CMB-S4 Technology Development — progress since the Harvard workshop

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In August 2017 at the end of the workshop..

- Identified that next steps after Technology book were:
  - A CMB-S4 development (R&D) program with priorities
  - Feeding this as input to the agencies to guide their decisions about how to fund pre-project development
  - Due ~now to feed into FY20 budget process
- We decided to start a community process for assessing our technology development priorities
- In parallel, the CDT was charged with developing the straw person concept for CMB-S4, *and also* assess and provide technology development priorities to the agencies
- In parallel parallel, CMB scientists from ANL, FNAL, LBNL and SLAC were working to assess, prioritize and synergies their own activities to best serve CMB-S4 development

What happened next..

- The CDT had an earlier deadline (October 2017)
  - Community process was slowly getting under way
  - DOE Labs process had made some progress
- The CDT asked the DOE labs to help with technology development prioritization
  - Brad Benson and I took on the challenge of coming up with a prioritized R&D plan backed with some quantitative assessment.
  - Provide this to the CDT to assess and decide what they agreed with and formally recommend in their report.
- Note that this was part of the CDT mandate, and is a separate assessment from the community process.

Analysis scheme we used

- Take CDT straw person as a reference or baseline (Detector counts, # of cameras etc). Add a few details to fill in blanks as necessary
- Evaluate COST, SCHEDULE and PERFORMANCE risks to the implementation of that plan

Definition of Risk Probability

Pts	Likelihood of Occurrence	Approximate Probability	Descripton of Probability
1	Rare	< 1%	Likelihood of occurrence is not credible
2	Unlikely	1-10%	Not reasonably expected to occur
3	Possible	10-25%	Possible, or difficult to assess the chance of occurrence
4	Likely	25-67%	Very likely that an adverse event will occur
5	Highly Probable	> 67%	High probability that an adverse event will come to pass

Definition of Risk Impact

Pts	Severity of Impact	Descripton of Impact
Cost Impact		
1	Insignificant	Overrun of cost of < $50K, recoverable with project contingency
2	Minor	Overrun of cost of $50k - $250K, recoverable with project contingency
3	Moderate	Overrun of cost of 250K - $1M, with significant impact on contingency
4	High	Overrun of baseline cost of $1M - $5M, with re baseline required
5	Critical	Overrun of baseline cost of >$5M, with project in jeopardy
Schedule Impact: Delay **in meeting baseline milestone date for the completion of your sub-system or** entire project		
1	Insignificant	System manager handles risk within his plan and does not impact his L4 (subsystem) milestones
2	Minor	Does not impact project critical path, but delays L4 (subsystem) milestones
3	Moderate	Impacts project critical path which results in a delay of 1 month
4	High	Impacts project critical path which results in a delay of 3 month
5	Critical	Impacts project critical path which results in a delay of 6 months
Performance Impact		
1	Insignificant	No effect on ability to meet requirements; minor design changes needed
2	Minor	Minor excursion from subsystem requirement, but compensated elsewhere
3	Moderate	Level 2 and/or Science Requirement Document (SRD) design specification exceeded
4	High	Level 1 and/or SRD minimum specification exceeded
5	Critical	Unable to achieve any of the primary science missions

Risk Score						
Total Impact	5	5	10	15	20	25
	4	4	8	12	16	20
	3	3	6	9	12	15
	2	2	4	6	8	10
	1	1	2	3	4	5
		1	2	3	4	5
		Risk Probability				

Risk Level
Critical
High
Moderate
Minor
Insignificant

→Objective qualitative process to assign values to probability of occurrence and impact of occurrence aspects of risk.

→Total Impact:
(0.33*Cost Impact) +
(0.33*Schedule Impact) +
(0.33*Performance Impact)

→Risk Score:
Risk Probability * Total Impact

Summary of CMB-S4 Project Risks Across Sub-Systems

Sub-System	Highest Risk in Sub-System	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	Develop simulation framework to evaluate instrument designs and systematics.
Optics	Half-wave plate, AR coating	ETU of half-wave plate and anti-reflection coating.
Cryostat	Complexity, Cryogenics	Stage-3 prototypes, early design and procurement.
Telescope	Ground pickup	Insufficient ground shielding causes significant systematic uncertainty.

Begin funding immediately to help burn-down risk

Presented to CDT and used in their report

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.

Next..

- Rely on community process to flesh this out in full detail
- Make adjustments to metrics as necessary.
- Consider not just risk, but opportunities more broadly
- Details in upcoming talks.