Technology Development Evaluation Working Group

Aritoki Suzuki
Lawrence Berkeley National Laboratory

CMB-S4: ANL Meeting
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Since Harvard CMB-S4 Meeting…

- **CMB-S4 Technology Book submitted to arXiv**
  - Technology description
  - Maturity
  - R&D to make technology "S4 ready"
- **What should next report from the instrument group be?**
  - Document that evaluate which TDs are important for CMB-S4

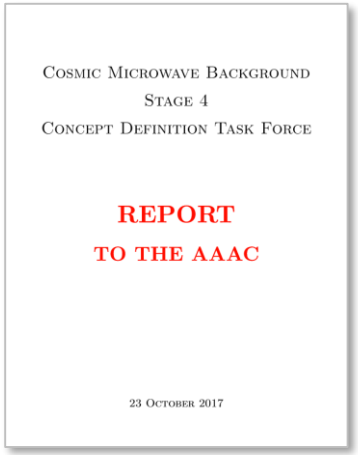

Table 3: Assessment of most significant project risks across subsystems. Risks are ordered from highest (top) to lowest (bottom). Pre-project investment is prioritized by risk and schedule.

Subsystem	Risk	Mitigation
Readout	Integrated performance (MUX factor, noise)	Develop multiple readout technologies with orthogonal technical risks, and downselect.
Detectors	Array production	Develop and validate processes, yield, and throughput at multiple fabs.
Data management	Simulations, especially those based on time-ordered data.	Develop simulation framework to evaluate instrument designs and systematics.
Optics	Half-wave plates and anti-reflection coatings	Demonstrate ETU of half-save plate and anti-reflection coating.
Cryostats	Complexity, cryogenics	Build Stage-3 prototypes; execute early designs and procurement.
Telescopes	Ground pickup	Early design and analysis of ground shields.

CDT's assessment of most significant project risks

CMB-S4 enthusiasts got together to evaluate TD.
We collected inputs from many experts from CMB community

Charge and Sub Group Organization

Charge:

In the first edition of the Technology Book, the experimental CMB community summarized the current state of CMB technology and evaluated its current technical readiness with a 5-level Technology Status Level (TSL) and manufacturing readiness with a 5-level Production Status Level (PSL). For each technology, we identified Technology Development (TD) efforts necessary to advance it for possible use in CMB-S4.

As a next step of the collaborative community wide effort, the CMB-S4 TD prioritization working group will **evaluate TD topics based on impacts they have on cost, schedule, and science return.** By the time of the Argonne meeting (March 2018) the working group will **produce a prioritized list of the TD topics that the community should pursue to ensure timely maturity of technologies that will enable the successful advancement of the project.**

We have grouped the relevant technologies into the following areas to tackle this immense task: Telescope and Site; Cryogenics, Cryostats and Optics; Detectors and Readout; and Data Management. Calibration of evaluation metrics across the subgroups is important for fair comparison of the TD topics. In addition, many TD topics are inter-dependent. To capture these ideas, the overall working group will communicate across all the subgroups in monthly combined group meetings.

The organization of subgroup is as follows:

- (CO) Cryogenics, cryostats and optics: Covers cryogenics (4K and mK), cryostats, windows, filters, lenses, HWP etc…
- (DM) Data management: DAQ, data transfer, simulation, analysis, publication, etc...
- (DR) Detector and readout: Detector (detector array and holder) and readout (warm/cold), etc...
- (TS) Telescope and site: Telescope, mount, site, power generation, etc...
- Combined telecon Discuss questions/topics that cut across multiple sub-groups

TD Topic Organization

A	B	C	D	E
Category	Sub-category	TD Topic	TD details	Short Description
Detector	Optical coupling	Feedhorn-standard		mature, spline-profiled design, NIST stacked Si array
		Feedhorn-advanced profile design		Improved optimization and complex non-circular geometries
		Feedhorn-dielectric feeds		Dielectrically-loaded feedhorns (increase bandwidth, improv
		Feedhorn-LF quadridge waveguide		Quadridge waveguide for LF horns. LF is only tenable band
		Feedhorn-improved coupling to microstrip		Better impedance matching between horn and microstric c
		Lenslet Number of AR Coating		Study number of layer coating that's necessary

F	G	H	I	J	K	L	M
				Impact			
Point(s) of contact	Baseline / TD goal reference	Baseline	TD Goal	Cost Reduction [$k]	Schedule [1-5]	Science (Stat) [1-5]	Science (Sys) [1-5]
Sara Simon	N/A	NIST Feed stack	Baseline	0	1	1	1
Sara Simon		depends on band and optics	improved sensitivity (5%) and sy	0	1	2	4
Sara Simon	S4 technology book	2.3:1 bandwidth	3:1 bandwidth, improved sensitivi	0	1	3	4
Sara Simon	S4 technology book	2.3:1 bandwidth	3.5:1 bandwidth (more developm	0	1	4	1
Sara Simon	simulations of CPW-MS transmissi	percent level loss	sub percent level loss? Need inp	0	1	2	1
Toki Suzuki, Shawn Beckman	2-layer AR for 90/150 --> 1-layer 90	2-layer to cover 90/150	1-layer to cover 90/150	900	4	4	1

N	O	P	Q
TD			Explanation
Target Completion Date [Yr]	Estimated Investment [$k]	Likelihood of Success [%]	Explanation slide template
18	0	5	
19	1 FTE for design	4	
20	1 FTE for design (can be s	3	
20	~$200k: 1 FTE for design,	3	
19	1 FTE for design	5	
18	10	3	

- **Technology development topic as entry**
- **Evaluated impact of each technology development**
  - Production cost
  - Construction schedule
  - Science impact (statistical)
  - Science impact (systematics)
- **Target completion date, investment, likelihood of success**
  - Target completion date – plan with S4 schedule in mind
  - Estimated investment
  - Likelihood of success – Made estimate with given time & investment

- **Identified topics to cover and experts during weekly meetings**
  - sub-group leads contacted experts to fill out entries

Evaluation Metric

		EXAMPLE: meaning of Schedule, baseline and TD goal columns
		Evaluation slide template
Cost [$K]		**Cost saving on fixed configuration (for example, using different detector fabrication method but producing same # of wafers)**
Schedule		**Saving on construction time (NOT observation time, we'll cover observation time in science stat)**
	1	No impact, no improvement
	2	few month
	3	0.5 year
	4	1 year
	5	2 year+
Science Stat		**Improvement on mapping speed for fixed cost**
	1	0%
	2	5%
	3	10%
	4	25%
	5	50%
Science Sys		**More value should be given to TD that will let us mitigate known major systematics uncertainty. Also more value should be given to mitigation method that cannot be mitigated with different method**
	1	No impact on systematics (for ex, improving test dewar's cool down time)
	2	Mitigation for systematics that may become important but not fully proven. Maybe good mitigation method, but systematics maybe able to be removed using other method
	3	Mitigation for systematics that may become important but not fully proven. TD addresses most effective way to remove this systematics
	4	Mitigation for known important systematics. TD addresses most effective way to remove this systematics
	5	Mitigate for major known systematics of the CMB experiment that cannot be removed with other method
Target Completion Date [Yr]		**Please think how TD's outcome fits with CMB-S4's schedule need (what's required for mission need, design, start of construction etc...) See strawperson schedule from the CDT**
	FY18-FY19	Pre-Project Development
	FY20-FY22	Design
	FY23-FY25	Construction
	FY25-FY26	Integration and Comissioning
	FY27-FY33	Operations
Estimated Investment [$K]		**Should consult expert on TD guestimate. Should include FTE in $$ as well inaddition to M&S**
Likelihood of Success [%]		**Likelihood of success of TD given allocated schedule and budget from previous columns**
	1	10% - Just an idea, not sure if it will work or not
	2	25% - Some concept developed. In general it is good idea, but development path is not clear
	3	50% - Concept is developed. Develop path is mostly figured out. Some unknowns in development path until some TD
	4	75% - Development path is well defined. Need demonstration of some critical steps
	5	100% - Development path and outcome is obvious. Simply requires demonstration to show that it works.

We came up with common evaluation metric as the working group

Reference…Schedule… Additional Assumptions

We needed references to evaluate impacts of technology developments

Table 2: Instrument configuration satisfying the measurement requirements.

Science	Item	Frequency [GHz] 20	30	40	85	95	145	155	220	270	Total
r	**14 x 0.5-m cameras**										
	# detectors	...	260	470	17 k	21 k	18 k	21 k	34 k	54 k	168 k
	Angular resolution [FWHM]		77′	58′	27′	24′	16′	15′	11′	8.′5	
	1 x 6-m telescope										
	# detectors	130	250	500	...	25 k	25 k	...	8.7 k	8.7 k	68 k
	Angular resolution [FWHM]	11′	7.′0	5.′2	...	2.′2	1.′4	...	1.′0	0.′8	
$N_{\rm eff}$											
	2 x 6-m telescopes										
	# detectors	290	640	1.1 k	...	50 k	50 k	...	17 k	17 k	136 k
	Angular resolution [FWHM]	11′	7.′0	5.′2	...	2.′2	1.′4	...	1.′0	0.′8	

- **Started out with parameters available from the CDT report**
  - 3x 6-m telescope, 14x 0.5-m cameras
  - 400k detectors
  - 20 GHz to 270 GHz

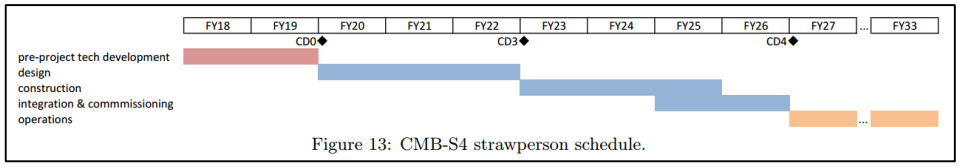

Figure 13: CMB-S4 strawperson schedule.

- **Assumed schedule given in CDT**
  - Used to come up with target TD completion date
  - For ex. DM group - Mapping degree of instrument/simulation refinement required at various stages of development

C	D	F	G
Topic		Baseline	Baseline Reference
TD Topic	TD details		
Fabrication	production rate, reliability, maximum size, uncertainty in dielectric constant.	1 lens/ 1 weeks, Si < 450 mm, Alumina < 800 mm, 6month lead time	650 mm - BICEP3 (Coorstek);
Performance	AR performance, in-band loss, reflection	Si groove (< 0.2% for octave bandwidth)	Si/AdvACT lenses

- **For design parameters that were not defined in the CDT, TD group made assumptions through weekly discussions.**

Progress, Next Step

Thank you for your contributions!

Progress we made

- Sub-groups identified important TDs
  - Production rate
  - Systematics
  - Timely refinement of simulation
- Detailed reports from each sub-groups in following presentations

Next Step

- CMB-S4 community is putting together Decadal Concept Design Report (CDR)
  - Many scientists worked on TD evaluation will play key role in putting together this document

- **Technology book** will be useful to come up with reference design
- **TD evaluation table** will be useful to evaluate options that are available to realize/exceed reference design