CMB-S4 Integration & Commissioning Plan for Small Aperture Telescope System

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Scope and Assumptions

- CMBS4-doc-729 (comments welcome)

- The plan is currently written on a per-SAT basis. (It does not include schedule considerations such as e.g. staggering tasks for parallel I&C of several SATs.)

- The plan was written with the environmental and logistical constraints of the South Pole in mind. It is otherwise relatively agnostic to the details of site & support facilities and could be generalized to encompass the Chile site.

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Describes the state of readiness of each SAT subsystem before handoff to I&C at the site.

(More in the following slides.)

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This is the “guts” of the document. Content is based on experience with third-generation receivers, especially 2019-20 BICEP Array deployment.

(More in the following slides.)

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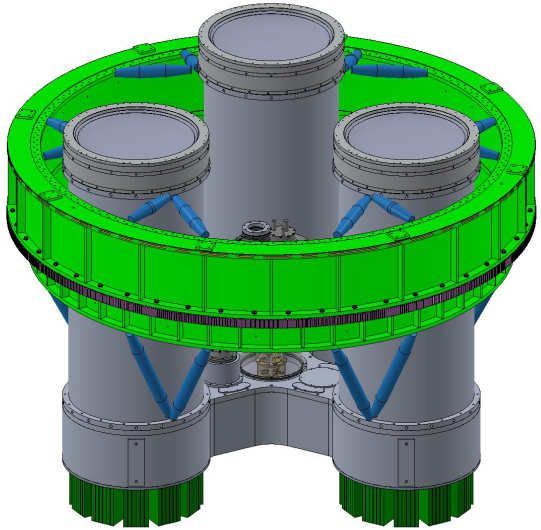
This shows an example task-based schedule for I&C of a SAT receiver at the Pole. The goal is primarily to demonstrate how activities can fit within an austral summer season.

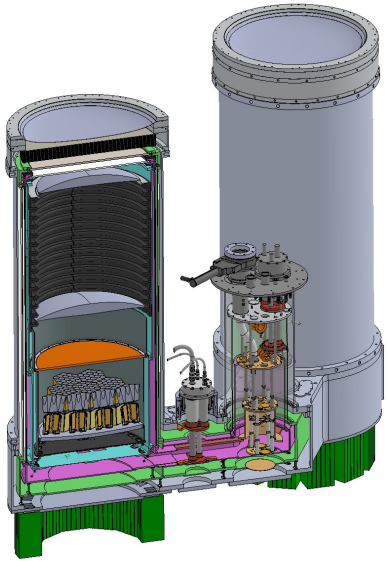
Background Information: SAT Receiver Features Critical For I&C

- SAT receiver = 3 optical tubes mounted on a single cryo bus.
- Each receiver has 1 dilution refrigerator + 3 pulse tubes with associated helium compressors.
- For each tube (~70 cm in diameter), a series of nesting cylindrical shells provide an ambient-temperature vacuum barrier, radiative and magnetic shielding at 40 K and 4 K, and house the optical elements.



Receiver envelope:

- Height 2.2 m
- Diameter 2.7 m
- Mass 1,800 kg



Cutaway of individual optical tube and common dilution refrigerator.

Prerequisites: Overview

- SAT Receiver Testing
  - Cryogenics
  - Thermal and Vacuum-Cycling Survival
  - Detector and Readout Characterization
  - Diagnostics
- Subsystems Integration
  - Testing in North America
    - Mount Mechanical Capabilities for I&C Support
    - Mount and Receiver Integration
  - Subsystem Testing On-site Prior to I&C Activities
    - Telescope Mount
    - DAQ and DM
    - Calibration Hardware
- Facilities

Prerequisites: Overview

- SAT Receiver Testing
  - Cryogenics
  - Thermal and Vacuum-Cycling Survival

Example excerpt:

4.1.1 Cryogenics

- Pumpout procedure, duration and target pressure before cooldown.
- Cooldown times, gradients and base temperatures in different configurations. Cooldown duration to satisfy requirements. (See Jama External ID SAT-CRYO-0250 - Cooldown time, currently TBD.)
- Load curves for pulse tube coolers and dilution refrigerator.
- Verification that the dilution refrigerator cooling capacity can sustain the increased load of operations on the calibration transition during commissioning tests and calibration campaigns. (See Jama External ID SAT-CRYO-0180 - 100 mK Cooling.)
- Thermal performance of heat straps, readout cables, multi-layer insulation.
- Characterization of the thermal loading on each stage (optical vs. instrumental) and infrared filtering scheme.
- Verification of the temperature sensor calibration and housekeeping system.

4.1.2 Thermal and Vacuum-Cycling Survival

The integrity of the following subsystems will be verified over the course of at least 10 (TBC) thermal and vacuum cycles:

- Leak-checks of vacuum jacket and window interfaces.
- Anti-reflective coatings, including edge filters.
- RT-MLI stack filter compression.
- Vacuum window deflection and stresses at mounting interfaces.

I&C Phases:

- Preparatory Work
- Receiver Assembly
- Receiver Cooldown
- Ground Commissioning Tests
- Receiver/Mount Integration
- Integrated Commissioning

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A general description of the assembly and integration steps is provided; detailed procedures will be defined separately with the SAT group.

I&C Phases:

- Preparatory Work
- Receiver Assembly
- Receiver Cooldown
- Ground Commissioning Tests
- Receiver/Mount Integration
- Integrated Commissioning

These sections describe the verification process for the receiver prior and after integration with the mount.

Each test's subsection follows the same structure. →

Example excerpt:

5.6.7 Optical Performance: Far-Field

5.6.7.1 Goals

5.6.7.1.1 Acquire basic beam parameters for each detector. A beam width measurement is required in order to enable instrument verification through CMB map-making. The measurement requirements for a full systematics analysis are outside the scope of the present Integration & Commissioning Plan. Here we will conduct 1 measurement of the beam parameters for each detector at a single boresight angle.

5.6.7.1.2 Related requirement: CMBS4-L3-592

5.6.7.2 Description

5.6.7.2.1 Remove forebaffle; install Far-Field Flat (FFF) mirror; install calibration source.

5.6.7.2.2 Far-field beam maps will be acquired by rastering the telescope over a chopped thermal source mounted in the far-field. The FFF mirror position will have to be adjusted over the course of the observation campaign in order to allow coverage of every detector in the focal plane. This measurement is carried out in the high-temperature TES transition (not the science transition). Consult Section 3.6.6 of RD1 for details.

5.6.7.3 Prerequisites

5.6.7.3.1 Fully integrated system: detectors and readout optimized for operations; data acquisition and telescope motion integrated with OCS.

5.6.7.4 Resources

5.6.7.4.1 Hardware: Far-Field flat mirror; large chopped thermal source in the far-field.

5.6.7.4.2 Software: Dedicated data acquisition and analysis scripts.

5.6.7.4.3 On-site expertise: calibration / systematics.

5.6.7.4.4 Duration: TBC (driven by detector counts at each frequency and FFF mirror size)

Summary

- **Purpose**:
  - Describe the state of the SAT system prior to the beginning on on-site I&C.
  - Describe the I&C process for each SA system.
  - Describe the detailed task-based schedule for the I&C process.
  - Provide a starting point for defining the transition from Commissioning to Operations.
- **Status**:
  - This documented version of the SAT I&C process has been developed over the last year with input primarily from the Sites and SAT WG.
  - The plan in this document reflects the most current SAT receiver design and plans for Integration & Testing in North America.
  - On track for approval by the Change Control Board this month.