CMB-S4

South Pole Site - SAT Interface Control Document

CMBS4-doc-348-v5

Draft

Document release signatures

Prepared by:		
Names(s) and Signature(s)	**Role/Organization**	**Date**
John Kovac Akito Kusaka Benjamin Schmitt Amy Bender Erik Nichols Marion Dierickx	SAT L2 Scientist SAT L2 team SAT L2 team South Pole L2 Scientist South Pole L2 CAM South Pole L3 SAT I&C	30 April 2021
Approved by:		
Names(s) and Signature(s)	**Role/Organization**	**Date**
Approved by:		
Names(s) and Signature(s)	**Role/Organization**	**Date**

REVISION HISTORY

Version Letter	Revision Date	Author: Notes
v1	6/26/20	Initial draft
v2	5/4/21	Filling in details
v3	11/2/21	More details and identified interface features
v4	1/28/2022	Added shipping, refined cargo path interfaces
v5	7/17/2023	Significant scope definitions and technical details.

REFERENCED & APPLICABLE DOCUMENTS

The requirements in the following documents apply, but this document supersedes if there is a conflict.

Reference used within this doc	Version	Title & Description	Notes, relevant part of document
CMBS4-doc-889	v0	BART (SAT tower) Design	

TABLE OF CONTENTS

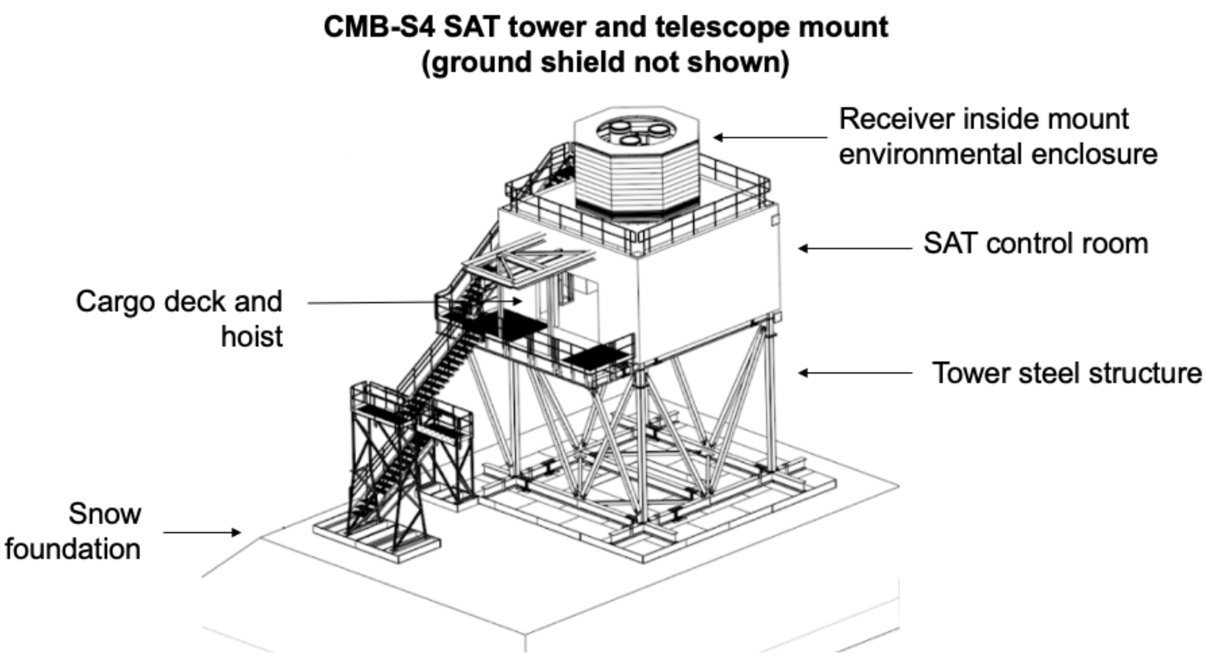
1. Purpose and Scope

This document defines and describes the interfaces between the South Pole Site and the SAT system. The SAT system consists of the SAT telescope mount with cryostat installed, the SAT ground shield, and SAT ancillary equipment. The mount and shield are to be installed atop a structural tower provided by the South Pole Site. The ancillary equipment is to be housed in an indoor facility provided by the South Pole Site.

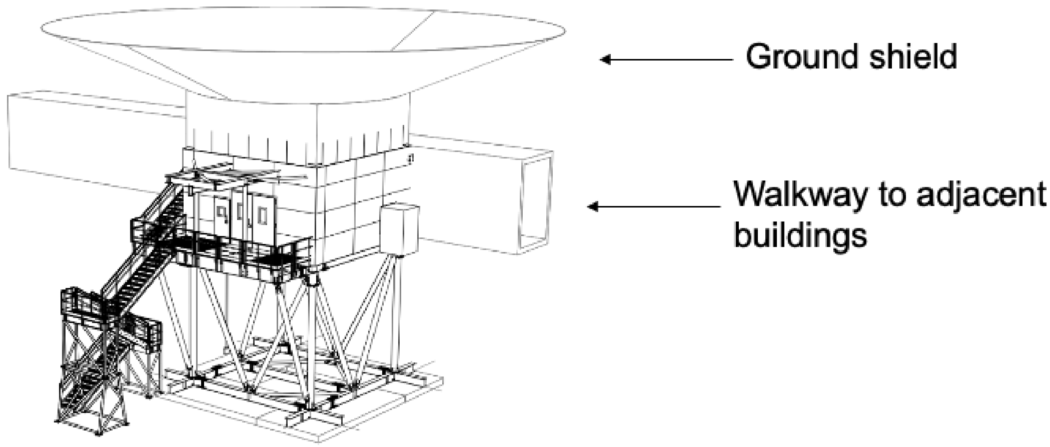
The scope of work to be performed by the Sites group includes:

- Infrastructure such as: laboratory support building, ice pad, wood raft footer, tower, control room. This includes external interfaces and fitout of utilities including cranes, hoists, electrical, cooling loop, heating, fire detection, monitoring, data.
- On-site assembly and commissioning of the telescopes.

The scope of work from the SAT group includes: ground shield, telescope mount, receivers, calibration equipment (including the masts), tower roof-level jib crane, and their delivery to Port Hueneme.



CMB-S4 SAT tower with conceptual ground shield and walkway attachment



2. Abbreviations and Definitions

2.2 Acronyms

Acronym	Full text
DAQ	Data Acquisition
DM	Data Management
DR	Dilution Refrigerator
PTH	Port Hueneme
SAT	Small Aperture Telescope
UHP	Ultra High Purity
OCS	Observatory Control System
UPS	Uninterruptible Power Supply

2.2 Definitions

Term	Definition
Site	Interchangeable with “South Pole Site” within this document.

3. Location of structures

3.1 Location of Telescopes in Relation to Other Structures

SAT Clear View (SP-SAT-001): Each SAT shall have no permanent structures visible within 2 degrees above the upper rim of the ground shield. (see diag xxx)

SAT Tower Minimum Separation (SP-SAT-002): The distance between the central axes of the SAT tower shall be located a minimum of XX m [TBD] apart to prevent conflict between ground shields.

4. Mechanical/Structural Interfaces

4.1 SAT subsystems specifications

This section is intended to serve as a centralized location to capture some key numbers relevant to many of the interfaces further below in the document. See Section 9 “Integration and Commissioning” for detailed interfaces between the receiver design and support infrastructure (doorways, space, hoists).
SAT tower design reference: **CMBS4-doc-889**

SAT receiver subsystem weights:

- Maximum cryobus weight (integrated portion sent shipped) is 618 kg.
- Estimated cryobus + focal plane + interior readout weight is 753 kg.
- Estimated cryobus + focal plane + interior readout + exterior readout + 3 optics tubes + DR gas handling system (using Janis estimate) is 2375 kg.
- Maximum integrated SAT receiver is 3000 kg (for both floor ratings & hoist requirements). Includes ancillary equipment.
- Reference for current best estimates: **CMBS4-doc-897**

SAT receiver physical envelope:

- SAT receiver cryobus: 2.78 m (diameter) x 2.5 m (height)
- SAT receiver cryobus + exterior readout (included in previous): 2.78 m (diameter) x 2.5 m (height)
- SAT receiver cryobus + all interior + optics tubes + exterior readout L x W x H will not exceed a cylinder with 2.78 m (diameter) x 2.5 m (height). (see SAT receiver-mount L3 ICD: SAT Mount - SAT Cryostat ICD)
- Maximum width required for SAT receiver/cryobus to pass through a space is 2.44 m.

SAT receiver mobility:

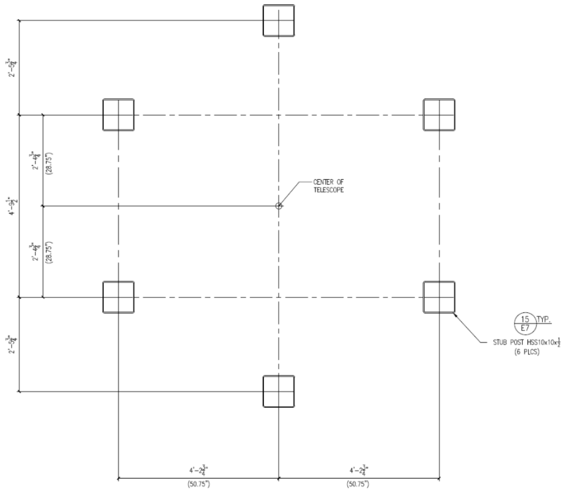
- SAT receiver support and mobility structure will weigh no more than 500 kg.
- Support brackets will be mounted on quantity X casters [TBC] each of diameter XX [TBC] of material X [TBC]
- Support structure will have a physical envelope not to exceed 2.5 m (height) x 2.44 m (maximum width requirement).

4.2. Structural Support for SAT Telescope Mount and Ground Shield

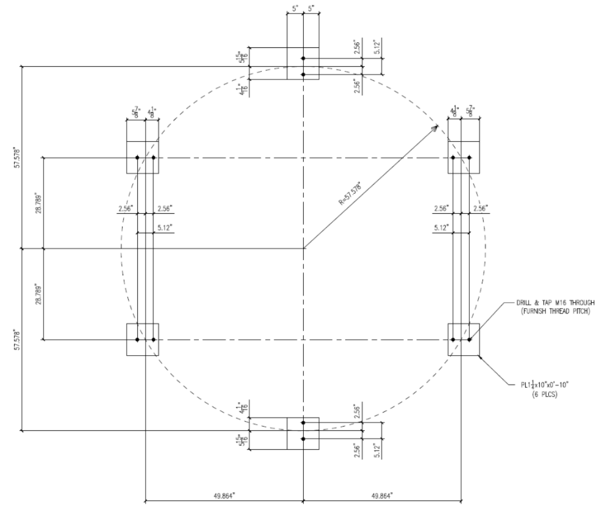
4.2.1 Telescope mount

The tower shall provide six support points for the Fixator adjusters. The mechanical interface between the SAT Telescope Mount and the Site is where the tower roof-level steel supports the six mount fixators. These are spaced as shown in the diagram below.

Mount support point plan:



HSS TELESCOPE SUPPORT POSTS ENLARGED PLAN
(DIMENSIONS ARE TO CENTERLINE OF HSS10x10 STUBS)



TELESCOPE SUPPORT MOUNTING HOLES PLAN

Collectively these 6 support points should be capable of supporting the mount and receiver mass. The mount weight without the receiver is 18,230 kg. The current estimate for receiver weight is 3000 kg. Mount and receiver mass are documented in {BA/SAT mount mass table/insert docDB number}.

The 6 support points shall be within X mm of the horizontal plane upon initial construction. This plane will not change by more than 0.5 degrees over a 10 year period.

The upper surface of the tower roof shall provide a flat surface to which the brush seal mounts at a height of X+/-Y inches above the plane of the Fixator support pads.

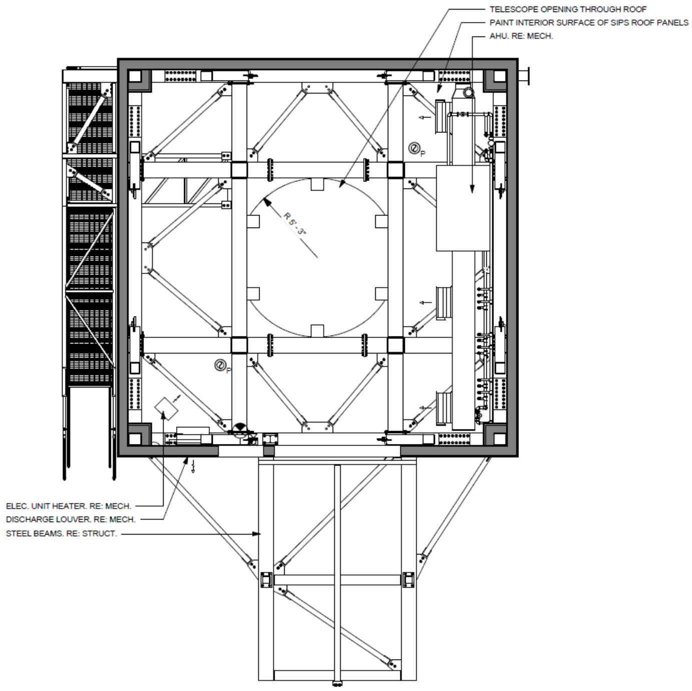
When subjected to max mount az torque (about vertical axis) of 10,000 newton-meters, the six support points shall deflect such that the mount pointing changes by less than 15 arcsec.

When subjected to max mount el torque (about horizontal axis) of 5,000 newton-meters the six support points shall deflect such that the mount pointing changes by less than 15 arcsec.

When the tower+shield are subjected to max wind load of 40m/s (L1 environments requirement SYS-PRJ-030) it shall cause the SAT pointing to deflect by less than 60 arcsec.

Natural frequency of oscillation of the integrated SAT tower facility shall be higher than XX Hz in any mode.

There shall be a clear volume inside the circle enclosed by the 6 support points, extending to the floor of the compressor room below.



The volume on the underside of the compressor room ceiling shall be kept clear to accommodate the winches and transfer pulleys required to raise the SAT cryostat into the mount. (This is vague but can't really become more concrete without resources to move the notional design forward.)

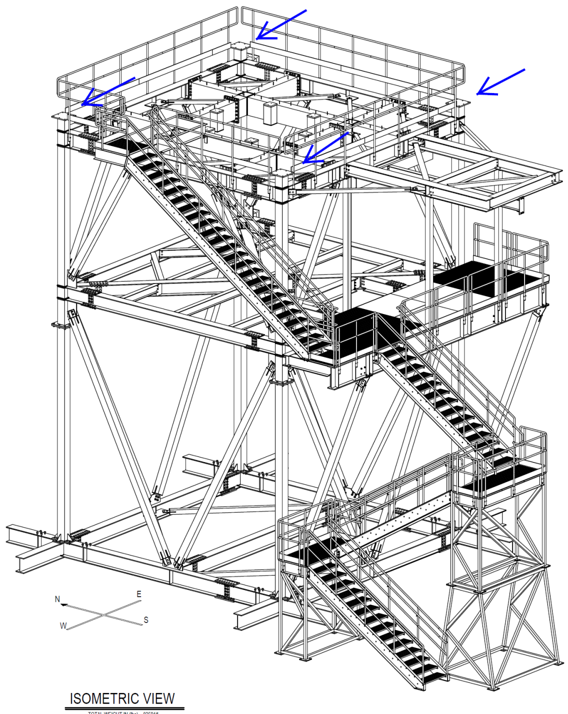
4.2.2 Ground shield

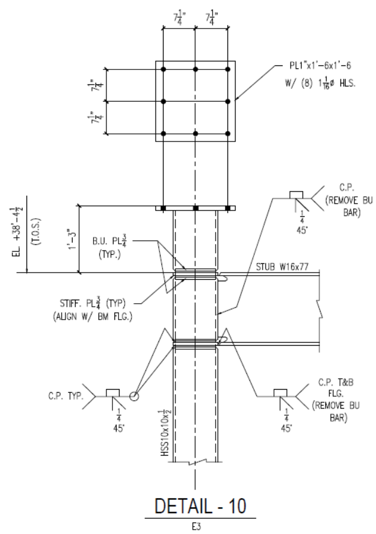
The ground shield assembly is mounted independently from the telescope mount to the top of the tower. The ground shield footprint is entirely outside that of the telescope mount.

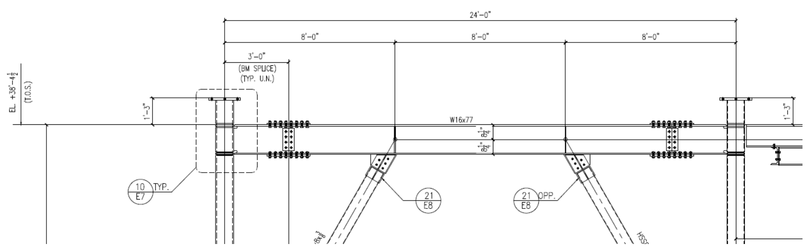
Basic specifications (to avoid overturning of the ground shield and tower), as driven by the design of the tower with notional ground shield parameters in mind, pending further structural design of ground shield variants:

- The SAT ground shield weight shall be greater than 34,091 kg (75,000 lb).
- The SAT ground shield weight shall not exceed 38,636 kg (85,000 lbs).
- Maximum SAT ground shield area exposed to wind is assumed to be 100 m^2 at a center of wind pressure at 16.2 m above snow.

Location of mounting points for ground shield atop telescope tower:







Details:

- Bolt specs
- Nearby obstructions (optical and mechanical interference)
- Construction tolerances (levelness, flatness)
- Supported mass, cg location (partially for hoisting purposes)
- Bounding dimensions of ground shield assembly.
- Mechanical mounting points for crane lift of the ground shield.

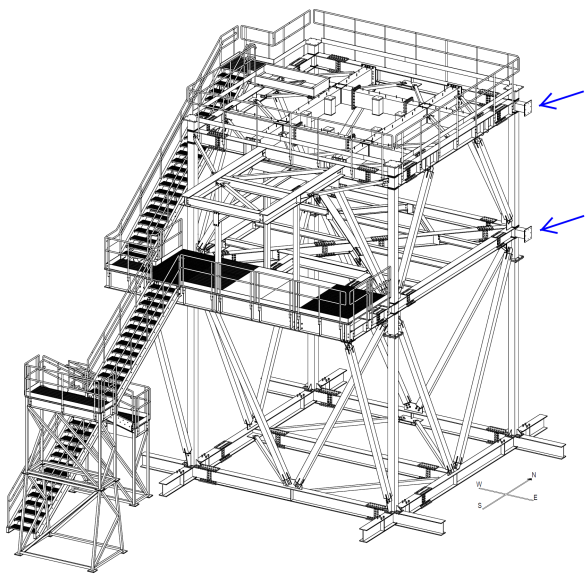
Ground shield-walkway interface:
The geometries of the ground shield (SAT responsibility) and of the walkways between buildings (Site responsibility) must be compatible. This requirement places design constraints (TBD) on the placement, height, and geometry of the walkways and ground shield.

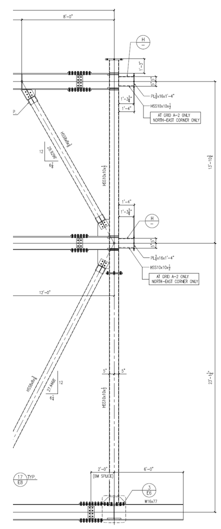
Ground shield jib crane:
Jib crane mount points are specified below; however, load case is notional and structural analysis of tower mounting points will be re-analyzed when defined. The crane storage location must be out of sight from the telescope (satisfy standard ‘double diffraction’ criterion as seen from the telescope windows) such that it does not require disassembly after use.

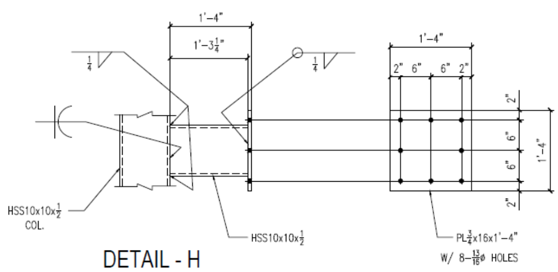
Details:

- Hoist capacity
- Height

- Mechanical interface to control room side
- Location within ground shield
- Ground shield door for transfer of equipment at roof level: size of aperture, opening/closing mechanism







4.2.3 Tower loading

Net forces and moments in all axes as a result of worst-case loading scenarios during integration and in-service. Includes torques on base for integrated tower + control room + mount/receiver load + ground shield under full range of wind & thermal conditions; and torques due to mount motion.

Loading conditions:

- Installation process of both mount and shield
- Dead weight loads, cg locations
- Variation of cg location during assembly and in different in-service orientations (if telescope is not balanced about its movement axes).
- Maintenance loads
- Cargo hoist with load
- Ground shield job crane with load
- Wind loads
- Snow/ice loads

Tower height will be designed for nominal South Pole snow accumulation, assuming 20.3 cm/year of drift accumulation. Locations of telescopes and infrastructure should be planned for predominant wind direction downwind drifting (should include other dark sector facility impacts).

4.2.4 Ice pad

Ice pad density will be verified to meet or exceed 0.55 kg/m^3 to support the combined loads of the SAT tower SAT control room, SAT ground shield, SAT receiver, ancillary equipment in control room, and humans (dead loads, live loads, wind, snow loads). Reactions at footer: max compression: 63,117 kg (139,150 lbs); max shear: 28,576 kg (63,000 lbs); max overturning moment: 5017 kN-m (3,700,000 pound feet); max uplift: 23,360 kg (51,500 lbs).

Ice pad area will be 21.34m by 27.43m to accommodate the SAT tower.

4.3 SAT Control Room

4.3.1 Floor rating

Floor will be able to support a fully integrated SAT receiver (< 3000kg) on an area of 2.44 m x 2.44m, with point loads to be defined per receiver cart design. See Section 3.0.3 for specifications of SAT receiver and receiver mobility.

4.3.2 Door Sizes

Exterior door for cargo allows 2.44m x 2.44m clear opening.

Interior door connected to the walkway should be capable of moving a full receiver through (2.44-2.78m wide x 2.5-3m tall [TBC]).

Interior doors will be compliant with fire code and not blocked with equipment, but will be able to remain open during I&C to increase workspace area into walkway.

4.3.3 Floor space allocation

Total control room floor space of 58.1 sq m (625 sq ft). Space will be allocated for the following permanent items:

- Air handler/ HVAC system, including pumps for glycol loop (Site responsibility)
- Electrical panel keep out zone and UPS (Site responsibility)
- Helium compressors
- One standard electronics rack (Site responsibility)
- One desk with computer workstation (Site responsibility)
- One freestanding large toolbox (Site responsibility)

Floor space in the control room will also be allocated within this footprint for a single SAT receiver in the center of the room, with enough clear space to access each optics tube from a mount hoisting point for radiation shield installation. Additionally, space will be occupied by a small number of active workers (assumed to <=6) and 2-3 ladders. Finally, floor space will be used for staging a small number of cryostat parts (e.g., 2-3 radiation shell pieces that are immediately next in the assembly process).

Other preparation and assembly work will be performed using a heated location outside the SAT control room. This can be either in a separate building (e.g. MAPO), the connecting walkway, or elsewhere. These additional activities include:

- Cargo receipt and unpacking
- Cleaning, preparation, pre-assembly of parts for installation
- Electrical prep and checks on detector modules and readout components

- Preparation of calibration equipment

This space is required and its final configuration with respect to the SAT control room will impact both project risk and schedule.

Storage of additional tools, equipment, chemicals, and spare parts (excluding spare compressors) will be in a heated location outside of the SAT tower.

4.3.4 Walkway connection

An enclosed, temperature-controlled walkway will connect each SAT tower to the laboratory support building.

Walkways will be in the 'North configuration' (see confluence page: SAT+--+Support+Building+Walkways).

Height of walkways will be configured such that the floor level of the SAT tower and walkway are continuous with no vertical change.

Roof of walkway will also connect support building to SAT tower roof, with an additional low-grade ramp (preferred) or step to bridge any vertical gaps to the tower roof level.

4.4 Cable Routing

4.4.1 Cable Tray Routing Drawing

Define cable routing from SAT structure to the distribution panel that interacts with the site.
Drawing showing spatial envelope available for cable routing.

4.4.2 Connection Points to SAT Structure

4.4.3 Cable Tray to SAT Structure Connection Detail

5. Electrical Power Interfaces

Interface between site and SAT shall be at:

- Any outlets that are distributed directly from the main electrical panel in each SAT control room (or a subsequent breaker box).
- Any connections to equipment (not building facility) that are hardwired to a breaker box.
- Uninterruptible power supply (UPS) output breaker panel in SAT control room.
- Outlets provided as part of the MAPO/Lab building fit out.

5.1 Main Three-phase and Single-phase Power interfaces

5.1.1 Telescope Main Electrical Distribution Panel

Electrical connection details/ drawing of panel layout.
Circuit definitions of all (non-UPS) circuits.

5.1.2 Overall power

Each SAT telescope, including drive motors, helium compressors, readout electronics, ancillary readout (like thermometry) shall have an average power draw of ~31 kW and a maximum power draw of ~39 kW [TBC]. as documented in the CMB-S4 Electrical Power Budget, DocDB-873..

5.1.3 Helium Compressor Outlets

Each helium compressor will be placed on its own dedicated breaker.

Each PT410 with CP2880 [TBC] will be supplied with input 3-phase power of 208/230 VAC 60 Hz on a 40 A dedicated breaker. Outlet will be receptacle NEMA L15-50 [TBC] twist lock.
OR [TBC]
The CP2880 will be supplied with input 3 phase power of 440/480 VAC 60 Hz on a 25 A dedicated breaker. Outlet will be receptacle: NEMA L16-30R [TBC] twist lock.

Each DR gas handling system [model? TBD] will be supplied with single phase power of 220VAC 60 Hz on a 20 A [TBC] dedicated breaker. Outlet will be receptacle NEMA L6-20R [TBC].

Each SAT control room shall have XX drops for PT410, XX drops for DR gas handling.

The MAPO building shall each have XX drops for PT410, XX drops for DR gas handling.

5.1.4 Additional Three-phase Outlets

Quantity 2 [TBC] 3-phase outlets will be provided inside of each SAT control room with 220/230 VAC 60 Hz on dedicated 50A [TBC] breakers. Outlet receptacle will be a NEMA 15-50 [TBC] twist lock.

The MAPO building lab space will be outfitted with additional XX [TBC] 3-phase outlets with 220/230VAC 60 Hz on dedicated 50 A [TBC] breakers. Outlet receptacle will be a NEMA 15-50 [TBC] twist lock.

5.1.5 Single-phase Outlets

All single-phase outlets will be 125 VAC with a NEMA 5-15R outlet (receptacle rated to 15A).
XX single-phase outlets will be provided in the SAT control room.
XX single-phase outlets will be provided in the MAPO and lab buildings.
4 single-phase duplex receptacles will be provided on roof.
Description of single phase outlets and individual breakers.

5.2 Grounding

Electrical system, data system, and building steel will be grounded through the station grounding system.

Grounding for the telescope mount is provided as follows: the stationary part of the mount is bolted to the tower steel.

A wall-mounted grounding bar will be provided in the interior of the control room for convenient access.

5.3 Uninterruptible Power Supply

4.3.1 Uninterruptible power supply (UPS) will enable the telescope drives (20 kW [TBC]), the DR control system (XX kW) and readout system (2 kW [TBC]) to continue operating for (30 minutes [TBC]) in the event of a power outage. (The UPS will not support the compressors.) The UPS for each SAT will be provided by South Pole Site.

5.4 Emergency Notification System

5.4.1 All SAT control rooms and MAPO will be connected to the station-wide notification system. Fire Protection System panel must be compatible with the station fire alarm annunciator system.

5.4.2 Site will provide a building monitoring system that both functions independently and can be integrated with the Observatory Control System (OCS). Telescope system-health pager system interfaces are TBC.

6. Plumbing Interfaces

6.1 Control Room Glycol Loop

Each SAT control room will have a dedicated cooling loop with a XX/XX ethylene [TBC] glycol/water mix. Flow rate and inlet temperature at each compressor will be dictated by the flow curves below.

- Value adjustment for 50/50 glycol/water: inflate flow rate by 10%. Pressure drop values increase by 40%. (These values are Cryomech's user manual, but note that actual requirements need to be verified against current experience, which has not always matched Cryomech manual claims.)
- Inlet pressure. Temperature at inlet XX-XX deg C.
- Water pressure drop?

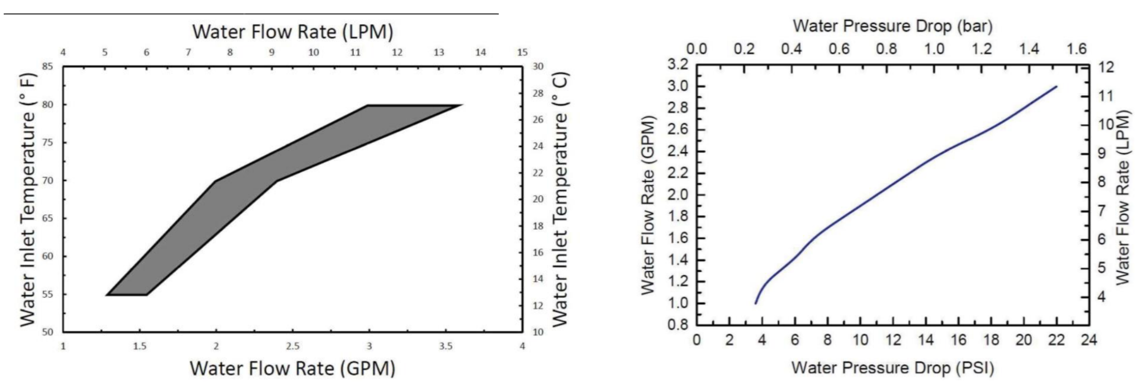


Fig XX: Water Flow Rate and Water Pressure Drop parameters for PT410 (from Cryomech)

Glycol cooling for readout electronics? [Determine if belongs here or with readout]

Connectors on the cooling loop will be 12.7 mm hose barb [TBC].

Each connection on the cooling loop (both inlet and outlet) will be individually valved.

7. Thermal / HVAC Interfaces

The interior temperature of the SAT control rooms and MAPO will be thermostatically controlled to a nominal set point around 15-20 degrees C to within 1-2 degrees.

Fluctuation in interior temperature of the SAT control room shall be no more than XX degrees C per minute.

There will be no humidity control. (ESD shall be addressed through rigorous grounding.)

HVAC shall provide positive pressure to ensure warm airflow out of the environmental enclosure boot on the mount.

Heat loss through the SAT mount (environmental enclosure boot and seals etc) will be no more than XX kW [TBC].

8. Communication Interfaces

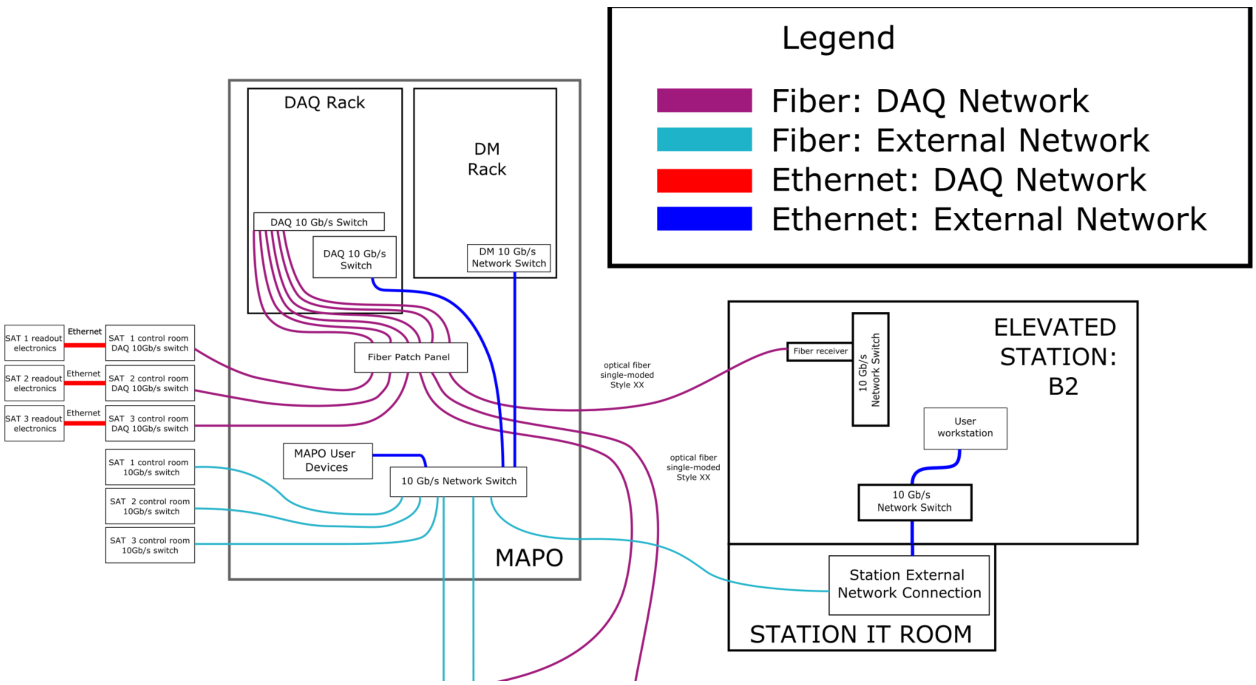
8.1 Phones

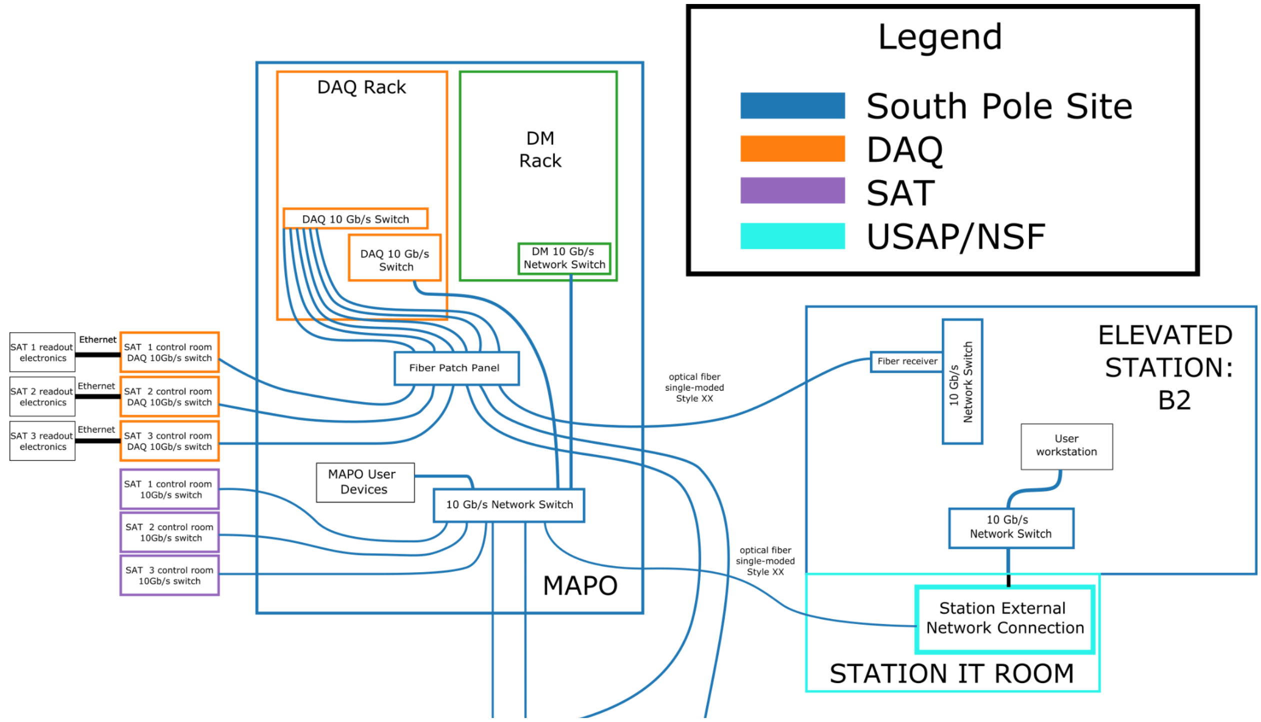
A Voice over Internet Protocol (VoIP) phone will be installed in each SAT control room. VoIP phones will also be available throughout the laboratory and MAPO buildings. These will connect to the station network and have Iridium call connectivity.

Analog phones

8.2 Ethernet Connections

Interface for ethernet connections will be at 'top of rack' switches (provided by SAT to meet their needs). Site will provide ethernet connections that connect these switches to the rest of the control room, MAPO/lab building, and the main station. These will include connections to the general 'station/external' network as well as dedicated connections for CMB-S4 (internal). Note that the interface to the data management system is technically via DAQ (Readout streams data to DAQ which interfaces to site via the ethernet/optical to transfer to DM system). It is therefore not described here.





8.2.1 Quantity XX 10 Gb/s [TBC] ethernet drops (cable endpoint) will be supplied to each SAT control room. These endpoints will connect to the 'internal' network.

8.2.2 Quantity XX 10 Gb/s [TBC] connections (ethernet switch endpoint) will be supplied in the integration/office space area in MAPO. These endpoints will connect to the 'internal' network.

8.2.3 Quantity XX 10 Gb/s [TBC] ethernet drops (cable endpoint) will be supplied to each SAT control room. These endpoints will connect to the 'station/external' network.

8.2.4 Quantity XX 10 Gb/s [TBC] connections (ethernet switch endpoint) will be supplied in the integration/office space area in MAPO. These endpoints will connect to the 'station/external' network.

8.2.5 The internal network will have an endpoint in the B2 Science lab office space/control room area.

8.2.6 Redundancy. The existing connection between the elevated station and the Dark Sector Hub includes 96 singlemode and 12 multimode fibers (TBC), with many open pairs (number TBC). There is another connection between the New Power Plant (located underneath the elevated station) and the DSH, similarly comprising 96 SM and 12 MM fibers.

8.2.7 SAT towers and adjacent lab buildings will have a common local subnet. Possibly interface with DAQ as well to ensure consistency with their scheme. There will be a dedicated fiber link for SAT instrument communication.

Calibration instruments power and DAQ needs will require cabling (TBD) between building interior and roof level.

Buildings with masts need to be able to communicate (data) with buildings with SATs (GB internal network).

8.3 Wireless Connections

8.3.1 Wireless connections (including wifi, bluetooth, and cellular) are prohibited in the dark sector and will not be used for any permanent function within the SAT facility.

9. Integration and commissioning

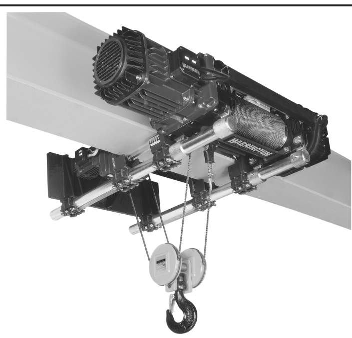
9.1 Facilities, equipment for receiver assembly and integration

9.1.1 Hoists

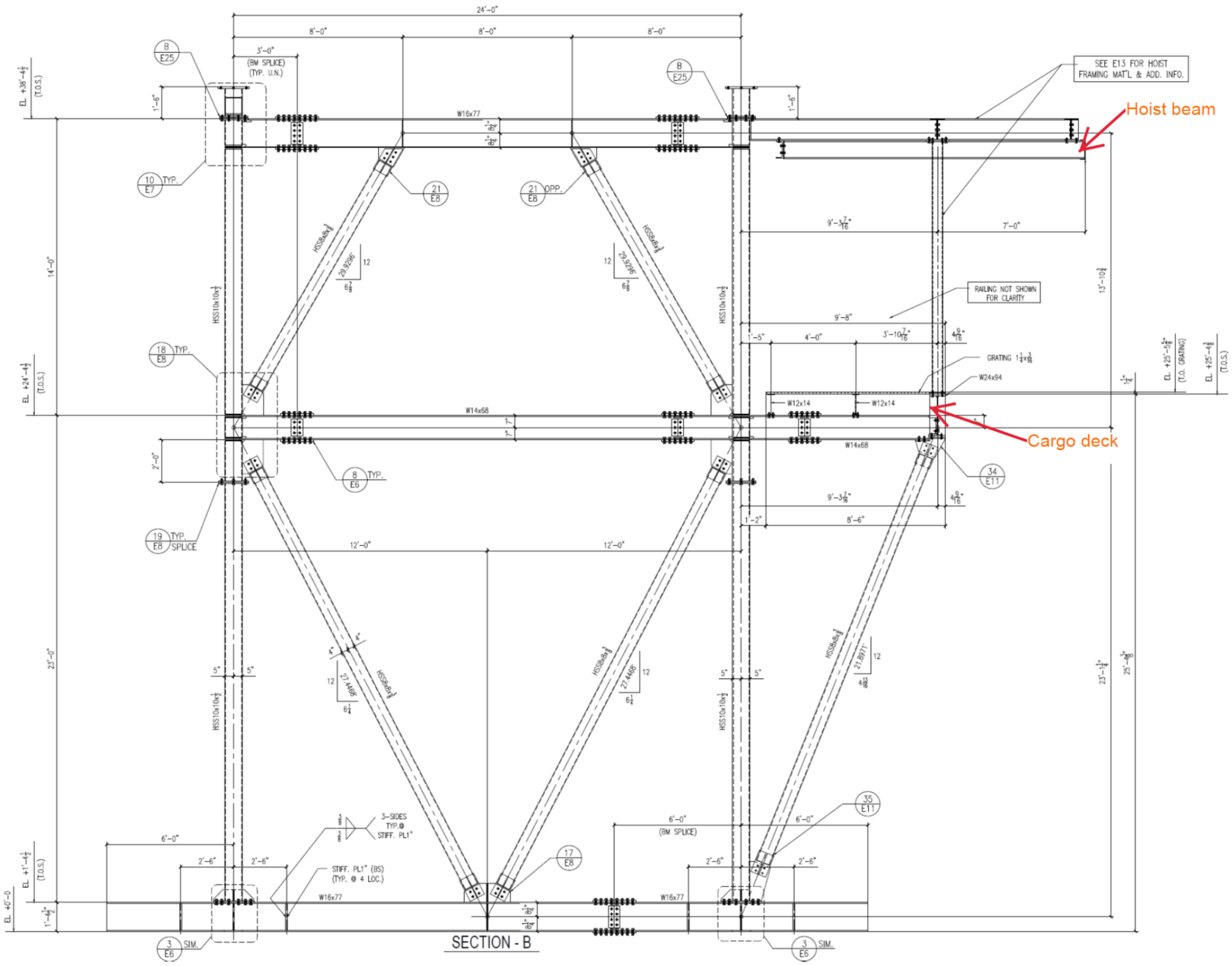
- General rigging equipment, accessories and training will be delivered by Sites.

- Mount winch system (delivered by SAT)
    - Receiver/shell assembly relies on the on-mount hoist system, both delivered by SAT. Specifications are set by the receiver and mount design.
    - Assembly of the optics tube onto the SAT receiver requires a hoist with 4.6 m hook height. Assembly hoist lift capacity is 3 metric tonnes [TBC].
    - Mechanical interface details: [TBC]
        - Locations
        - Clearances
        - Capacity
        - Heights
        - Fixture details

- Cargo deck hoist (delivered by Site)
    - This hoist has been fully specified as part of the BART design process. The S4 receiver specifications guided the design. This hoist is designed as a fixed beam with a hoisting point on a trolley.
    - Mechanical details:
        - Lift capacity: 4536 kg. (5 tons)
        - Rope length:10m. (33 ft.)
        - Max hook height to deck: 2.54m
        - Maximal envelope of cargo door opening: 2.44mx2.44m.



RH-Advantage
Ultra-Low Headroom Trolley
Hoists



9.1.2 Space in MAPO

Supporting facilities will be forklift-accessible for large cargo delivery, and snowmobile-accessible for light cargo.

There will be XX cubic meters of storage space, consisting of shelving and cabinets for tools and spare parts.

There will be XX workbenches to support assembly, inspection, electronics work, etc.

MAPO will include indoor cargo unpacking space. Unpacking space will include access to a hoisting point to raise crates and equipment to the second floor of the building, where it will be distributed to each SAT tower.

Relevant dimensions of the existing MAPO facilities (as measured by BICEP winterover operator Anthony DeCicco, reported by email to Marion Dierickx, May 2023):

Ground floor cargo dock area:

- Section 1, in front of the cargo doors: depth 128", width 116", height 99" (height limited by hanging light). This measured configuration pushes as close to the cargo door as possible and is limited in width by a pillar located next to the heater. In an alternative configuration (moving forward of the pillar), the maximal package dimensions are depth 116", width 129", height 99".
- Section 2 (area to the side of the cargo doors): depth 109", width 59", height 96" (height limited by a hanging light).
- Dimensions of ground floor cargo doors: 104”x96”
- Dimensions of control room floor hatch: 89.25”x41”

MAPO-walkway access doors:

- The current dimensions of the doorway between MAPO and the walkway leading to the DASI tower are: 95.5”x44”. The dimensions of the existing doorway shall be re-evaluated to allow for movement of SAT receiver parts TBD.
- The current dimensions of the doorway between the MAPO control room and AMANDA room are: 96”x68”. The dimensions of the existing doorway shall be re-evaluated to allow for movement of SAT receiver parts TBD.
- A new doorway shall be created on the opposite side of the building, with dimensions of X x Y.

Tower-walkway access doors:

- Dimensions must allow the full 2.44 m x 2.5-3.0m envelope of the largest crates.

Hanging lights currently installed in MAPO limit vertical clearance in many spaces. The lighting scheme inside MAPO shall be re-evaluated (light fixtures raised, built into the ceiling, etc.) to minimize obstruction.

South Pole SIP floor loading standard is:

- Uniform load:
    - Long term live load = 60 PSF
    - Short time live load = 100 PSF
- Concentrated load:
    - 2000 pounds on 3'-0" X 3'-0" area

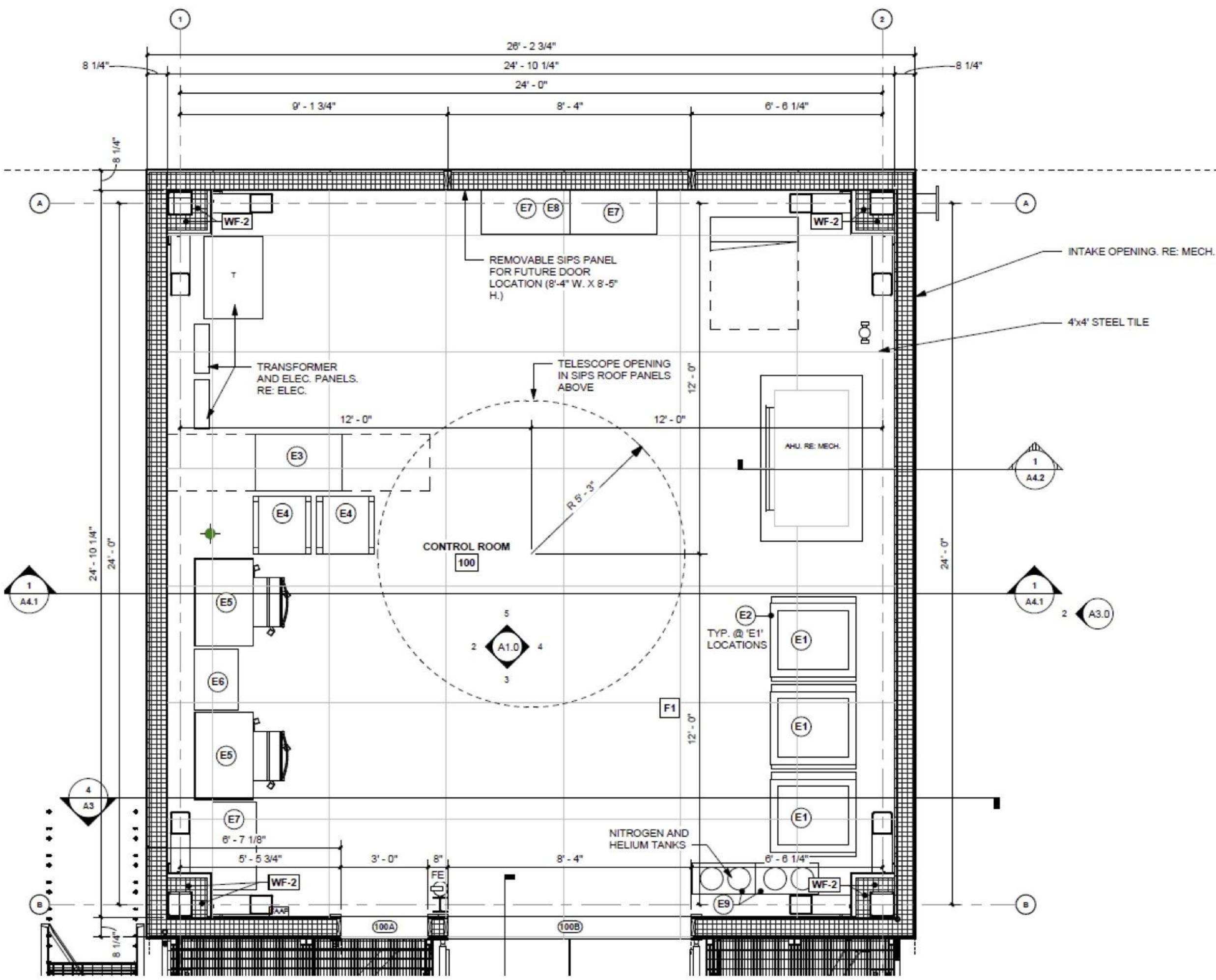
9.1.3 Space in the SAT tower

The dimensions of the doorways leading to the SAT control room are:

- Exterior cargo deck doors: XX x YY
- Walkway door: XX z YY

Sites shall provide an enclosed lab space approximately 24’ x 24’ in total size, known as the SAT control room, to support assembly and operations of each SAT receiver. This space is where the final assembly of each SAT receiver is to be performed. The diagram below, entitled “CMB-S4 SAT control room floor plan,” shows the layout of this room, including planned locations of utilities, helium compressors, and compressed gas cylinders.

CMB-S4 SAT control room floor plan



There will be room for a standard tool cabinet inside the control room.

SAT receiver assembly requires access to the top of the receiver. Rotation of the receiver is not required on-site.

SAT receiver assembly requires XX meters of clearance underneath the receiver in order to install warm readout and housekeeping electronics.

The control room is expected to be at a Noise Criterion 45. This is consistent with a general laboratory space noise requirement.

9.1.4 Storage

SATs will require XX cubic meters of indoor (temperature-controlled) storage space, consisting of shelving and cabinets. This space must be adjacent to the telescopes.
Link to the [working version of the CMB-S4 Spare Equipment and Supplies worksheet]

- General-purpose tools (provided by Sites)
- General lab equipment (electronics, instruments) (provided by Sites)
- Specialty tools (provided by SAT?)
- Spare parts for telescope and receiver systems (provided by SAT?)

SATs will require XX cubic feet of outdoor (cold) storage for various equipment, such as:

- Ladders and support structures to access the SAT mount and ground shield.
- Custom wooden and pelican crates
- Gas cylinders
- Calibration equipment
- Ancillary instruments to be installed on building roof (for example: weather station, RF monitor, GPS antenna, water vapor radiometer)

9.1.5 Machine Shop

Access to a dedicated science machine shop, with machinist time (Site responsibility). Access to shop tools for a subset of trained personnel.

Access to basic stock materials.

9.2 Facilities & equipment for telescope commissioning and calibration

9.2.1 Ground commissioning of the receiver inside the SAT tower

This section describes interfaces related to in-lab commissioning measurements prior to receiver installation on the mount: Optical Efficiency, Fourier Transform Spectrometry, Near-Field Beam Mapping, etc. (For further details, refer to CMBS4-doc-729 “CMB-S4 South Pole Commissioning Plan for Small-Aperture Telescopes.”)

During ground commissioning of the SAT receiver inside the SAT tower, the maximal dimensions of the calibration apparatus are constrained by the geometry of the mount and the outer envelope of the receiver.

- When temporarily stowed aside, the outer envelope of the receiver allows for a circle of diameter X meters of clear floor space underneath the mount, allowing for staging and raising of calibration apparatus.
- Ceiling height of control room
- Vertical clearances underneath mount (diagram?)
- Approximate dimensions for current NFBMer
- Approximate dimensions of current FTS
- Approximate dimensions of current Optical Efficiency LN2 load.
- Power and communication requirements for each type of calibration apparatus
- Link rendering of SAT control room that shows approximate envelope for each apparatus [Amy]
- Envelope of SAT receiver with FTS installed is XX m x YY m x ZZ m.
- Envelope of SAT receiver with Near field beam mapping equipment is XX m x YY m x ZZ m
- Mount winch system (delivered by SAT)
  - In the ground commissioning phase, positioning the calibration equipment atop the receiver relies on the on-mount hoist system, both delivered by SAT. Specifications are set by the calibration hardware and mount design.
  - Mechanical interface details: [TBC]
    - Locations
    - Clearances
    - Capacity
    - Heights

        - Fixture details

9.2.2 Integrated commissioning of the telescope, and calibration interfaces

This section describes interfaces related to integrated commissioning measurements after the receiver has been installed on the mount: Far-Field Beam Mapping (FFBM), Far-Sidelobe Mapping (FSL), forebaffle on/off measurements, etc. (For further details, refer to CMBS4-doc-729 “CMB-S4 South Pole Commissioning Plan for Small-Aperture Telescopes.”)

Location and number of masts (calibration masts are SAT scope):

- Far-Sidelobe Mapping
    - A mast will be required within XX meters (to enable Far-Sidelobe Mapping), with height XX and weight capacity YY.
- Far-Field Beam Mapping
    - Masts will be installed at a location TBD at a minimum distance of XX m, raised for calibration and lowered for routine observing. (The minimum far-field distance is frequency-dependent.)
    - SAT calibration source needs to be able to point to each tower (clear line-of-sight).
    - XX [TBD] SATs should be able to beam-map simultaneously.
    - SAT beam mapping noise level requires XX observing time to meet calibration requirements.
    - Calibration mast should be 2 degrees [TBC] above the clear horizon (or above ground shield when viewed by a SAT with far-field flat mirror configuration (diagram needed).

Interfaces between mast (built by SAT) and supporting building (provided by Site):

- Mast will occupy an TBD x TBD m footprint on the building roof. A number X [TBD] guy lines will be attached at a distance of XX m.
- Building roof (TBD) must include storage space for the mast when lowered/retracted. Define footprint on storage surface.
- Mast will have the following bolt pattern [TBD] to attach to the roof. Bolts will be XX size.
- Mast height (vertical and when stored on roof).
- Mast weight will be XX kg [including calibration sources], and building roof will be reinforced as necessary for support.

Interfaces between far-field flat mirror (built by SAT) and Site:

- SAT tower structural design will accommodate the initial installation and annual storage of far-field-flat mirror. Cover for winter mirror storage will be provided by SAT.

Roof-level lifting equipment:

- Lifting equipment inside the ground shield will be delivered by SAT. It must allow for installation and removal of calibration equipment (far-field flat mirror) and other equipment (warm baffling) on/off the mount.
    - Location
    - Clearance
    - Capacity
    - Height
    - Automatization
    - Precision
    - Fixture details
- Roof crane (delivered by Sites). Must allow lifting of equipment from the second floor interior to the roof level.

9.3 Cryogens and compressed gasses

The list below describes needs for the commissioning phase of each SAT.

- Compressed nitrogen: 10 [TBC] bottles of UHP N2. Primary usage is receiver backfills and nitrogen membrane installation. Provided by Site.
- Compressed helium: 10 [TBC] bottles of UHP Helium. Primary usage is for the pulse tube and compressor system of each SAT. Provided by Site.
- Liquid nitrogen: 40L/month of LN2 per SAT. Primary uses are for the dilution fridge cold trap refills and for calibration loads. Provided by Site.
- Compressed air: Compressed air will be provided for the SAT receiver dilution refrigeration system through a small local compressor (SAT responsibility). There will be no additional compressed air infrastructure in the SAT towers or MAPO building.

9.4 Lab Office/Facilities

Site will supply furniture for MAPO and SAT towers.

Furniture including desks, benches, and toolboxes will be lightweight and mobile to enable reconfiguration of the space as needed during integration and commissioning.

9.5 Personnel, know-how and procedures

SAT and Sites teams will develop procedures for receiver assembly and receiver/mount integration given infrastructure, personnel and schedule constraints.

10. Shipping

All SAT materials shipping to the South Pole shall adhere to the project-wide shipping requirements in CMBS4-L1_SYS-208, including the South Pole specific requirements found in: The South Pole Site Shipping Plan CMBS4-doc-703 and USAP Packing and Shipping Instructions CMBS4-doc-722

Site will plan in collaboration with NSF support for the movement, storage and delivery of XX tons of DNF cargo and XX tons of cold cargo (approximately XX wooden and plastic crates; per SAT).

All components, inclusive of shipping crates, shall weigh less than 4,536kg and fit within the LC-130 cargo envelope: 2.64m wide x 2.44m tall x 2.13m long (single pallet), up to 8.68m long (T-4).

All cargo items will be shipped to Port Hueneme, CA with arrival by Sept 1 to enter the cargo stream for that year.

Crates, boxes and other shipments destined for the South Pole shall NOT use packing peanuts or other small lightweight materials (like shredded paper). Bubble wrap and packing foam are acceptable.

Cargo shall be packed to the following shock standard TBD

Cargo shall be packed to the following vibration standard TBD.

Do Not Freeze (DNF) cargo restrictions. Cargo that cannot be allowed to freeze during shipping (electronics, gaskets, etc) must be marked as such and packed separately from cargo that can.

Crates will be marked with TBD labels on each side.

There is no SAT cargo that is planned for transport by overland traverse from McMurdo.