize and develop integrated detector modules
- Expect to test ~ 12 wafers from 2-3 sites in CY22











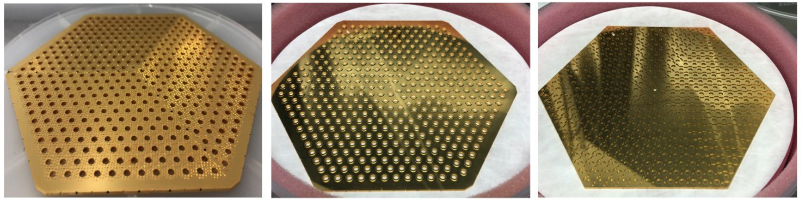
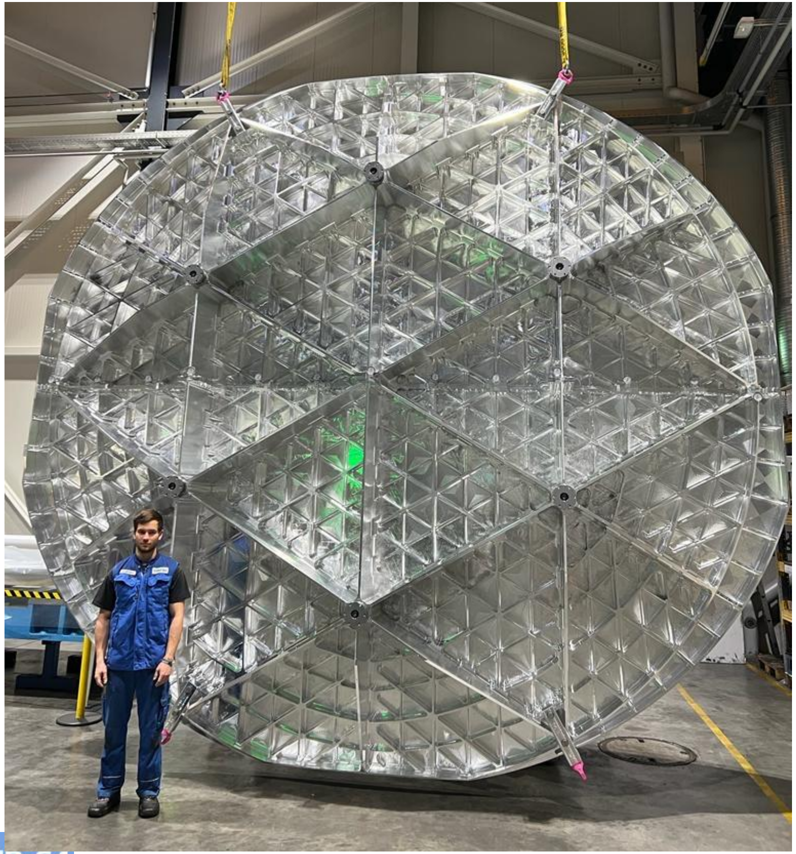
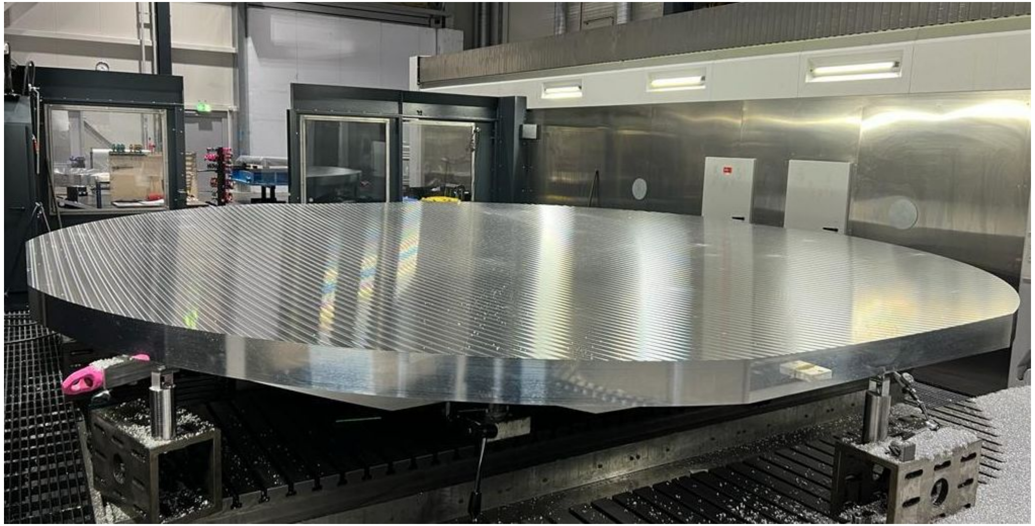


Figure 43: **Left:** A photonic choke wafer. **Center:** A waveguide interface plate. **Right:** A backshort array.

SPLAT TMA Primary Mirror Development





Accomplished Management, CMB, and Telescope Scientists and Engineers Fill Key Positions from L1 to L3

NSF funded

DOE funded

*interim position

L1 Scientists and Engineers

Senior Advisors
Jim Yeck
Steve Kahn

Education & Public Outreach
Manager Juliet Crowell

Equity, Diversity & Inclusion
Manager tbd

1.01
PROJECT OFFICE

- **Project Director** *John Corlett** (LBNL)
- **Deputy Project Director** *Gil Gilchriese** (LBNL)
- **NSF Principal Investigator** John Carlstrom (U. Chicago)
- **Project Manager** Matthaeus Leitner (LBNL)
- **Deputy Project Manager** Jeff Zivick (U. Chicago)
- **Project Engineer** Robert Besuner (LBNL)
- **Lead Systems Engineer** *Robert Besuner** (LBNL)
- **Technical Integration Scientist** Brenna Flaugher (FNAL)
- **Project Scientist** John Carlstrom (U. Chicago)
- **Instrument Scientist** John Ruhl (Case Western)
- **Data Scientist** Julian Borrill (LBNL)

Project Operations

- **Project Controls Manager** David Sala
- **Project Controls**
  Kevin Long, Dianna Jacobs (DOE Leads), Sherese Humphrey (NSF Lead), Suzanne Nelson
- **Operations Manager (LBNL)** Jessica Aguilar
- **Finance Liasion (LBNL)** Bill Fortney
- **Finance Liaison (U. Chicago)** Haskell Swygert
- **Procurement Lead (U. Chicago)** Diane Stanek
- **Procurement Lead (LBNL)** Ashley Loper
- **Risk Manager** Jeff Zivick
- **ES&H** Ingrid Peterson
- **QA** *Jessica Aguilar**
- **Project IT** Jeffrey Anderson
- **Administrative Support** Tami Blackwell
- **US Transportation and Material Flow Coordinator** Jessica Aguilar
- **Legal (U. Chicago)** Russell Herron
- **Legal (LBNL)** Michelle Wong
- **IP** Sebastian Ainslie

Project Operations Team

L2 Scientists

CAMs

1.03 DETECTORS	1.04 READOUT	1.05 MODULE ASSEMBLY AND TESTING	1.06 LARGE APERTURE TELESCOPES	1.07 SMALL APERTURE TELESCOPES	1.08 DATA ACQUISITION AND CONTROLS	1.09 DATA MANAGEMENT	1.10 CHILE INFRASTRUCTURE INTEGRATION AND COMMISSIONING	1.11 SOUTH POLE INFRASTRUCTURE INTEGRATION AND COMMISSIONING
*Brenna Flaugher** (FNAL)	Zeesh Ahmed (SLAC)	Brad Benson (FNAL)	Mike Niemack (Cornell)	John Kovac (Harvard)	Laura Newburgh (Yale)	Julian Borrill (LBNL)	Kam Arnold (UCSD)	Amy Bender (ANL)
John Joseph (LBNL)	Gunther Haller (SLAC)	Hogan Nguyen (FNAL)	Nick Emerson (U. Arizona)	*Robert Besuner** (LBNL)	Gregg Thayer (SLAC)	*Kevin Long** (LBNL)	Mauricio Pilleux (EONS)	Erik Nichols (RSS)

L2s are responsible for preparing designs and plans, and managing the cost and schedule of their subsystems

CMB-S4 Organization Is Developed To The Lowest Technical Levels

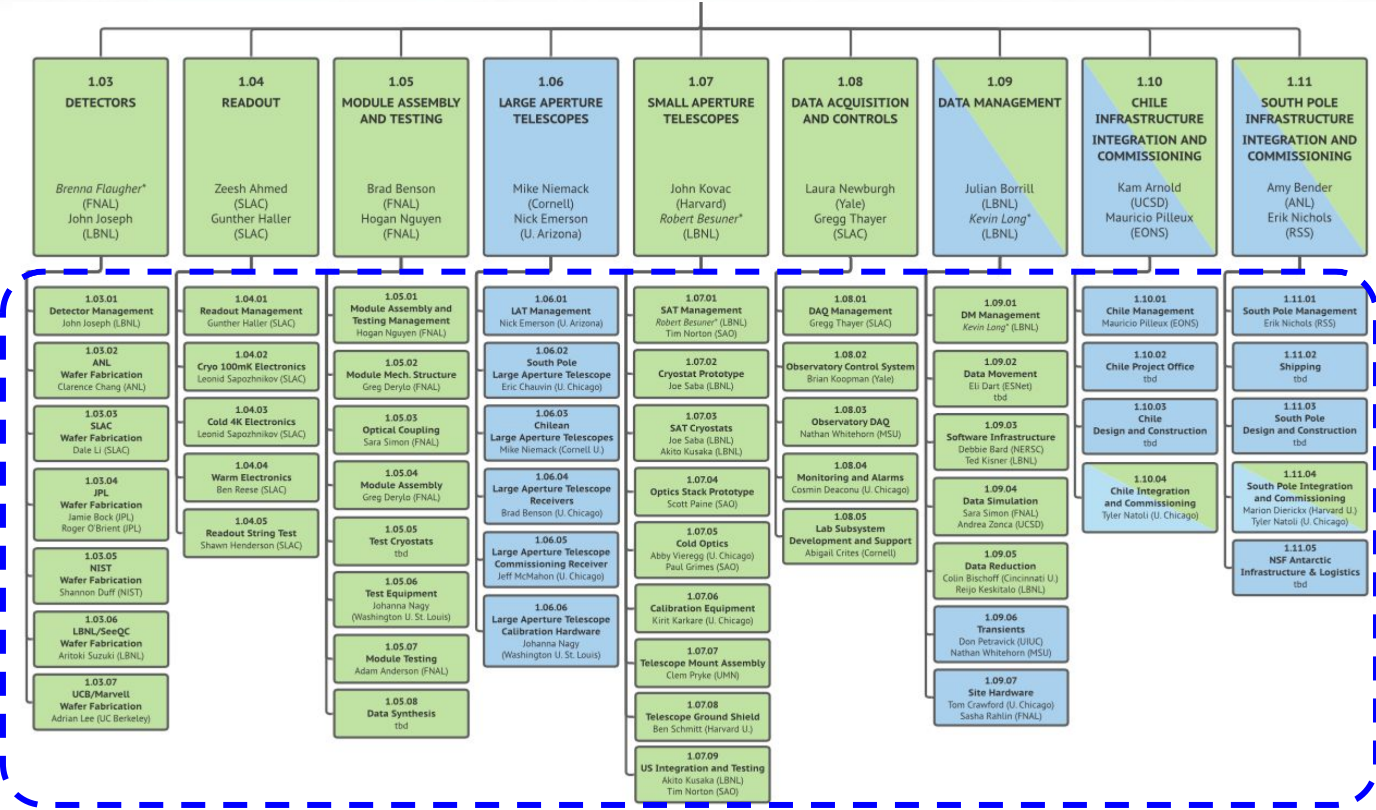
Project Organization Is Distributed Across National Laboratories and Universities

NSF funded

DOE funded

*interim position

L3 Technical Leads



CMB-S4 Organization Is Developed To The Lowest Technical Levels

Project Organization Is Distributed Across National Laboratories and Universities

- Berkeley Lab
- The University of Chicago
- Argonne National Laboratory
- Jet Propulsion Laboratory, California Institute of Technology
- The University of Arizona
- Michigan State University
- Berkeley, University of California
- University of Minnesota
- Caltech
- NIST, National Institute of Standards and Technology
- Case Western Reserve University, Est. 1826
- UC San Diego
- Cornell University
- SLAC
- Fermilab
- Washington University in St. Louis
- Harvard University
- Yale University
- University of Illinois Urbana-Champaign
- Center for Astrophysics, Harvard & Smithsonian

1.03 DETECTORS — *Brenna Flaugher** (FNAL), John Joseph (LBNL)
- 1.03.01 Detector Management — John Joseph (LBNL)
- 1.03.02 ANL Wafer Fabrication — Clarence Chang (ANL)
- 1.03.03 SLAC Wafer Fabrication — Dale Li (SLAC)
- 1.03.04 JPL Wafer Fabrication — Jamie Bock (JPL), Roger O'Brient (JPL)
- 1.03.05 NIST Wafer Fabrication — Shannon Duff (NIST)
- 1.03.06 LBNL/SeeQC Wafer Fabrication — Aritoki Suzuki (LBNL)
- 1.03.07 UCB/Marvell Wafer Fabrication — Adrian Lee (UC Berkeley)

1.04 READOUT — Zeesh Ahmed (SLAC), Gunther Haller (SLAC)
- 1.04.01 Readout Management — Gunther Haller (SLAC)
- 1.04.02 Cryo 100mK Electronics — Leonid Sapozhnikov (SLAC)
- 1.04.03 Cold 4K Electronics — Leonid Sapozhnikov (SLAC)
- 1.04.04 Warm Electronics — Ben Reese (SLAC)
- 1.04.05 Readout String Test — Shawn Henderson (SLAC)

1.05 MODULE ASSEMBLY AND TESTING — Brad Benson (FNAL), Hogan Nguyen (FNAL)
- 1.05.01 Module Assembly and Testing Management — Hogan Nguyen (FNAL)
- 1.05.02 Module Mech. Structure — Greg Derylo (FNAL)
- 1.05.03 Optical Coupling — Sara Simon (FNAL)
- 1.05.04 Module Assembly — Greg Derylo (FNAL)
- 1.05.05 Test Cryostats — tbd
- 1.05.06 Test Equipment — Johanna Nagy (Washington U. St. Louis)
- 1.05.07 Module Testing — Adam Anderson (FNAL)
- 1.05.08 Data Synthesis — tbd

1.06 LARGE APERTURE TELESCOPES — Mike Niemack (Cornell), Nick Emerson (U. Arizona)
- 1.06.01 LAT Management — Nick Emerson (U. Arizona)
- 1.06.02 South Pole Large Aperture Telescope — Eric Chauvin (U. Chicago)
- 1.06.03 Chilean Large Aperture Telescopes — Mike Niemack (Cornell U.)
- 1.06.04 Large Aperture Telescope Receivers — Brad Benson (U. Chicago)
- 1.06.05 Large Aperture Telescope Commissioning Receiver — Jeff McMahon (U. Chicago)
- 1.06.06 Large Aperture Telescope Calibration Hardware — Johanna Nagy (Washington U. St. Louis)

1.07 SMALL APERTURE TELESCOPES — John Kovac (Harvard), *Robert Besuner** (LBNL)
- 1.07.01 SAT Management — *Robert Besuner** (LBNL), Tim Norton (SAO)
- 1.07.02 Cryostat Prototype — Joe Saba (LBNL)
- 1.07.03 SAT Cryostats — Joe Saba (LBNL), Akito Kusaka (LBNL)
- 1.07.04 Optics Stack Prototype — Scott Paine (SAO)
- 1.07.05 Cold Optics — Abby Vieregg (U. Chicago), Paul Grimes (SAO)
- 1.07.06 Calibration Equipment — Kirit Karkare (U. Chicago)
- 1.07.07 Telescope Mount Assembly — Clem Pryke (UMN)
- 1.07.08 Telescope Ground Shield — Ben Schmitt (Harvard U.)
- 1.07.09 US Integration and Testing — Akito Kusaka (LBNL), Tim Norton (SAO)

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)

1.09 DATA MANAGEMENT — Julian Borrill (LBNL), *Kevin Long** (LBNL)
- 1.09.01 DM Management — *Kevin Long** (LBNL)
- 1.09.02 Data Movement — Eli Dart (ESNet), tbd
- 1.09.03 Software Infrastructure — Debbie Bard (NERSC), Ted Kisner (LBNL)
- 1.09.04 Data Simulation — Sara Simon (FNAL), Andrea Zonca (UCSD)
- 1.09.05 Data Reduction — Colin Bischoff (Cincinnati U.), Reijo Keskitalo (LBNL)
- 1.09.06 Transients — Don Petravick (UIUC), Nathan Whitehorn (MSU)
- 1.09.07 Site Hardware — Tom Crawford (U. Chicago), Sasha Rahlin (FNAL)

1.10 CHILE INFRASTRUCTURE INTEGRATION AND COMMISSIONING — Kam Arnold (UCSD), Mauricio Pilleux (EONS)
- 1.10.01 Chile Management — Mauricio Pilleux (EONS)
- 1.10.02 Chile Project Office — tbd
- 1.10.03 Chile Design and Construction — tbd
- 1.10.04 Chile Integration and Commissioning — Tyler Natoli (U. Chicago)

1.11 SOUTH POLE INFRASTRUCTURE INTEGRATION AND COMMISSIONING — Amy Bender (ANL), Erik Nichols (RSS)
- 1.11.01 South Pole Management — Erik Nichols (RSS)
- 1.11.02 Shipping — tbd
- 1.11.03 South Pole Design and Construction — tbd
- 1.11.04 South Pole Integration and Commissioning — Marion Dierickx (Harvard U.), Tyler Natoli (U. Chicago)
- 1.11.05 NSF Antarctic Infrastructure & Logistics — tbd

DOE and NSF Guidance for FY22

- Both DOE and NSF remain enthusiastic for CMB-S4
- DOE funding for FY22 is, however, limited to $9M
  - Reason given for the reduced DOE funding level from the $20M in the appropriations bill is lack of alignment between agencies, specifically:
    - NSF is not ready to work with CMB-S4, or others, on South Pole Station needs
    - NSF is developing plans in response to Astro2020 recommendations including CMB-S4
    - NSF says our baseline plan is not supportable at this time
    - Same message as given for postponement of the February OPA review
- NSF guidance is also for reduced funding in FY22, via a MSRI supplement
- Both agencies have indicated that an Analysis of Alternatives is urgently needed that will inform the future direction of the project
- CMB-S4 plans will be developed as the NSF responds to:
  - Science needs at the South Pole Station
  - Broad set of Astro2020 recommendations
  - Availability of NSF design & development funding

Analysis of Alternatives (AoA)

- In February of 2022 it became apparent that some of the assumptions being used by the project are not correct, and the funding agencies need time to clarify those assumptions
- In particular, constraints on the South Pole Station do not currently allow for support of the CMB-S4 preliminary baseline configuration
- DOE and NSF requested that the CMB-S4 project perform an analysis of alternatives to assess options for configuration of the project including different distributions of equipment between the South Pole and Chile sites, the science potential of each option in comparison to the goals articulated in the Preliminary Baseline Design Report and Program Level Requirements, and estimated life-cycle costs of those options
- Emphasis of this analysis should be on options that minimize the use of South Pole Station infrastructure and logistics, in particular on options that fit within the current SP logistical "footprint"

AoA Status

- Mandate is to identify alternate approaches to CMB science using the Chile and South Pole sites, assess telescope needs to achieve identified science goals, and assess life cycle costs for each option
  - Not a re-start; using existing designs with potential modifications
  - To inform an optimization of science/dollar

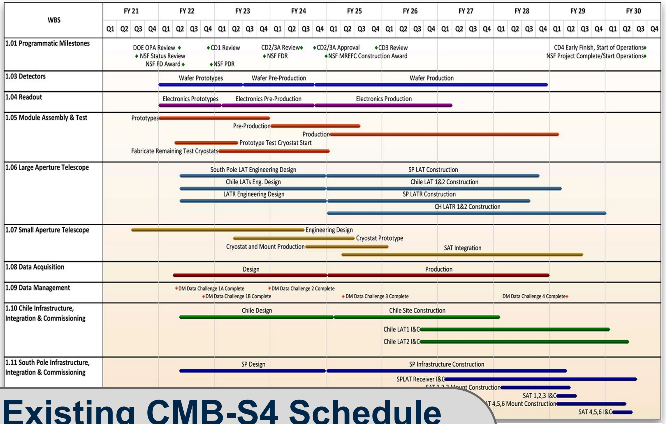
- L1 has re-directed project effort to support a broad AoA, with three core perspectives to assess in development of integrated alternate approaches:
  - Chile r forecasts, comparison with South Pole
  - Chile configurations
  - South Pole configurations and r forecasts

- Holding regular dedicated meetings to provide L1 and other oversight with input an all aspects of the AoA

AoA - Cost Estimating

Matthaeus Leitner, Project Manager
Jeff Zivick, Deputy Project Manager

- We have developed a parametric cost model utilizing latest project cost roll-up data from P6 and Cobra
- Cost model parametrizes all project sub-systems based on fixed and per-unit costs
  - SAT and LAT telescope mounts
  - Detector modules (wafers, readout, modules)
  - Site installation and commissioning
  - Optional credit for mass-production discounts
- Analysis of Alternatives incorporates a more detailed life-cycle analysis based on a draft operations plan
  - Developed a strawperson operations organization with FTE counts
  - Yearly material and supplies budget
  - Site operations budget
  - Spare part budget
  - Divestment costs
- Schedule impact is also analyzed



Existing CMB-S4 Schedule and Cost Database

[illegible]	[illegible]	[illegible]	NSF MREFC	TOTAL
[illegible]	[illegible]	[illegible]	$ 13,779,652	$ 58,079,150
1.03 - Detectors	[illegible]	[illegible]		$ 65,684,588
1.04 - Readout	$ 4,563,064	$ 61,241,747		$ 65,804,811
1.05 - Module Assembly and Test	$ 2,750,302	$ 37,768,288		$ 40,518,590
1.06 - Large Aperture Telescope (LAT) and Receivers			$ 82,912,307	$ 82,912,307
1.07 - Small Telescopes	$ 3,624,307	$ 60,502,378		$ 64,126,685
1.08 - Observatory Control and Data Acquisition System (DAQ)	$ 2,938,718	$ 17,454,885		$ 20,393,603
1.09 - Data Management	$ 1,377,261	$ 34,264,083	$ 6,348,613	$ 41,989,957
1.10 - Chile Site	$ 5,573,094		$ 48,946,695	$ 54,519,789
1.11 - South Pole Site	$ 4,974,699		$ 61,579,550	$ 66,554,249
1.11 - South Pole NSF AIL			$ 110,303,818	$ 110,303,818
SUBTOTAL	$ 35,056,052	$ 311,960,859	$ 323,870,635	$ 670,887,546
40% contingency on DOE (OPC Commissioning + TEC) and NSF MREFC	$ 4,219,117	$ 124,784,344	$ 129,548,254	$ 258,551,714
TOTAL DOE OPC+TEC Plus NSF MREFC Cost	$ 39,275,169	$ 436,745,203	$ 453,418,889	$ 929,439,260

DOE OPC includes actuals before FY22, remaining conceptual design effort, and commissioning costs

Life Cycle Cost = Projectized Costs + Operations Costs + Decommissioning

AoA Timeline

- Collaboration meeting May 9-13
  - Inform the Collaboration, provide transparency in process and concepts, preliminary results
- L1 meeting in Chicago May 18
  - Outline of presentations for a June agency briefing
- Dry run(s) late May, early June
- Agency briefing(s) first half of June
  - Progress in AoA that has options for project scope supportable by NSF/OPP
- Internal review August
- Agency briefing September
- Continued interactions and iteration to fully converge with agencies

Key Near-term Project Goals

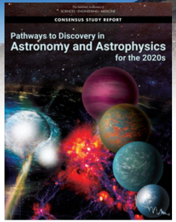
- Perform a broad Analysis of Alternatives (AoA)
- Maintain a minimal Project Office to support development of AoA and enable readiness for agency phase-gate processes
- Support R&D with a focus toward maintaining core technical team capabilities and demonstrating first articles of Detectors, Readout, Modules, and test stands:
  - Fabrication of first articles of prototype Detector wafers, integration into Modules with Readout
  - Perform tests of prototype assemblies
  - Support for critical teams working on SAT, LAT/LATR, DM, and DAQ
- Strong participation in Snowmass process, emphasizing CMB-S4 science case and project readiness, including in-person Seattle meeting July 17-26
- Perform an internal review of the AoA in late summer

Summary

- The CMB-S4 experiment has an exciting science case crossing critical thresholds in fundamental physics, cosmology, astrophysics and astronomy and this is recognized by strong endorsements and continued agency support
- Project organization and infrastructure is in place and actively functioning to Level 3
- Technical maturity is near to conceptual level, and we have demonstrated ability to prepare at CD-1/PDR level
- We have a solid plan and process in place for Analysis of Alternatives, performance and cost
- We will propose option(s) to converge with agencies on science reach and resource availability
- It will likely be late CY22 before the configuration is agreed with our funding agencies

Backup slides

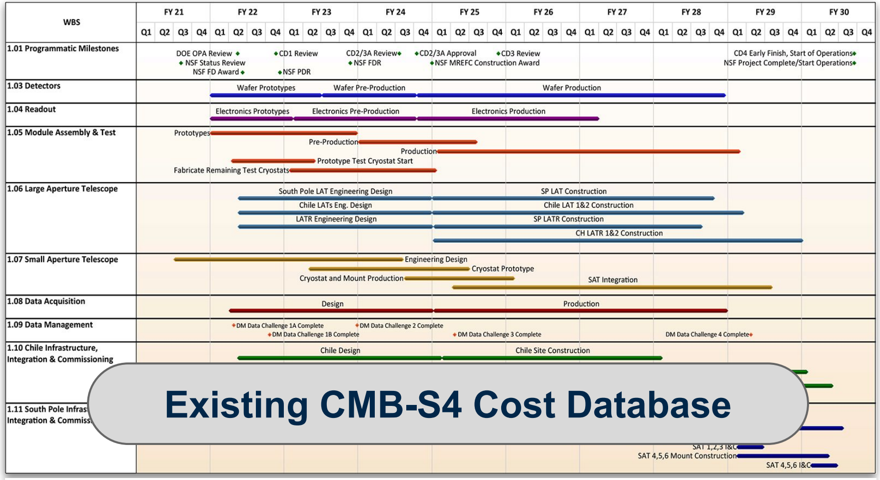
CMB-S4 Strongly Endorsed In The Astro2020 Report



- **Recommendation: The National Science Foundation and the Department of Energy should jointly pursue the design and implementation of the next generation ground-based cosmic microwave background experiment (CMB-S4)**
- … ground-based cosmic microwave background (CMB) studies are poised in the next decade to make a major step forward, and the **CMB Stage 4 (CMB-S4) observatory (with support from NSF and DOE) will have broad impact on cosmology and astrophysics**
- The Panel on Radio, Millimeter and Submillimeter Observations from the Ground (RMS) evaluated a number of CMB projects, and suggested that the **CMB-S4 observatory as the compelling and timely next leap for ground-based observations**
- Important to our recommendation is that **CMB-S4 is a project with a balanced commitment from both NSF and DOE from inception, to design, implementation, operations and science. NSF nurtures and supports university groups with broad scientific and technical experience who have been leading groundbased CMB efforts both in Chile and in Antarctica, and that have been and will continue to train new generations of talent. DOE brings to bear the technical expertise of its national laboratories, scientific expertise including large scale computation, and importantly systematic management approaches that have proven to be effective for large-scale projects.** The agencies have been working jointly and effectively to prepare for initiating this compelling project.

Matthaeus Leitner, Project Manager
Jeff Zivick, Deputy Project Manager

AoA - Cost Basis and Methodology



	DOE OPC	DOE TEC	NSF MREFC	TOTAL
1.01 - Project Management & Systems Engineering	$ 4,104,399	$ 40,195,099	$ 13,779,652	$ 58,079,150
1.03 - Detectors	$ 5,150,209	$ 60,534,379		$ 65,684,588
1.04 - Readout	$ 4,563,064	$ 61,241,747		$ 65,804,811
1.05 - Module Assembly and Test	$ 2,750,302	$ 37,768,288		$ 40,518,590
1.06 - Large Aperture Telescope (LAT) and Receivers			$ 82,912,307	$ 82,912,307
1.07 - Small Telescopes	$ 3,624,307	$ 60,502,378		$ 64,126,685
1.08 - Observatory Control and Data Acquisition System (DAQ)	$ 2,938,718	$ 17,454,885		$ 20,393,603
1.09 - Data Management	$ 1,377,261	$ 34,264,083	$ 6,348,613	$ 41,989,957
1.10 - Chile Site	$ 5,573,094		$ 48,946,695	$ 54,519,789
1.11 - South Pole Site	$ 4,974,699		$ 61,579,550	$ 66,554,249
1.11 - South Pole NSF AIL				
SUBTOTAL				
40% contingency on DOE (OPC Commiss				
TOTAL DOE OPC+TEC Plus NSF MREF				

DOE OPC includes actuals before FY22, remaining

Parameterize WBS Data (Fixed & Variable Costs)

+

Site Specific Cost Modifications

Specific Alternative Project Cost

Life Cycle Cost = Projectized Costs + Operations Costs + Decommissioning

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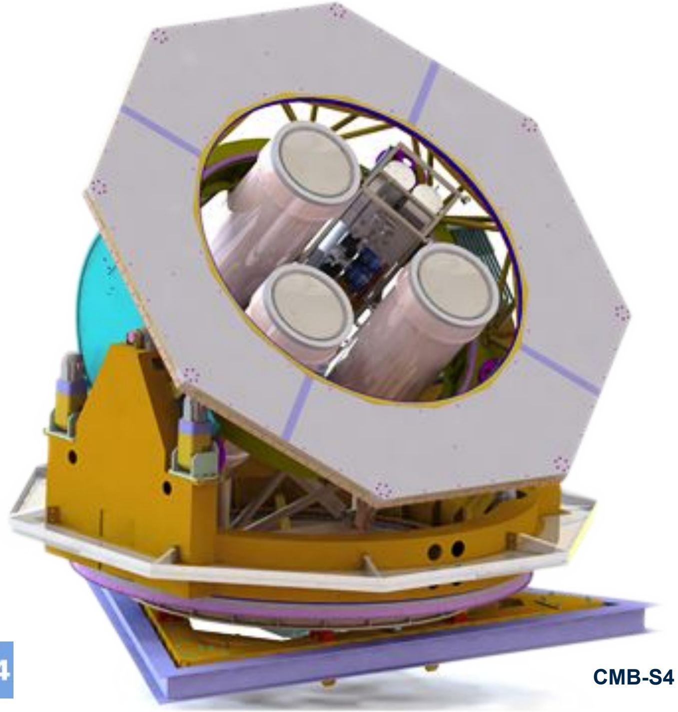
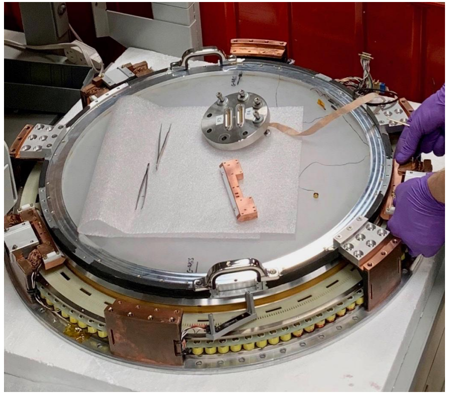
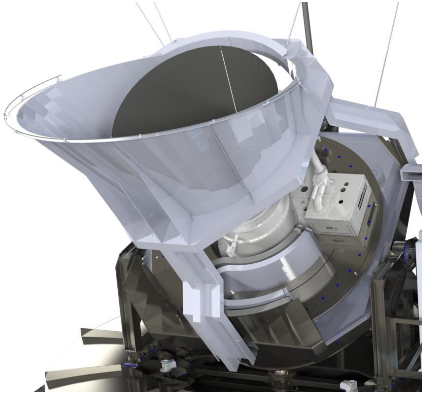
Parametric Model Allows For Adding Site Specific Cost Modifications

- e.g., Chile SATs may have additional fixed and variable costs due to the need for half wave plates or modified ground shields
- Site installation may need an additional highbay building







Credit: UC Berkeley, Simons Observatory

MOUs/MOAs/SOWs

MOU: Memorandum of Understanding
MOA: Memorandum of Agreement
SOW: Statement of Work
IPMP: Intellectual Property Management Plan

- MOUs (standard format)
  - Legal framework for work in Chile. U of Chicago: completed
  - Framework for potential in-kind contributions to CMB-S4 are completed:
    - Harvard-Smithsonian
    - CCAT Prime Observatory, Inc. and U. Chicago
    - Simons Observatory and U. Chicago
- MOAs (bespoke format)
  - Detector fab sites MOA and IPMP completed
  - Institutional MOAs (signed once) + FY Appendix (update each FY):
    - LBNL, ANL, FNAL, SLAC completed
    - Caltech and CfA | Harvard in progress
- SOWs (key part of contracts between LBNL and DOE funded institutions)
  - Being renewed for FY22, based on recent budget allocation and capabilities

Opportunities - MOUs and Non-US Contributions

- Realization of Opportunities would reduce the DOE & NSF Project costs
- It's very early in our understanding of Opportunity probabilities
- We have not "taken credit" for possible realization of any Opportunities, at this time, in the establishment of a point estimate or lower cost range for the Project
- Realization of most Opportunities needs to occur to match DOE or NSF agency gates
- Exception is detector-related opportunities that can be maintained during the early fabrication phase and gradually realized or not
- As Opportunities are realized, they will be incorporated into P6 via the baseline change process

AoA Update - Chile Alternatives

- Preliminary Baseline Design
- All CMB-S4 telescopes in Chile
  - Determine # detectors/telescopes required for all science goals with sky conditions
  - Assess science risk and required R&D
- Impact of SAT deployment on site resources
  - Power generation, fuel storage, telescope towers, laboratory facilities, concession size
- Technical issues in operating SATs in Chile
  - Ground shielding, ½-wave plates, terrain blockage
- Opportunities for use of SO and CCAT infrastructure and data
- What can be done with a constrained budget
  - Science reach and gaps

AoA Update - South Pole Alternatives

- Preliminary Baseline Design
- Continuation of existing SP CMB program
  - Use of SPT-3G, BICEP3, BICEP Array (BA)
  - BICEP Array (with Bicep Array Replacement Tower BART) potentially with 1 optics tube of CMB-S4 detectors (i..e, pathfinder SAT)
- Alternative configuration (with assumptions identified: power, transportation, towers, buildings)
  - SPLAT and use of existing BICEP Array with CMB-S4 Detectors
  - Above with an additional SATs
  - Smaller aperture LATs with or without SATs
  - Assess science risk and required R&D
- What can be done with a constrained budget
  - Science reach and gaps

Simons Observatory (SO)

- MOU among LBNL, U Chicago and Simons Observatory (SO) (represented by UC San Diego)
  - Potential in-kind contribution: reuse of SO equipment
  - Two options, dependent on future SO funding
    - Utilize the SO LAT and fully populated SO LATR
      - Advanced SO, MRSI-2 proposal submitted to NSF to fully populate the SO LATR
      - Proposal moving through NSF review process
    - Or utilize only the SO LAT
  - Note that partially instrumented LATR(SO) is not sufficient to meet CMB-S4 requirements: full LATR (ASO) needed to provide one CHLAT and CHLATR for CMB-S4
  - Status
    - Multiple discussions
    - Held a technical workshop March 1 that brought together representatives from the two projects
      - Meeting Science Requirements for CMB-S4
      - LAT and LATR and DAQ Critical Interface Requirements
      - Site Critical Interface Requirements
      - Data Management Critical Interfaces

CCAT / Fred Young Submillimeter Telescope (FYST)

- MOU among LBNL, U Chicago and CCAT Prime Corporation
  - FYST would provide one CHLAT for CMB-S4
  - CCAT is an International partnership, with interests in other science as well as CMB
  - 2 instruments simultaneously mounted
  - Operations planned to start June 2024

- Status
  - Members of CMB-S4 are part of CCAT and facilitating discussions
  - Met twice with chair of CCAT board from Cornell
    - Timescales discussed
    - CCAT constraints for use
    - Will not move FYST to CMB-S4 site
  - Planning for a joint CCAT/CMB-S4 workshop this summer to gain common understanding of the minimum set of interfaces and specifications needed to evaluate and define scenarios for the use of FYST infrastructure and/or data as part of a program to attain the science goals of CMB-S4

Project Contributions from non-US Members

- Typical US science projects expect international partners to contribute to construction project costs in return for data/publication rights
- The project is now engaging with non-US members to identify their contributions that can offset project costs
  - Currently 89 non-US members at 75 institutions in 17 countries
- Project leadership has been meeting with groups of non-US members with common funding sources (typically at the country level)
  - Explaining the expectations and timeline (pre-CD2/FDR) of the necessary cash or in-kind contributions
  - Initiating discussion on possible in-kind contributions
- This will also require changes in the collaboration bylaws on membership and governance; the co-Spokespeople have started this discussion with the Governing Board

Who Am I

John Corlett

Interim Project Director

- 30 years at LBNL
- Involved in scientific contributions and project management of DOE projects for last 30 years
    - Advanced Light Source
    - PEP-II B-Factory
    - Linear Colliders
    - LCLS-II
    - LCLS-II HE
- LBNL Project Management Office since 2018
    - Broad portfolio of science and facility construction projects