Julian Borrill

CMB-S4 Co-Spokesperson

Computational Cosmology Center, Berkeley Lab

& Space Sciences Laboratory, UC Berkeley

Current Status

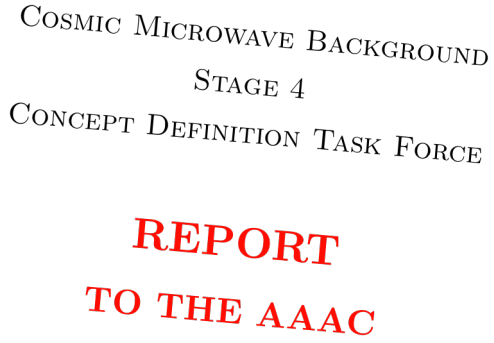
Particle Physics Project Prioritization Panel (P5)

- **Recommendation 18: Support CMB experiments as part of the core particle physics program. The multidisciplinary nature of the science warrants continued multiagency support.**
- *"As the scale of CMB experiments grows from Stage 3 … to Stage 4 … increased international collaboration and coordination among major CMB projects will be needed."*

- Envisioned in 2014 as a $200M project with construction starting in ~2016 and operations in ~2023.
- Recommended under all budget scenarios.

Astronomy & Astrophysics Advisory Council (AAAC)

- At DOE/NSF request, AAAC convened the Concept Definition Taskforce (CDT).
- Core principle: two sites, one collaboration, one project, one experiment, one dataset.
- CDT strawperson design:
  - ***r*** : 14 SAT + 1 LAT; ~200K detectors @ 30/20-270GHz; 3% sky
  - N_{eff} : 2 LAT; ~200K detectors @ 20-270GHz; 40% sky
  - Other science (m_ν, dark sector, galaxies) captured by default
  - Two sites necessary and sufficient (but others could be added)
- $412M DOE/NSF construction (FY20-26); operations (FY27-34).
- Final report unanimously endorsed by AAAC in October 2017.



Collaboration

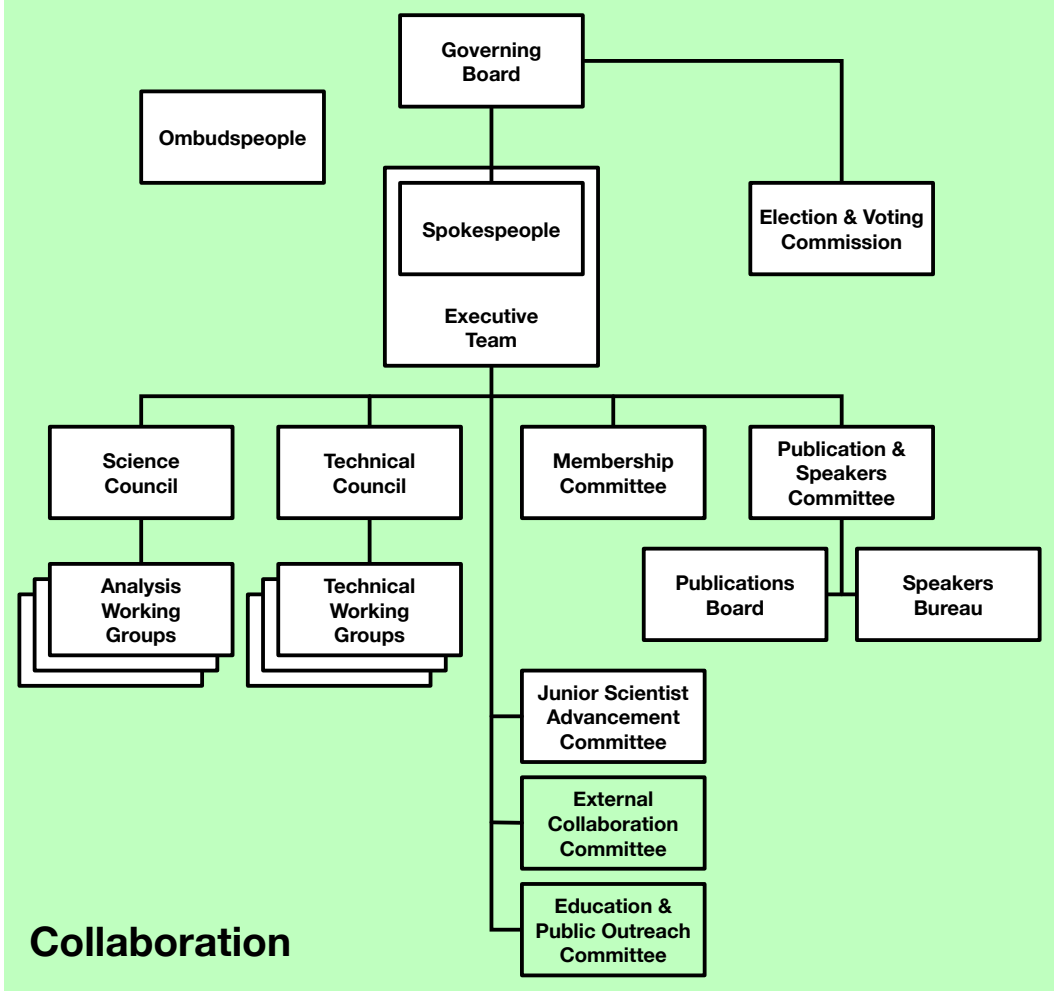
- Biannual open meetings to develop CMB-S4 starting in 2015, alternating between a university and a DOE laboratory.
- CDT: *"Going forward with the CMB-S4 project with multiagency and other support requires a formal CMB-S4 collaboration."*
  - Fall 2017 (Harvard): Interim Collaboration Coordination Committee + 3 Bylaws Working Groups convened.
  - Spring 2018 (Argonne): draft bylaws debated & amended.
- Final bylaws overwhelmingly approved; collaboration formed & first elections held.
- 174 members:
  136 US + Australia, Canada, France, Germany, Italy, Japan, Sweden, UK

Princeton – Fall 2018

Collaboration Org Chart

Executive Team

- Spokespeople:
  Borrill & Carlstrom
- Science Council Chairs:
  Holder & Knox
- Technical Council Chairs:
  McMahon & Vieregg
- Membership Committee Chair:
  Ruhl
- Publication/Speakers Chair:
  Huffenberger



Project Prioritization

- From the outset, CMB-S4 was conceived as a joint DOE/NSF project with international and private partners.
- Agency priorities set by major reviews of their field(s) every decade.
- DOE:
  - Office of High Energy Physics (P5 – 2014) ✓
- NSF:
  - Division of Physics (P5 – 2014) ✓
  - Office of Polar Programs (NAS “Strategic Vision” – 2015) ✓
  - Division of Astronomy (Decadal Survey – 2021)

- Until recently, the mismatch between the physics/polar & astronomy review cycles was the major stumbling block for the project.

pre-Project – DOE HEP

- P5 to CDT (2015-17)
  - Cosmic Visions CMB-S4 Working Group
- CDT to Project (2017-19)
  - pre-Project Development Group (ANL, BNL, FNL, LBNL, SLAC)
  - Designated Point of Contact: Jim Yeck
  - Laboratory Directors' Council
  - Initial technology development funding ($1.5M in FY18)
  - IPA assignee: Drew Baden
- Bonus: CMB-S4 called out by name in Senate FY19 appropriations:

  "… the Committee urges the Department to support the P5 recommendation for a next-generation Stage 4 Cosmic Microwave Background experiment for precision studies of the early universe."

NSF/DOE Project Review Cycles

NSF Major Research Equipment & Facility Construction (MREFC)	DOE Construction Project
Conceptual Design Review (CDR)	CD-0: Mission need
Preliminary Design Review (PDR)	CD-1: Alternative selection & cost range
Final Design Review (FDR)	CD-2: Performance baseline
Start of construction	CD-3: Start of construction
	CD-4: Start of operations

- Starting the project requires both agencies be ready.
- If NSF requires Decadal Survey blessing then the project cannot start before 2021, by which time the next P5 review will be imminent, potentially delaying us to 2024.
- Then construction starts in 2030, operations in 2033, results by 2040!

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Recent Breakthrough! NSF will start us on the CD phase now, and use the Decadal Survey as the scientific review component of the PDR.

start

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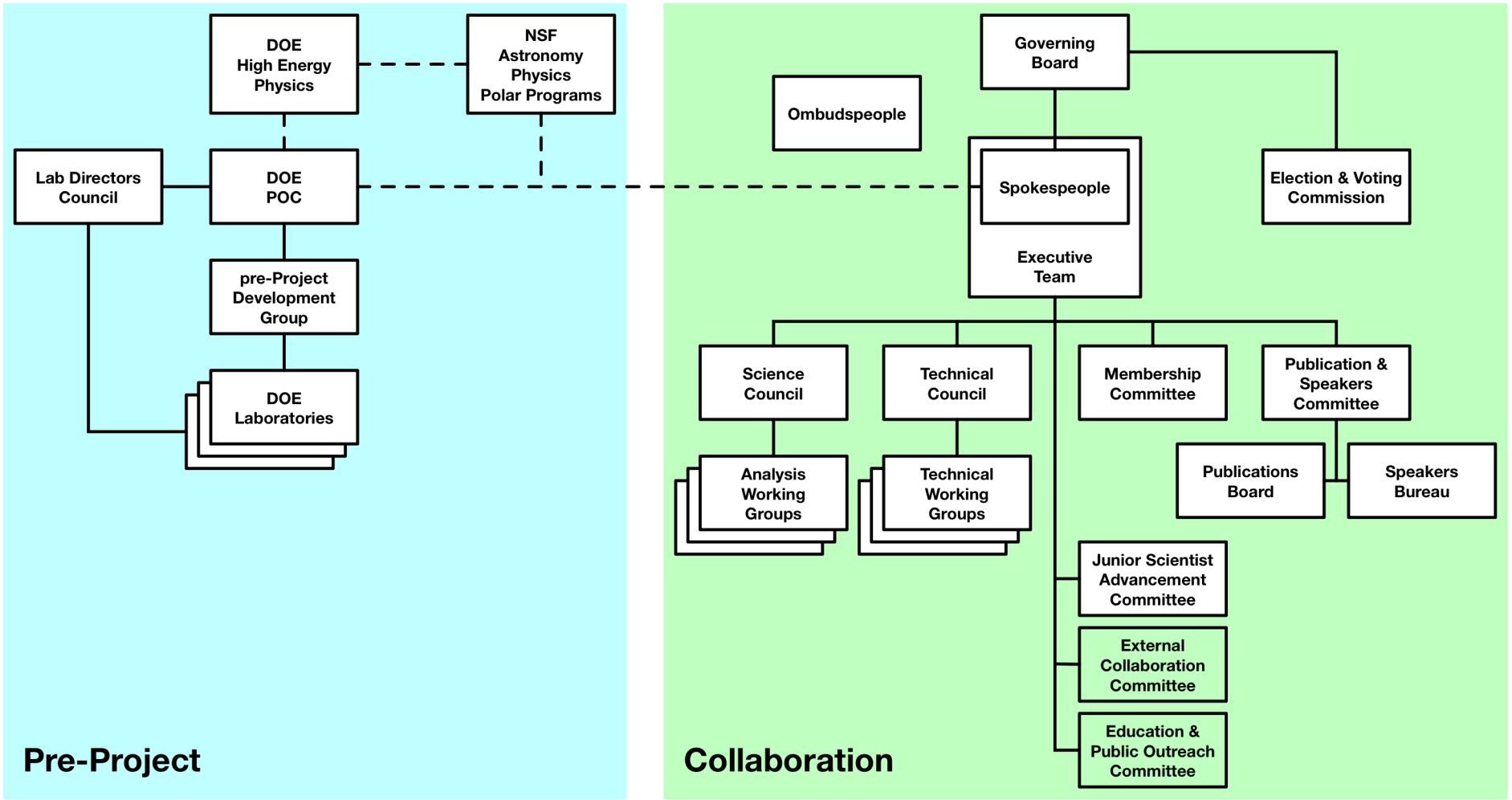
Nominal Project Schedule

Fiscal Year Quarter	Review Milestones
Q4 FY2018	R&D Proposal to DOE & CDR Proposal to NSF
Q2 FY2019	DOE CD-0 Approved
Q2 FY2019	Initial Input to the Decadal Survey
Q4 FY2019	NSF CDR Approved
Q2 FY2021	Decadal Survey Results
Q2 FY2021	NSF PDR and DOE CD-1 & CD-3A (Long Lead Construction) Approved
Q2 FY2022	NSF FDR and DOE CD-2 Approved
Q4 FY2023	DOE CD-3B Approved
Q4 FY2026	DOE CD-4 Approved
Q1 FY2027	Start of Operations

Pre-Project/Collaboration Org Chart



Next Steps

“Decadal Survey Report”

- Intended to meet the needs of CD-0, Decadal Survey & CDR:
  - Full science case (especially expanding astrophysics)
    - 8 analysis working groups
  - CATE-able reference design (reliable cost, high TRL)
    - 6 technical working groups
    - 6 x 2 project management/engineering experts (pPDG)
      - WBS, budget & schedule
  - Project management plan
  - Preliminary technically-limited schedule
  - Preliminary division of agency responsibilities

- Review scheduled for December 11-13th (Reichanadter & Ritz).

Working Groups

Technical

- Sites & Infrastructure
- Large Aperture Telescopes (including cryostats)
- Small Aperture Telescopes (including cryostats)
- Detectors & Readout
- DAQ & Control
- Data Management
- Integration & Commissioning

Analysis

- Primordial Gravitational Waves
- Primordial Density Perturbations
- Neutrino Mass
- Light Relics
- Dark Matter
- Dark Energy
- Galaxy Formation & Evolution
- Legacy Catalogs

(also: microwave transients, mm sky survey, etc)

Decadal Survey

- It is vital that the CMB in general, and CMB-S4 in particular, does well in the Decadal Survey:
  1. Outreach activities
     - Princeton meeting
     - Neutrino Theory Network workshop
     - AAS Special Session
  2. Community science white papers (due January 18th)
     - Not tied to any one project
     - CMB alone and cross-correlations/complementarities
  3. Ground/balloon/space complementarity white paper
  4. CMB-S4 project white paper (referencing above)
     + whatever additional material the committee then asks for.

Beyond The Decadal

- By early 2021 we must be ready for
  - CD-1 & PDR:
    - Complete down-selects for baseline design
      - DOE “conceptual”, NSF “preliminary”
  - CD-3a
    - Identify long-lead time construction items
      - Mature technically-limited schedule
      - Current suspects include detectors & large telescopes

- This will requires an intense, coordinated program of targeted technology development and design studies
  - Significant funding anticipated in FYs 19 & 20

European Engagement – Collaboration

- Membership:
  - 10 France, 3 Germany, 2 Italy, 2 Sweden, 6 UK = **23 Total**
  - https://cmb-s4.org/wiki/index.php/Main_Page#Membership
- Committees:
  - Bouchet [GB]; Baccigalupi, Gerbino [PB]
  - https://cmb-s4.org/wiki/index.php/Main_Page#Administration
- Working groups:
  - Alonso, Meerburg, Sherwin [SC]
  - https://cmb-s4.org/wiki/index.php/Science_Council
  - https://cmb-s4.org/wiki/index.php/Technical_Council
  - mailing lists: https://cmb-s4.org/mailman
- Community white papers:
  - https://zzz.physics.umn.edu/decadal2020/

European Engagement – Project

- Compete
  - Hard to justify to funding agencies.
  - There aren't enough of us in the world!
- Complement
  - Expand the breadth of CMB(-S4) science
  - Each experiment naturally stands alone
  - The whole is greater than the sum of the parts
    - eg. LiteBIRD dust channels + CMB-S4 delensing power
- Contribute
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  - Requires tight coordination & global optimization
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Coordinate

Discuss