CMB-S4

READOUT-SAT INTERFACE CONTROL DOCUMENT

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REVISION HISTORY

Version Letter	Revision Date	Author: Notes
v1	6/26/20	Initial draft
v2	11/05/21	adding details
v3	7/17/23	Clarify boundaries and add substantial technical detail

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

TABLE OF CONTENTS

1. Purpose and Scope

This document defines and describes the interfaces between the Readout and the SAT. All references to readout within this document are assumed to mean readout of the detectors only, unless otherwise specified. In Table 1 the quantities of items and in which document they are specified are listed.

Item	Specified in which document	Quantity **(Numbers below are just informational, see respective document for current quantity)**
# of TES/detector per detector wafer type (LF/MF1/MF2/HF)	RO-Detector ICD	48/588/672/1,872
# of sides detector wafer is read out (= # of 100mK Readout Modules) for LF/MF1/MF2/HF (and which side(s))	RO-Detector ICD	1/3/3/6
Order of TES and type along detector edge by pixel (frequencies/polarization/Dark-lit)	RO-Detector ICD	12 groups of 25 pad pairs. Each group looking from inside out: dark, followed by 24 sets of lit: frequency 1, polarization 1, frequency 1, polarization 2, frequency 2, polarization 1, frequency 2, polarization 2
Order of pixels at each detector wafer edge	MAT-Detector-ICD	Readout does not care about the order of pixels as long as the frequencies are in the same order in each pixel as specified in this ICD to observe the two different TES bias levels.
Number of 4K SSA modules per detector wafer LF/MF1/MF2/HF	see this ICD	1/2/2/3
Number of vacuum flange connectors per detector wafer LF/MF1/MF2/HF	see this ICD	2/3/3/4
Number of 300K Row Address Modules per detector wafer	see this ICD	1/1/1/1
Number of 300K Readout Modules per detector wafer LF/MF1/MF2/HF	see this ICD	1/2/2/3
Number of detector wafers/modules per SAT tube LF/MF1/MF2/HF	SAT-Modules ICD	12/12/12/12
Number of tubes per type for all SAT's LF/MF1/MF2/HF	PBDR/Instrument Configuration	1/3/3/2
Frequencies per band LF/MF1/MF2/HF	Jama band definitions and detector req'ts	27/39;85/145;95/155;220/270 GHz

Table 1: Quantity of Items and in which document they are specified.

The detector readout system includes the 100mK components (Nyquist chips, SQUID multiplexing chips, and the associated column readout boards) that are integrated in the detector modules by MAT. SAT then integrates the assembled detector modules into the appropriate optics tube inside the SAT cryostat. Additionally, the readout has SSA modules that are operated at 4K (1K tbd) within the SAT cryostat. Also included in the readout system are the specialty cables that connect the 100 mK electronics to the 4K (1K) SSA modules as well the wiring out to 300K. The detector TES addressing is via a 100mk to 4K row address cable with a 4K mounted row address assembly and a 4K to 300K row addressing cable. Room temperature row address and column readout modules that operate and readout these components and the TES detectors operate on the exterior of the SAT cryostat and in the SAT telescope mount.

In the current architecture readout is via 80-row addressing and 4-columns for each of the detector wafer edges (up to 6). The 300K warm row address modules and column readout modules are powered via 48V on-receiver rack-mounted power supplies connected to on-flange 48-V-to-12V DCDC converter modules. Timing/networking is via rack-mount Ethernet switches with a connection from the Ethernet switches to a stationary server off the receiver (Latter is a DAQ-SAT interface).

The component owners are: (see Figure 1 for block diagram)

- SAT
    - Structures for routing and thermal sinking of 100mK-to-4K and 4K-to-300K row address and readout cabling with attached heat sinks, provided by Readout, within the cryostat.
    - Routing of cables provided by Readout
    - Installation of 4K SSA modules with mounting brackets, provided by Readout
    - Radiation shields & vacuum vessel including assembly of flanges with electrical connectors as specified by Readout. SAT to purchase hermetic connector flanges with connectors.
    - Installation of 300K row address and readout assemblies, supplied by Readout.
    - Routing of short daisy-chain cables between 300K row address and column readout modules in a readout group. Short fan-out harness cables supplied by Readout.
    - Supplying and routing of Ethernet cables from flanges to rack-mounted switch, specification of cables by Readout.
    - Ethernet /timing from switch to site interface is defined in DAQ-SAT ICD
    - Installation of 48V-to-12V DC converter modules on flanges. Modules supplied by Readout.
    - Supplying and routing of 48V DC power cables from rack mount supplies to each 48V-to-12V DC converter module. Cable/connector type specified by Readout.
    - Supplying and routing of 12V DC power cables from 48V-to-12V DC converter modules to each power pig-tail at each Readout board group at flange. Cables specified by Readout
    - Telescope mount and sub-structures like electronics racks.
    - Power supply rack mounting for 110V to 48V power supplies supplied by Readout
    - Ethernet switch rack mounting with power, Ethernet switches supplied by Readout.
    - Readout of temperature sensor on 4K electronics module.
    - Magnetic shielding integrated into cryostat (readout will inform requirement through systems engineering process)
    - RF filters purchase and installation from specification by Readout

- Cooling, and environmental conditioning for 300K electronics. (Pipes to flanges, temperature monitoring, chillers).
- Protection of Warm Electronics Modules by disabling power if issue with cooling is detected.
- Uninterruptible Power Supply (UPS)

- Readout
  - Modules including mounting bracket of 4K SSAs and 4K row address interface assembly for detector addressing and readout.
  - Cables including heat sinks connecting electrical signals within the detector readout system between 100 mK & 4K and 4K & 300K
  - Specification of RF filters
  - Specification of vacuum flange feed-thru connectors.
  - 300K electronics for detector addressing and readout. Mechanical enclosures for warm readout modules (each module has its own enclosure).
  - Daisy chain power and network cables between 300K row address and column readout cables in a group to local pig-tails.
  - Specification of long-run 48V power cable/connectors and connectors and Ethernet cables from rack mount power supplies/Ethernet switches.
  - Procure and deliver 48V-to-12V DC converter modules.
  - Procure and deliver rack-mount 48V power supplies and Ethernet switches.
  - Thermometry - onboard sensor with pigtail @ 4K SSA boards

  Comments:
  - Modules of 100 mK detector readout are integrated into detector module
  - Heaters and supply of power to heaters are outside Readout scope

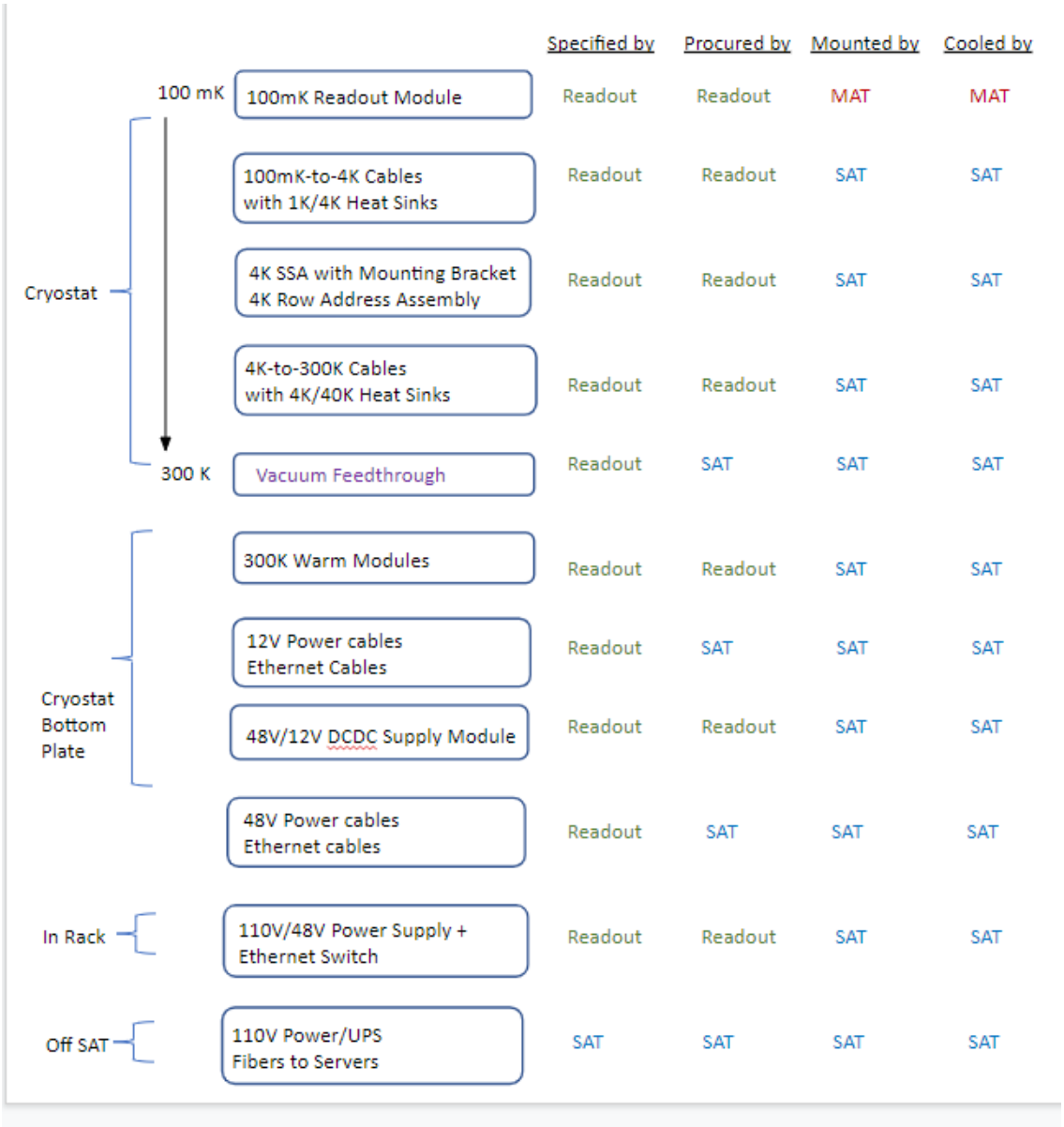

Figure 1: Block Diagram of Readout Electronics Components see PPT file of Figure 1

2. Abbreviations and Definitions

2.1 Abbreviations

RO ReadOut (Here "RO" refers to the RO L2 WBS)
SAT Small Aperture Telescope (Here "SAT" refers to the SAT L2 WBS, not specifically the telescope)
MAT Module, Assembly, and Test L2 WBS
TDM Time-Division Multiplexing
SQUID Superconducting Quantum Interference Device
SSA Series SQUID Arrays

2.2 Definitions

3. Mechanical/Structural/Thermal Interfaces

3.1 100mK to 4K (1K tbd) Cable Information

Current scenario implies a single continuous cable routing from 100mK module assembly to 4k (or 1K tbd) cold electronics passing through a heat shield. There are row address cables and column readout cables.

RO-SAT-0010 Number of column readout cables to be routed for LF modules

SAT shall route a total of 1 readout cable from each of the detector assemblies with a single Readout module.

RO-SAT-0015 Number of column readout cables to be routed for MF modules

SAT shall route a total of 3 cables from each of the detector assemblies with 3 Readout modules.

RO-SAT-0017 Number of column readout cables to be routed for HF modules

SAT shall route a total of 6 cables from each of the detector assemblies with 6 Readout modules.

RO-SAT-0020 Number of row address cables to be routed for LF/MF/HF modules

SAT shall route a total of 1 cable from each of the detector assemblies.

RO-SAT-0025 Length of column readout cables to be routed

The length from the detector modules to the 4K SSAs shall be a maximum length of 0.5m (TBC). Note: Eventually, need a table of length for each of the cables.

RO-SAT-0030 Type of column readout cables to be routed

The SAT shall route cables specified in drawing tbd. (Number of conductors, cable thickness and width, connector part number).

RO-SAT-0035 Length of row address cables to be routed

The length from the detector modules to the 4K row address assembly shall be a maximum length of 0.5m (TBC). The 100mK-to-4K row address cable is directly plugged into the 4K-to-300K row address cable, with a mounting bracket attached to the 100mK-to-4K cable.)

RO-SAT-0040 Type of row address cables to be routed

The SAT shall route cables specified in drawing tbd. (Number of conductors, cable thickness and width, connector part number).

RO-SAT-0045 Cable Path layout for column cables

The cable path for each cable from 100mK to 4K (1K tbd) shall be as specified in Drawing xxx. (Drawing showing the path through the SAT, including connection points, segments, and lengths, and general space envelope allowed for cabling).

RO-SAT-0050 Cable Path layout for row address cables

The cable path for each cable from 100mK to 4K (1K tbd) shall be as specified in Drawing xxx. (Drawing showing the path through the SAT, including connection points, segments, and lengths, and general space envelope allowed for cabling).

RO-SAT-0055 Minimum bend radius on cables

The SAT shall not bend cables more tightly than the minimum bend radius of tbd mm.

RO-SAT-0060 100mK to 4K readout cable weight

The SAT shall support a weight of up to tbd Kg for each cable. (Need table)

RO-SAT-0065 100mK to 4K row address cable weight

The SAT shall support a weight of up to tbd Kg for each cable. (Need table)

RO-SAT-0070 100mK Mechanical/Thermal Interface

The 100mK RO hardware is mechanically supported by and thermally sunk to the MAT structure. Thus there is currently no SAT-RO interface.

RO-SAT-0075 1K Mechanical/Thermal Interface Column Readout cables

The SAT shall mount cable clamps for the 100mK to 4K cable specified in drawing tbd at 1K with maximum thermal impedance of tbd at operating temperature.

RO-SAT-0080 1K Mechanical/Thermal Interface Row Address cables

The SAT shall mount cable clamps for the 100mK to 4K cable specified in drawing tbd at 1K with maximum thermal impedance of tbd at operating temperature.

RO-SAT-0085 1K shield cable clamp mount Installation

SAT and Readout shall specify the mounting details of the cable heat-sinks at 1K.
Info: Cable heat sinks on the cable. (Installation details, potting , etc.)

RO-SAT-0098 4K Mechanical/Thermal Interface Column Readout cable clamps

The SAT shall mount cable clamps for the 100mK to 4K cable specified in drawing tbd at 4K for each cable. (Installation details, potting, number of clamps for thermal reasons, maximum spacing of clamps,etc.)

RO-SAT-0092 Distance between cable clamps for Column Readout cables

The maximum distance between cable clamps shall be tbd cm. (for thermal and vibration reasons.). Maybe need drawing for each of the cables with clamp location? Then need drawing number(s).

RO-SAT-0095 4K Mechanical/Thermal Interface Row Address cable clamps

The SAT shall mount cable clamps for the 100mK to 4K cable specified in drawing tbd at 4K for each cable. (Installation details, potting, etc.)

RO-SAT-0097 Distance between cable clamps for row address cables

The maximum distance between cable clamps shall be tbd cm. (For thermal and vibration reasons.). Maybe need drawing for each of the cables with clamp location? Then need drawing number(s).

3.2 4K Cold Electronics SSA module and Mount

Cold readout mounted and contained inside the cryostat

RO-SAT-0100 Number of SSA modules per detector module: LF

The SAT shall be able to mount up to one SSA module per LF detector module. (For a tube of 12 detector modules: 12 SSA modules total),

RO-SAT-0110 Number of SSA modules per detector module: MF.

The SAT shall be able to mount up to two SSA modules per MF detector module. (For a tube of 12 detector modules: 24 SSA modules total).

RO-SAT-0120 Number of SSA modules per detector module: HF.

The SAT shall be able to mount up to three SSA modules per HF detector module. (For a tube of 12 detector modules: 36 SSA modules total).

RO-SAT-0130 Cold SSA readout module dimensions

SAT shall mount 4K SSA modules with dimensions shown in Figure 2.

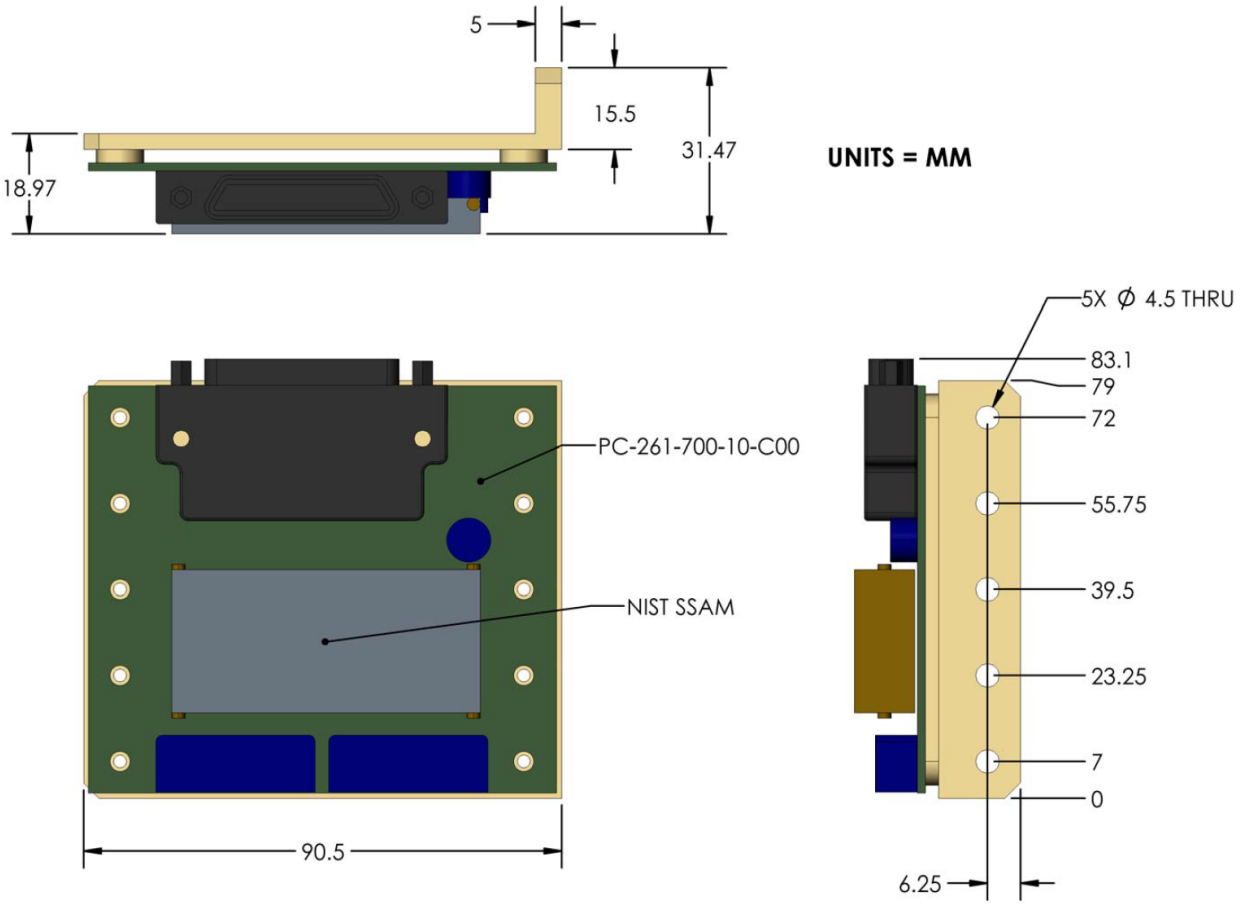

Figure 2: Dimensions of 4K SSA module.

RO-SAT-0140 Cold SSA module weight

The SAT shall support a weight of up to tbd Kg for each module.

RO-SAT-0150 Physical connection detail for SSA cold electronics

The physical connection between SAT and SSA module shall be as specified in drawing tbd. (Also specifies fasteners)

RO-SAT-0160 Material of mounting bracket

The material of the mounting bracket shall be tbd.

RO-SAT-0170 Connection detail for magnetic shielding

Not clear whether needed, since Readout magnetically shields SSA's themselves but there might be overall allocations to SAT and Readout, tbd.

3.2 4K Cold Electronics Row address Assembly and Mount

RO-SAT-0200 Number of Row address interface assemblies per detector module

The SAT shall be able to accommodate 1 row address interface assembly per detector module. (For a tube of 12 detector modules: 12 row address assemblies total).

RO-SAT-0210 Row address interface modules mounting

The assembly is a mounting bracket attached to the 4K side of the 100mK-to-4K cable and then plugging in the 4K side of the 4K-to-300K cable into the 100mK-to-4K cable connector. The mounting bracket is fastened to the SAT. See drawing (tbd). (Also specifies fasteners)

RO-SAT-0220 Cold Row address interface assembly dimensions.

The space required to mount the row address assembly in the SAT shall be two cable connectors (4K side of the 100mK-to-4K cable and 4K side of the 4K-to-300K cable) plugged into each other together with the mounting bracket specified in drawing tbd attached to the 4K side of the 100mK-to-4K cable. Figure 3 shows the connectors, 100-pin connector dimensions are A=56mm, E=10mm, G=11mm.

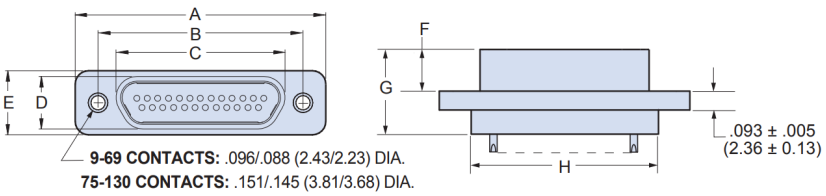

Figure 3: Dimensions of cable connectors at 4K

RO-SAT-0230 Cold row address mounting bracket weight

The mounting bracket weight shall not exceed tbd Kg. (The weight of the cables with connectors is specified under Cable weight specification. The only addition at 4K is the address mounting bracket which attaches to the address cable going to 100mK).

3.3 4K to 300K Cable Information

RO-SAT-0300 Number of column readout cables to be routed for each SSA module

Number of cables shall be a total of 1 from each of the SSA modules

RO-SAT-0310 Number of row address cables to be routed servicing each detector module

Number of cables shall be a total of 1 servicing each detector assembly.

RO-SAT-0320 Length of cables to be routed

The length from the 4K SSAs and row address interface to the flange connectors shall be a maximum length of 0.5 m. (Note: Eventually need a table of length for each of the column readout and row address cables.)

RO-SAT-0330 Type of column readout cables to be routed

The SAT shall route cables specified in drawing tbd. (Cables supplied by Readout) (Number of conductors, cable thickness and width, connector part number).

RO-SAT-0340 Type of row address cables to be routed

The SAT shall route cables specified in drawing tbd. (Number of conductors, cable thickness and width, connector part number).

RO-SAT-0350 4K to 300K readout cable weight

The SAT shall support a weight of up to tbd Kg for each cable.(Need table)

RO-SAT-0360 4K to 300K row address cable weight

The SAT shall support a weight of up to tbd Kg for each cable. (Need table)

RO-SAT-0370 Cable path layout

SAT shall specify the cable path for each cable in Drawing xxx. (Drawing showing the path through the SAT, including connection points, segments, and lengths, and general space envelope allowed for cabling).

RO-SAT-0375 Distance between cable clamps for Column Readout cables

The maximum distance between cable clamps shall be tbd cm. (for thermal and vibration reasons.). Maybe need drawing for each of the cables with clamp location? Then need drawing number(s).

RO-SAT-0380 Distance between cable clamps for row address cables

The maximum distance between cable clamps shall be tbd cm. (for thermal and vibration reasons.). Maybe need drawing for each of the cables with clamp location? Then need drawing number(s).

3.4 40K Cable Mounts

RO-SAT-0400 40K Mechanical/Thermal Interface Column Readout cables

The SAT shall mount cable clamps for the 4K to 300K cable specified in drawing tbd at 40K for each cable.

RO-SAT-0410 40K Mechanical/Thermal Interface Row Address cables

The SAT shall mount cable clamps for the 4K to 300K cable specified in drawing tbd at 40K for each cable.

RO-SAT-0420 40K shield cable clamp mount Installation

SAT and Readout shall specify the mounting details of the cable heat-sinks at 40K.
Info: Installation details (potting , etc.)

3.5 Vacuum Flange Feedthrough

RO-SAT-0500 Number of vacuum feed-thru connectors for row addresses per detector module: LF, MF, and HF.

The SATs shall provide one feed-thru connector for each LF/MF/HF detector module for row addressing, specified by Readout. (For a tube of 12 detector modules: 12 row address

connectors,). Note: for now we keep 100-pin connectors to be compatible but only have 51 wires on the cable.

RO-SAT-0510 Number of vacuum feed-thru connectors for column readout per detector module: LF

The SATs shall provide one feed-thru connector for each LF detector module for readout, specified by Readout. (For a tube of 12 detector modules: 12 readout connectors,).

RO-SAT-0520 Number of vacuum feed-thru connectors for column readout per detector module: MF

The SATs shall provide two feed-thru connectors for each MF detector module for readout. (For a tube of 12 detector modules: 24 readout connectors,).

RO-SAT-0530 Number of vacuum feed-thru connectors for column readout per detector module: HF

The SATs shall provide three feed-thru connectors for each HF detector module for readout. (For a tube of 12 detector modules: 36 readout connectors,).

RO-SAT-0540 Type of vacuum feed-thru connectors for SAT for column readout

The SATs shall use connector part number tbd for the column readout flange hermetic connectors.

RO-SAT-0550 Cryostat Feedthrough detail

The SATs shall provide hermetic connector flanges meeting specifications in doc tbd (Installation details, potting , etc.) (Current plan is to use o-ring seals versus laser welding)

RO-SAT-0560 Cryostat Feedthrough Architecture

The SAT shall arrange the row address and column readout connectors in groups specified in doc tbd originated by SAT. (Each detector needs one row address cable but column readout modules are dependent on detector module type. This document should specify what the groups are which are to be daisy-chained into one readout group).

3.6 Warm Electronics Module Mount and Interconnection

Warm electronics is to be mounted to the external surface of the SAT cryostat. Each row address and column readout module comes with its own enclosure which is mounted to the vacuum flange by SAT via screws, see Fig 4 and Fig.5 (Drawings will need more detail, tbd). Current view is that SAT plugs the modules in and thermally and electrically interconnects the modules together in groups of 4 and each group is then electrically and thermally interconnected by SAT and to the rack mounted electronics or chiller (Power is via cryostat mounted 48V-to-12V DC converter modules supplied by Readout). Row address and column readout modules will have the same 100-pin connectors, thus some form of keying is needed, tbs.

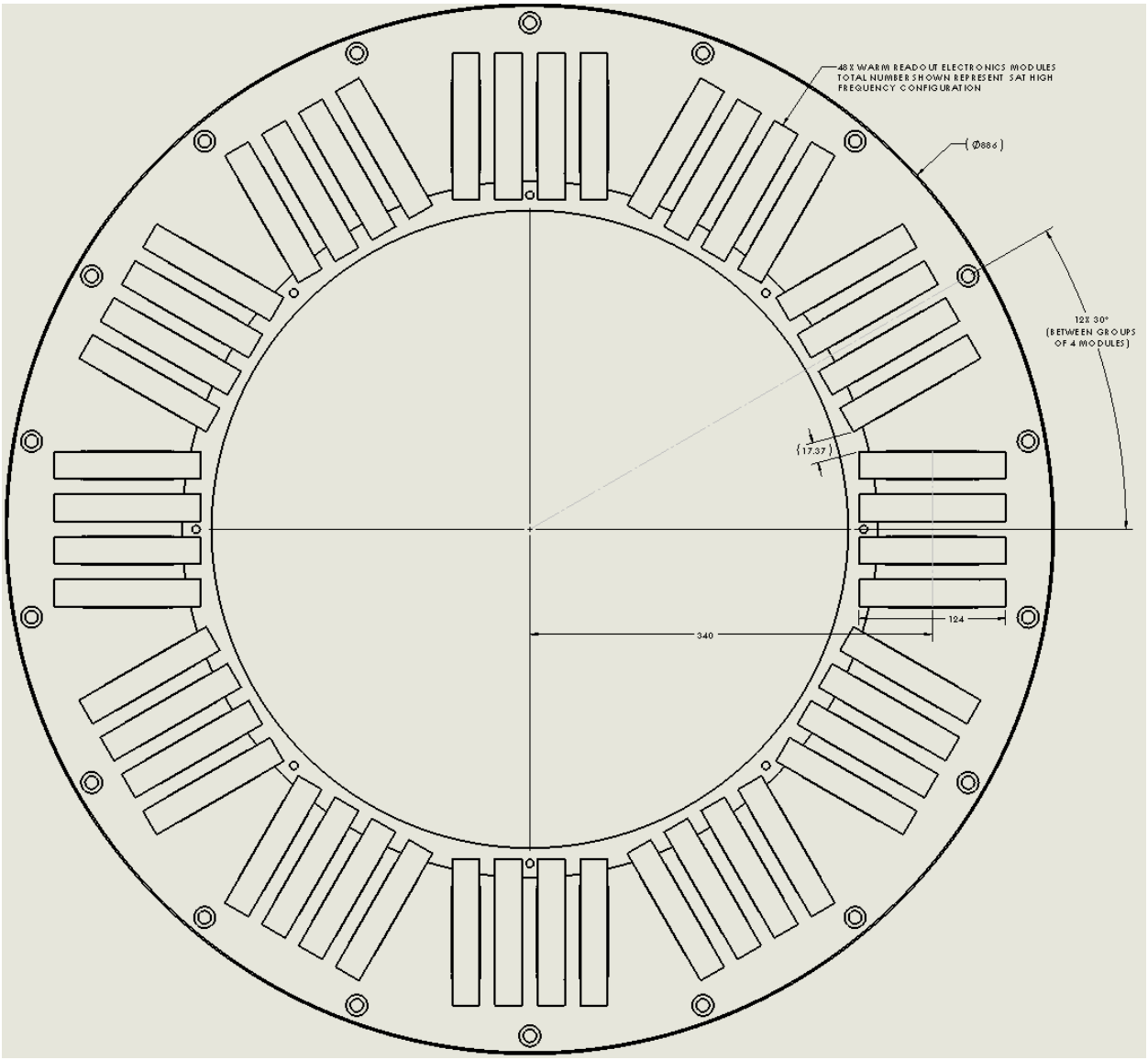

Figure 4: Plan view, warm readout modules on bottom of each optics tube. Total of 12 x 4 = 48 connectors/slots.

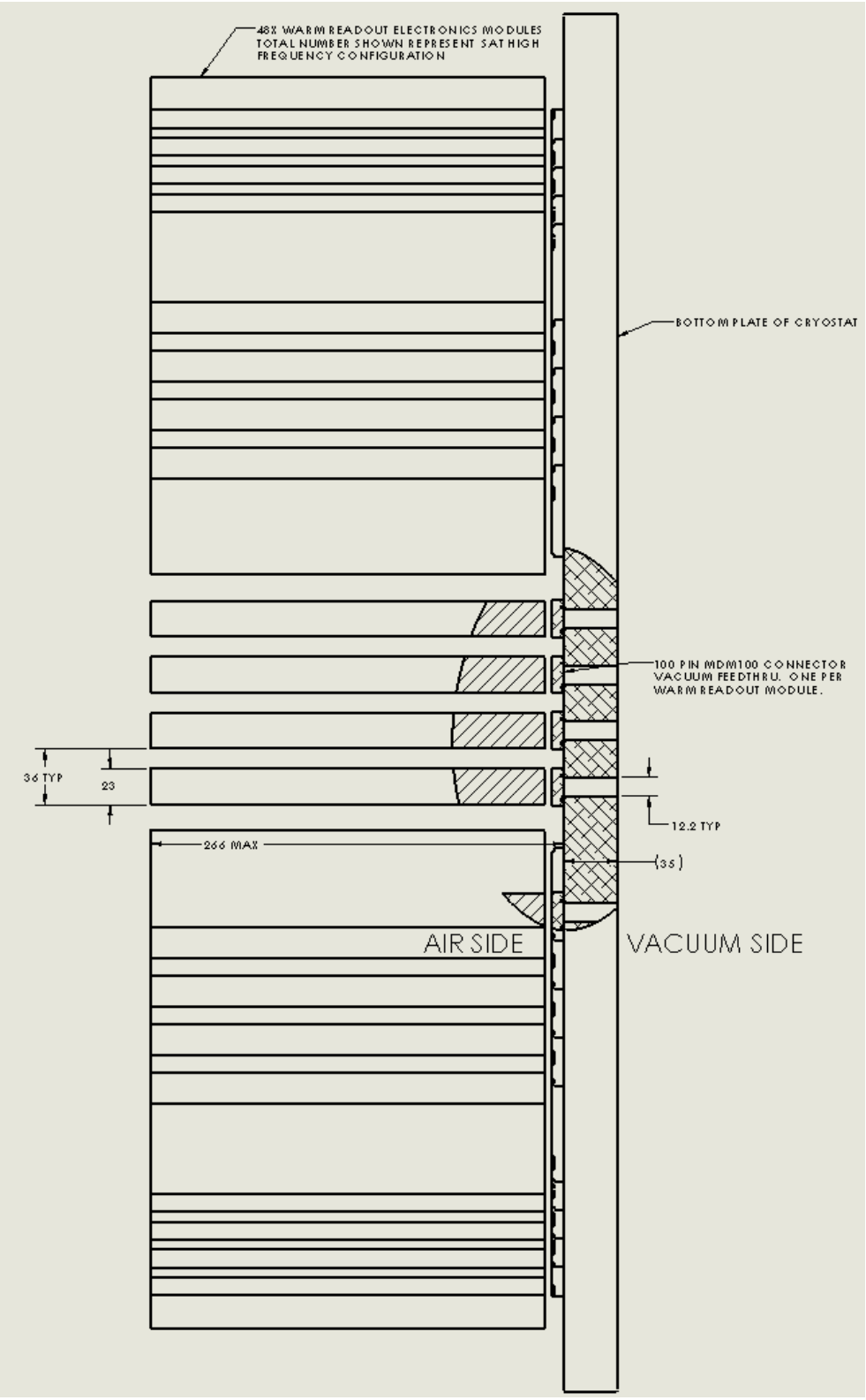

Figure 5: Side view, warm readout modules on bottom of each optics tube

RO-SAT-0600 Warm row address module dimensions and mounting

The SAT shall mount row address modules as specified in drawing tbd.
(Dimensions, how to mount, what mounting hardware, etc)
(Current approx size is 124 mm wide, x 266 mm max tall, x 23 mm thick). Currently the row address and column readout are the same size).

RO-SAT-0610 Warm column readout module dimensions and mounting

The SAT shall mount column readout modules as specified in drawing tbd. (Dimensions, how to mount, what mounting hardware, etc)
(Current approx size is 124 mm wide, x 266 mm max tall, x 23 mm thick). Row address and column readout are the same size.

RO-SAT-0620 Warm electronics row address module weight

The SAT shall mount modules with a maximum weight of tbd kg. (Only know once enclosure is designed).

RO-SAT-0630 Warm electronics column readout module weight

The SAT shall mount modules with a maximum weight of tbd kg. (Only know once enclosure is designed).

RO-SAT-0640 Warm electronics module sets to detector mapping.

SAT shall specify and document on which flanges and which connector the row and column boards for each detector are assigned in doc xxx tbd. (Probably done in concert with Readout).

RO-SAT-0650 Warm electronics module interconnection into groups

The SAT shall interconnect modules as specified in doc tbd. Short local fan-in/fan-out harnesses/pig-tails are supplied by Readout.

Info: This doc specifies how the row address and column readout modules are arranged in groups for each detector module type. The low TES count detectors have one row address and one column readout module, the high count have 1 row address module and 3 column readout modules. Group more modules to have less cables from cryostat to rack mounted power supply and network switch, tbd).

RO-SAT-0655 48V-to-12V DCDC supplies on flange

The SAT shall mount one Readout supplied 48V/12V DC converter module specified in drawing tbd in between two groups of 4 connectors. (If there are 12 groups -> 6 converters)

RO-SAT-0660 48V Power connections from 48V/12V DC converter modules to bulk supply in rack

The SAT shall route one SAT supplied 48V power cable specified in drawing tbd from each 48V/12V DC converter module to the rack mounted power supplies. (This may require cable trays and routing through various parts of moving SAT systems.)

RO-SAT-0665 48V Power wire length from 48V/12V DC converter module to bulk supply in rack

The maximum length of the SAT supplied 48V power cable from rack supplies to 48V/12V DCDC converter modules shall be 10m (tbc).

(Readout needs to know the maximum length from SAT in order to specify the gauge of the cable wires). (Info: if groups of 8 warm boards with maybe 12W tbd each then about 100W at 48V => 2A. For e.g. that is 4 ohm per 1000 ft at 16 AWG: for 15 feet cable one-way distance => 0.24 ohm round trip or 0.48V round trip drop. However multi-pair wire cables will be used not just for wire redundancy)

RO-SAT-0670 Maximum 12V Power wire length from readout groups to 48V/12V DC converter modules.

The maximum length of 12V power cable from 48V/12V DC converter module to warm electronics boards shall be 1 m (tbc).

RO-SAT-0675 Minimum distance from readout groups to 48V/12V DC converter modules

The minimum distance to mount the DC converters from the Readout modules is 10 cm (tbc). (Conservative separation of DC converter and readout Modules in space for noise reasons).

RO-SAT-0680 Ethernet connections from readout groups to network switches in rack

The SAT shall route one tbd network cable specified in drawing tbd from each module group to the rack mounted network switches. (This may require cable trays and routing through various parts of moving SAT systems.)

3.8 RF Shielding

RO-SAT-0800 Gasket sealing material and cleanliness at vacuum flanges

tbd

RO-SAT-0810 Gasket sealing material and cleanliness grounding connection

tbd

3.9 Vibration

RO-SAT-0900 Maximum mechanical vibration to cryo electronics. (This specification will be moved to Readout-MAT ICD, keep for now until verified that it was added.

The maximum vibration for cryo electronics shall be less than tbd. (Vibration->heat->signal change as well as capacitance change to e.g. ground)

3.10 Component Cleaning and ESD

RO-SAT-1000 Readout component cleanliness

The cryo and cold Readout electronics shall be cleaned according to doc tbd before delivering to SAT. (Intend is that SAT does not make it dirtier than received)

RO-SAT-1010 ESD handling

Readout components to be handled according to the ESD CMB-S4 document tbd. (There should be a project wide ESD doc.)

RO-SAT-1020 ESD bagging

Readout components to be stored and transported in ESD bags.

4. Electrical Power

4.1 Power

For now it is assumed that each optics tube has its own 48V rack-mount power supply. Eventually a common supply for a SAT might be considered, tbd. Power for a specific SAT depends on the type of tubes in each SAT.

Example is the Wiener PL512 Power Supply System

- https://www.wiener-d.com/product/pl512-power-supply-system/
- up to 12 channels at 250W each
- Dimensions: 430mm x 3U (133mm) x 325mm [whd].
- Weight:19 kg with 12 modules.

RO-SAT-1100 Power to rack-mount HF 48V power supplies in operation

The SAT shall supply power to the HF 48V supplies providing the operational power draw of the supplies. See table 2 for break-down of output power of supplies required by the optic tube type in operation. Note: This is to expected power needs in operation from the Southpole power generator.

Optics Tube Type	Total number of 300K Row Address Modules per tube	Total Number of 300K Readout Modules per tube	Total power (W) Row Address Modules assuming 15W tbd each	Total Power (W) Readout Modules, assuming 20W, tbd each	Total power per tube (W)
HF	12	36	180	720	900

Table 2: Warm electronics power for HF tube

RO-SAT-1105 Maximum Power to rack-mount HF 48V power supplies

The SAT shall supply power to the HF 48V supplies providing the maximum power draw of the supplies. Assuming the Wiener supply with 5 channels loaded, the maximum load is 1,250W output power for the HF. Requiring input power at 90% efficiency of 1.4kW or 12A from 110V. Note: this requirement is to make sure the wiring/breakers are sized appropriately.

RO-SAT-1110 Power to rack-mount MF 48V power supplies in operation

The SAT shall supply power to the MF 48V supplies providing the operational power draw of the supplies. See table 3 for break-down of output power of supplies required by the optic tube type in operation. Note: This is to expected power needs in operation from the Southpole power generator.

Optics Tube Type	Total number of 300K Row Address Modules per tube	Total Number of 300K Readout Modules per tube	Total power (W) Row Address Modules assuming 15W tbd each	Total Power (W) Readout Modules, assuming 20W, tbd each	Total power per tube (W)

MF	12	24	180	480	660

Table 2: Warm electronics power for MF tube

RO-SAT-1115 Maximum power to rack-mount MF 48V power supplies

The SAT shall supply power to the MF 48V supplies providing the maximum power draw of the supplies. Assuming the Wiener supply with 4 channels loaded,the maximum load is 1,000W output power for the MF. Requiring input power at 90% efficiency of 1.1kW or 10A from 110V. Note: this requirement is to make sure the wiring/breakers are sized appropriately.

RO-SAT-1120 Power to rack-mount LF 48V power supplies in operation

The SAT shall supply power to the LF 48V supplies providing the maximum power draw of the supplies. See table 4 for break-down of output power of supplies required by the optic tube type in operation. Note: This is to expected power needs in operation from the Southpole power generator.

Optics Tube Type	Total number of 300K Row Address Modules per tube	Total Number of 300K Readout Modules per tube	Total power (W) Row Address Modules assuming 15W tbd each	Total Power (W) Readout Modules, assuming 20W, tbd each	Total power per tube (W)
LF	12	12	180	240	420

Table 4: Warm electronics power for LF tube

RO-SAT-1125 Maximum power to rack-mount LF 48V power supplies

The SAT shall supply power to the LF 48V supplies providing the maximum power draw of the supplies. Assuming the Wiener supply with 2 channels loaded,the maximum load is 500W output power for the LF. Requiring input power at 90% efficiency of 560W or 5A from 110V. Note: this requirement is to make sure the wiring/breakers are sized appropriately.

RO-SAT-1130 Uninterruptible Power Supply (UPS) Power to rack-mount equipment

The SAT shall provide 110VAC/60Hz UPS power for the Readout equipment lasting at least 1 hour (tbd) in full observing mode via 110 VAC (South-Pole) receptacles type tbd.

RO-SAT-1135 Power load sharing to rack-mount equipment

The SAT shall not connect any motors or pumps to the 110V phase to the Readout equipment.

RO-SAT-1140 Rack space and weight for 48V power supplies

The SAT shall provide 3 times 3U air cooled rack space 19-inch wide 24-inch deep for 3 48V power supplies, one per tube

(Example is Wiener PL512 Power Supply System

- https://www.wiener-d.com/product/pl512-power-supply-system/
- up to 12 channels at 250W each (~75W required, tbd)
- Dimensions: 430mm x 3U (133mm) x 325mm [whd].

- Weight:19 kg with 12 modules.

RO-SAT-1145 Rack space and weight for network switches

The SAT shall provide 1u rackspace 19-inch wide 24-inch deep for each of three network switches with a weight each of 10 Kg (tbd).
(e.g. S5850-48T4Q, 48-Port Ethernet L3 Switch, 48 x 10GBASE-T, with 4 x 40Gb QSFP+)

RO-SAT-1150 Power to rack-mount network switches

The SAT shall supply 200 W(tbd) power to each of the rack-mount network switches.

RO-SAT-1180 Rack space and weight for Fiber optics distribution panel

The SAT shall provide 2 x 1u rackspace 19-inch wide 24-inch deep for the fiber distribution panels with a weight of 2.5 Kg each.

5. Thermal Heat Requirements and Loads

5.1 Cryo Electronics

There is no direct thermal connection between Readout and SAT. That connection is between Readout and Modules so see that ICD. For now just keep the headers until confirmed.

RO-SAT-1200 Cryo electronics Heat load to 100mK heat sink

RO-SAT-1210 Cryo electronics required operational temperature range :

RO-SAT-1220 Cryo electronics required temperature stability (rate of change):

RO-SAT-1230 Cryo electronics required temperature spatial gradient:

5.2 100mK to 4K Cable

(Note: eventually will need to list requirements for each heat-sink separately)

RO-SAT-1300 100mK to 4K Cable Heat load to 100mK heat sink

The SAT shall accommodate cable heat load up to tbd W for each cable heat-sink. But baseline is that there is no 100mK heat sink on cables, tbd.

RO-SAT-1310 100mK to 4K Cable Heat load to 1K heat sink

The SAT shall accommodate cable heat load up to tbd W for each cable heat sink (or total across cables)

RO-SAT-1320 100mK to 4K Cable Heat load to 4K heat sink

The SAT shall accommodate cable heat load up to tbd W for each cable heat sink (or total across cables)

RO-SAT-1330 100mK to 4K Cable required operational temperature range at 1K plate

The SAT shall keep the cable heat-sinks within ##mK - ##mK temperature.

RO-SAT-1340 100mK to 4K Cable required temperature stability (rate of change) at 1K plate:

The SAT shall keep the cable at better than # mK/s temperature stability.

RO-SAT-1350 100mK to 4K Cable required temperature spatial gradient at 1K plate

The SAT shall keep the cable at better than # mK/m spatial temperature stability.

RO-SAT-1360 100mK to 4K Cable required operational temperature range at 4K plate

The SAT shall keep the cable heat-sinks within ##mK - ##mK temperature.

RO-SAT-1370 100mK to 4K Cable required temperature stability (rate of change) at 4K plate:

The SAT shall keep the cable at better than # mK/s temperature stability.

RO-SAT-1380 100mK to 4K Cable required temperature spatial gradient at 4K plate

The SAT shall keep the cable at better than # mK/m spatial temperature stability.

5.3 4K Cold Electronics

RO-SAT-1400 Cold electronics Heat load to 4K heat sink

The SAT shall accommodate module heat load up to tbd W for each module.

RO-SAT-1410 Cold electronics required operational temperature range

The SAT shall keep the module bracket interface to the SAT within ##mK - ##mK temperature.

RO-SAT-1420 Cold electronics required temperature stability (rate of change)

The SAT shall keep the module bracket interface to the SAT at better than # mK/s temperature stability.

5.4 4K to 300K Cable

(Note: eventually will need to list requirements for each heat-sink separately)

RO-SAT-1500 4K to 300K Cable Heat load to 4K heat sink

The SAT shall accommodate heat load up to tbd W for each heatsink (or total across cables)

RO-SAT-1510 4K to 300K Cable load to 40K heat sink

The SAT shall accommodate heat load up to tbd W for each heatsink

RO-SAT-1520 4K to 300K Cable sink required operational temperature range

The SAT shall keep the heat-sinks within ##mK - ##mK temperature.

RO-SAT-1530 4K to 300K Cable heat-sink required temperature stability (rate of change)

The SAT shall keep the heat-sinks at better than # mK/s temperature stability.

RO-SAT-1540 4K to 300K Cable heat-sink required temperature spatial gradient

The SAT shall keep the cable heat-sinks at better than # mK/m spatial temperature stability.

5.5 Warm electronics cooling

RO-SAT-1600 Row address module liquid cooling

The SAT shall liquid cool the modules with a power consumption up to 15W tbd for each module.

RO-SAT-1610 Column readout module cooling

The SAT shall cool the module with a power consumption up to 20W tbd for each module.

RO-SAT-1620 Cooling liquid

The SAT shall cool the modules with water (tbd whether Glycol?).

RO-SAT-1630 Cooling liquid pressure

The SAT shall cool the modules with a maximum pressure at the modules of tbd.

RO-SAT-1640 Cooling liquid flow-rate

The SAT shall cool the modules with a maximum flow-rate at the modules of tbd.

RO-SAT-1650 Flow impedance through module

The maximum flow-impedance through each module shall be tbd.

RO-SAT-1660 Warm module temperature range

The SAT shall keep the modules within a temperature range of 18C (tbc, above dew point at location) to 40C (tbc)

RO-SAT-1670 Warm module temperature gradient across all modules

The SAT shall keep the modules at less than 5C tbd temperature gradient across all modules.

RO-SAT-1680 Warm module temperature stability

The SAT shall keep the modules at less than 5K/h tbd temperature stability.

RO-SAT-1690 Warm module thermal interface fitting

The SAT shall connect the cooling pipes to tbd part number fitting at the module interface.

6 Equipment Protection for Warm Electronics

Note: Although a sub-system is supposed to protect itself during operation, in this case the cooling system is provided by SAT so SAT can monitor pressures and temperatures in pipes and turn off bulk supply power, tbd).

RO-SAT-1700 Equipment Thermal Low Temperature survival

The Warm Readout electronics shall not be exposed to temperatures below -20C.

RO-SAT-1710 Equipment Thermal High Temperature survival

The Warm Readout electronics shall not be exposed to temperatures above 80C.

RO-SAT-1720 Maximum shock to cold electronics

The Readout equipment shall not be exposed to mechanical shock above 100 g (tbd)

RO-SAT-1730 Warm electronics cooling pipe flow rate

The SAT shall monitor the incoming and outgoing flow rate in the cooling pipes and turn off power to the Warm Readout electronics if either flow-rate is outside the limits tbd.

RO-SAT-1740 Warm electronics temperature low limit during operation

The SAT shall monitor the incoming and outgoing temperature in the cooling pipes and turn off power to the Warm Readout electronics if either temperature is below 16C (tbd, below dew point).

RO-SAT-1750 Warm electronics temperature high limit during operation

The SAT shall monitor the incoming and outgoing temperature in the cooling pipes and turn off power to the Warm Readout electronics if either temperature is above 50C (tbd).

7. Grounding and Shielding

RO-SAT-1800 Grounding and Shielding

SAT to follow CMB-S4 grounding and shielding plan doc tbd.

8. 4K Temperature monitoring

RO-SAT-1900 4K SSA temperature monitoring

SAT shall procure and install temperature monitoring cables from SSA modules, cables specified by Readout. (SAT is responsible that those sensors are monitored by DAQ).
(Note: row address modules have no active components at 4K)

8 Questions