Integration, Validation, and Calibration of the SO SAT

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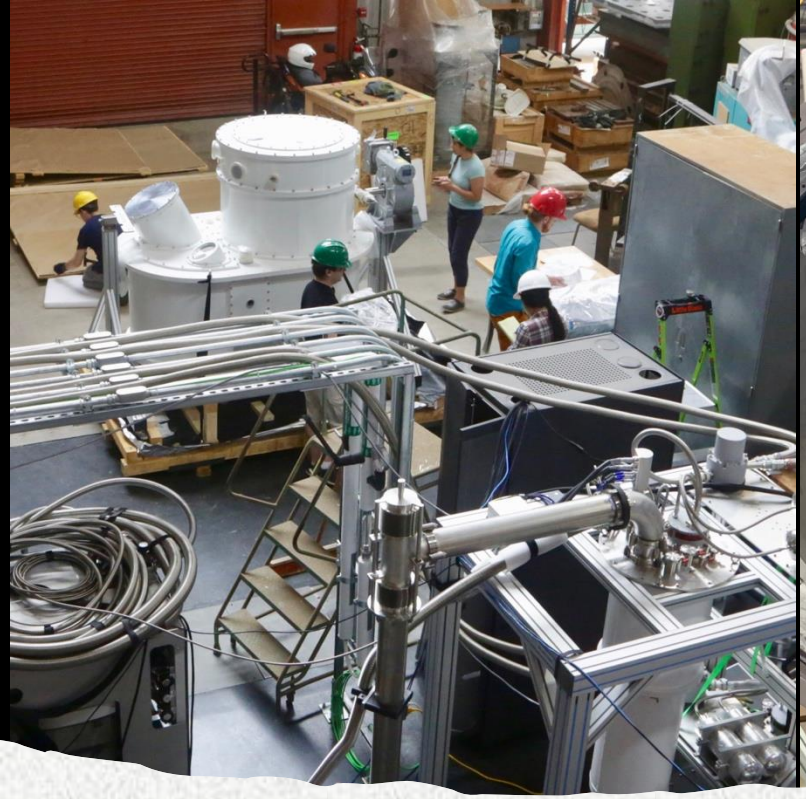
CMB-S4 Spring Collaboration Meeting

JSAC Talk. March 25, 2025.

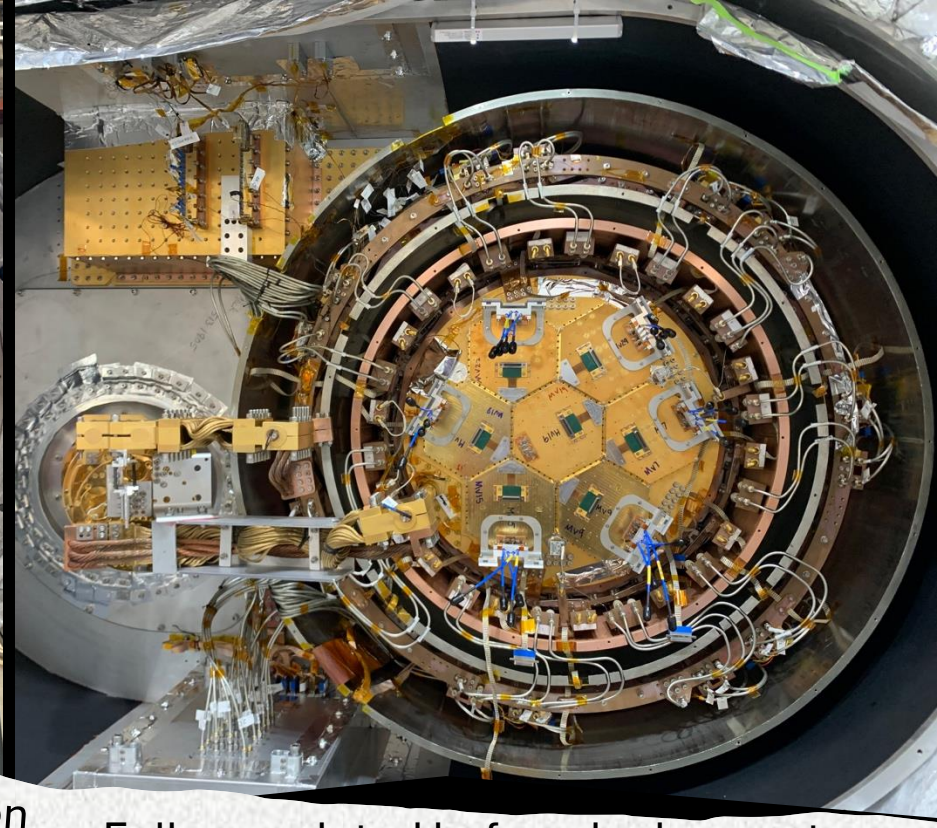
Simons Observatory

Credit: SO Collaboration



SAT arrival at UCSD

The backend before subsystem installation



Fully populated before deployment

SAT-MF1 Lab Integration & Testing

The first SAT arrived at UCSD for testing and integration. The SAT went through different validation of the subsystems and reviews before its deployment to Chile.

UCSD

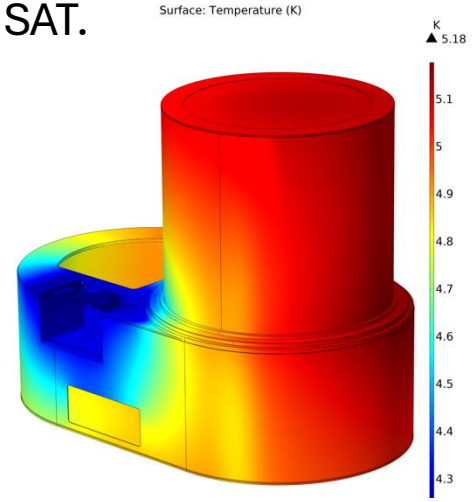
Integration & Testing Process

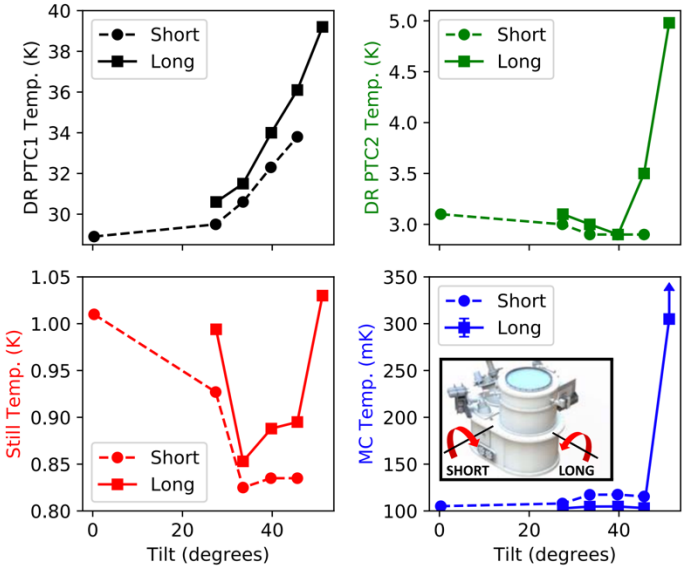
Subsystems (e.g. dilution refrigerator, pulse tube) arrived . Validated them individually.

Integrated the components inside the telescope.

credit: Nick Galitzki

Tested and re-validated the components to understand their contribution to the environment inside the SAT.

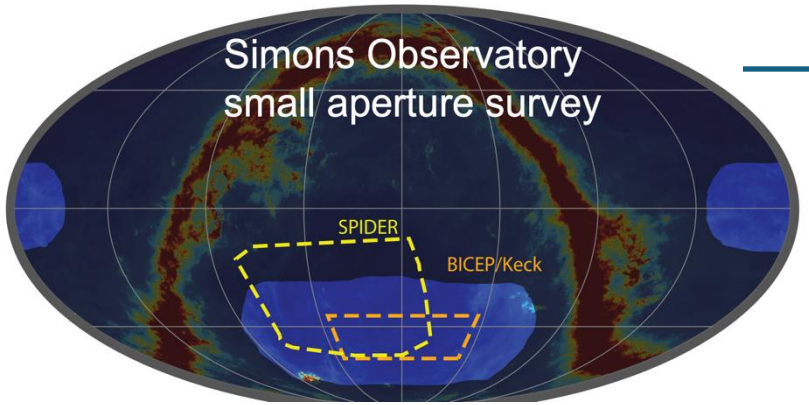




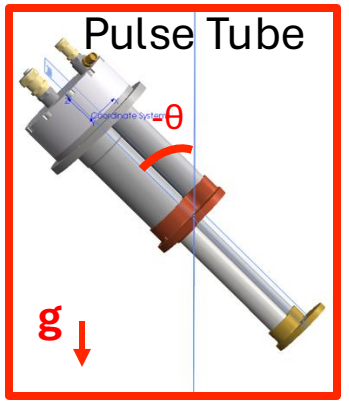
credit: N. Galitzki, T. Tsan, et al. (2024)

Cryogenic Validation for SAT-MF1

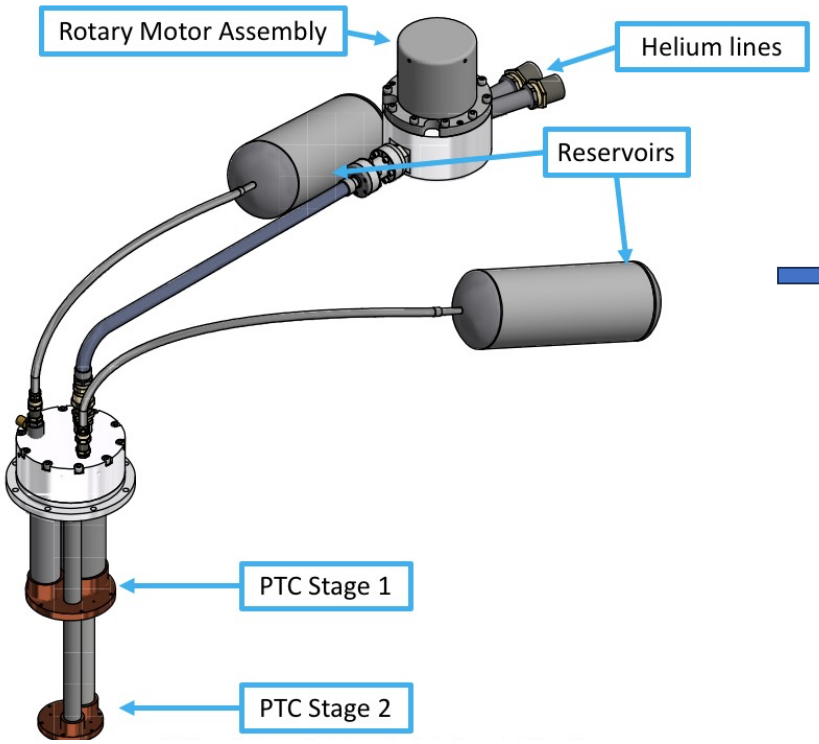
Investigate various cooling subsystems (e.g. pulse tube, dilution refrigerator, heatstrap, etc.) to ensure that the cryostat meets the thermal budget.

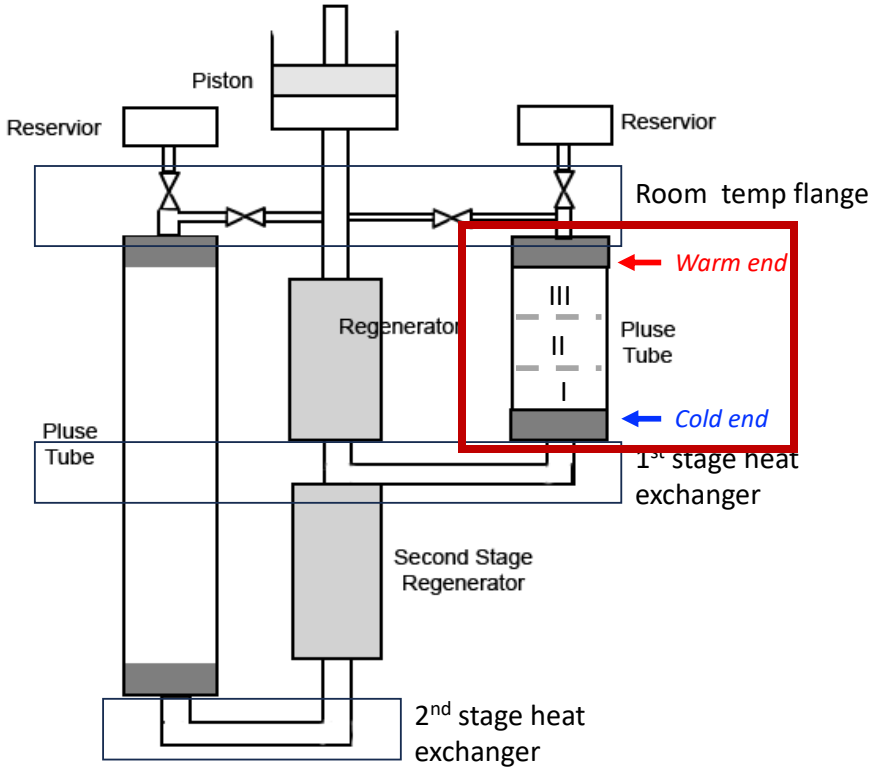


credit: SO forecast paper

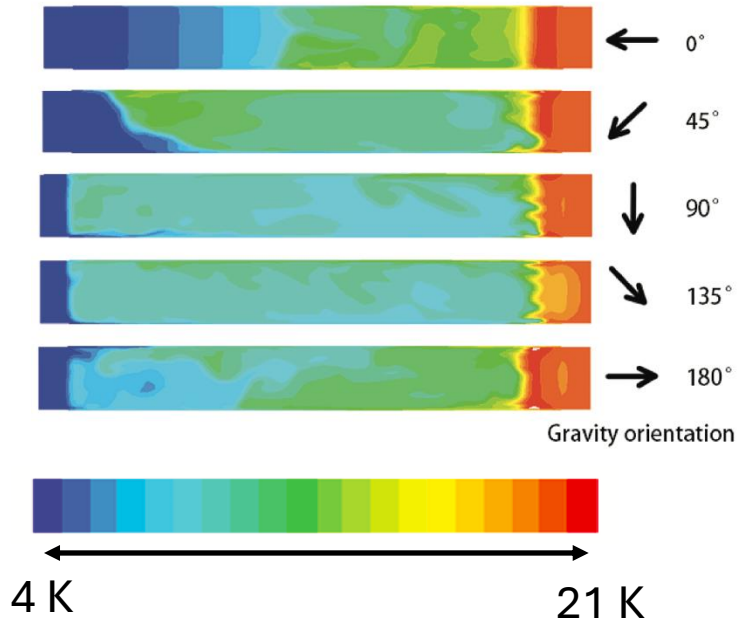


Cryogenic validation: The pulse tube cryocooler (PTC) structure and how it operates





Credit: Fang et al. (2016)

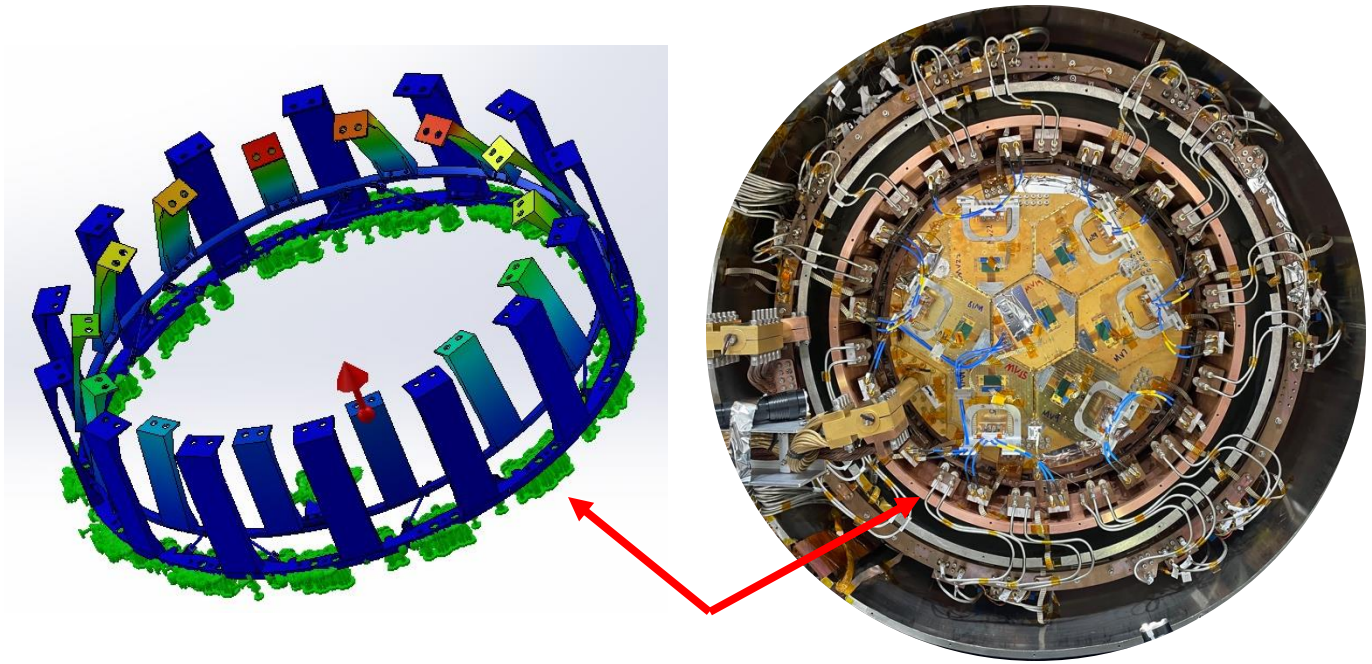


Sim for high frequency pulse tube so only for conceptual purpose. It's not for the PTC I'm investigating.

The gas inside the pulse tube creates a thermal gradient through the adiabatic process, which then cools the sample on the heat exchangers during depressurization.

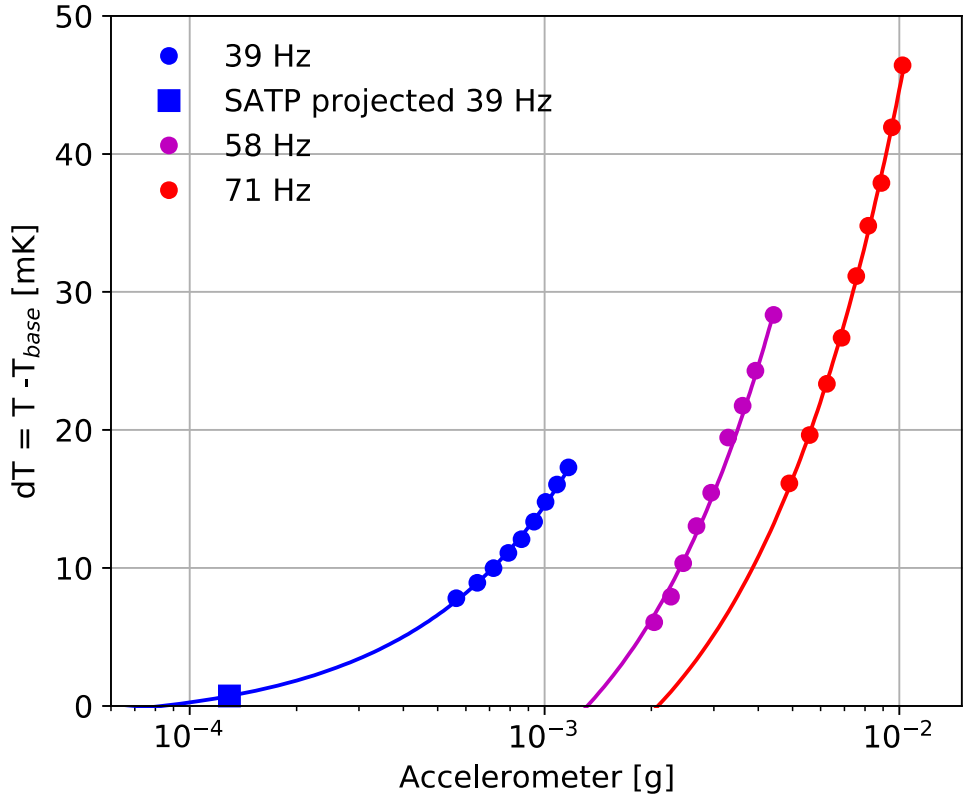
Vibration Testing: Assessing the vibrational coupling of the SAT's mechanical system.

- Identified resonant modes from mechanical structures inside the SAT using Solidworks vibration simulation.
- Designed vibration/shake tests and assessed the thermal impact.
- Extrapolated the results to what we would expect during an actual observation scan on the platform.



Solidworks vibration simulation of the SAT's **cold readout assembly (CRA)** from 1-0.1K.

Minimal heating (~1 mK) due to vibration coupling. This temperature fluctuation can be managed through temperature control programming (PID).

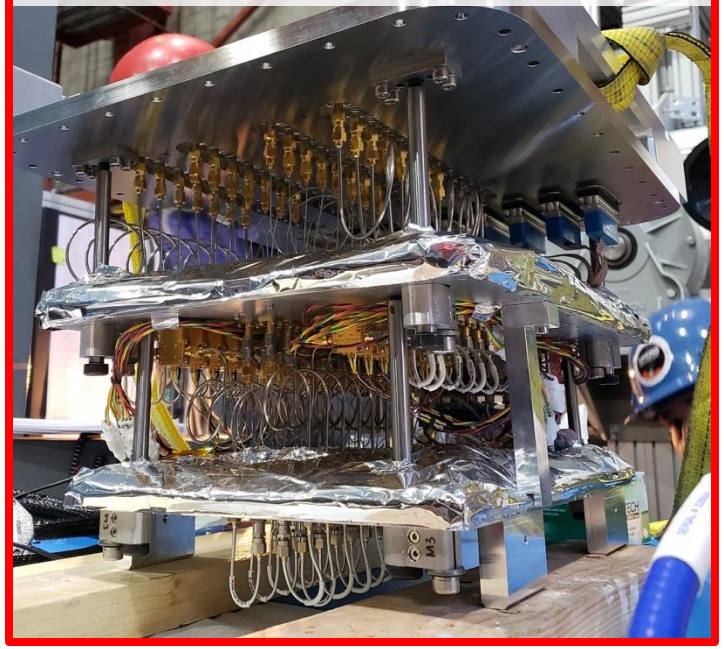


N. Galitzki, T. Tsan, et al. (2024)

RF Transmission Model Development: Health Check For All the Readout Chains

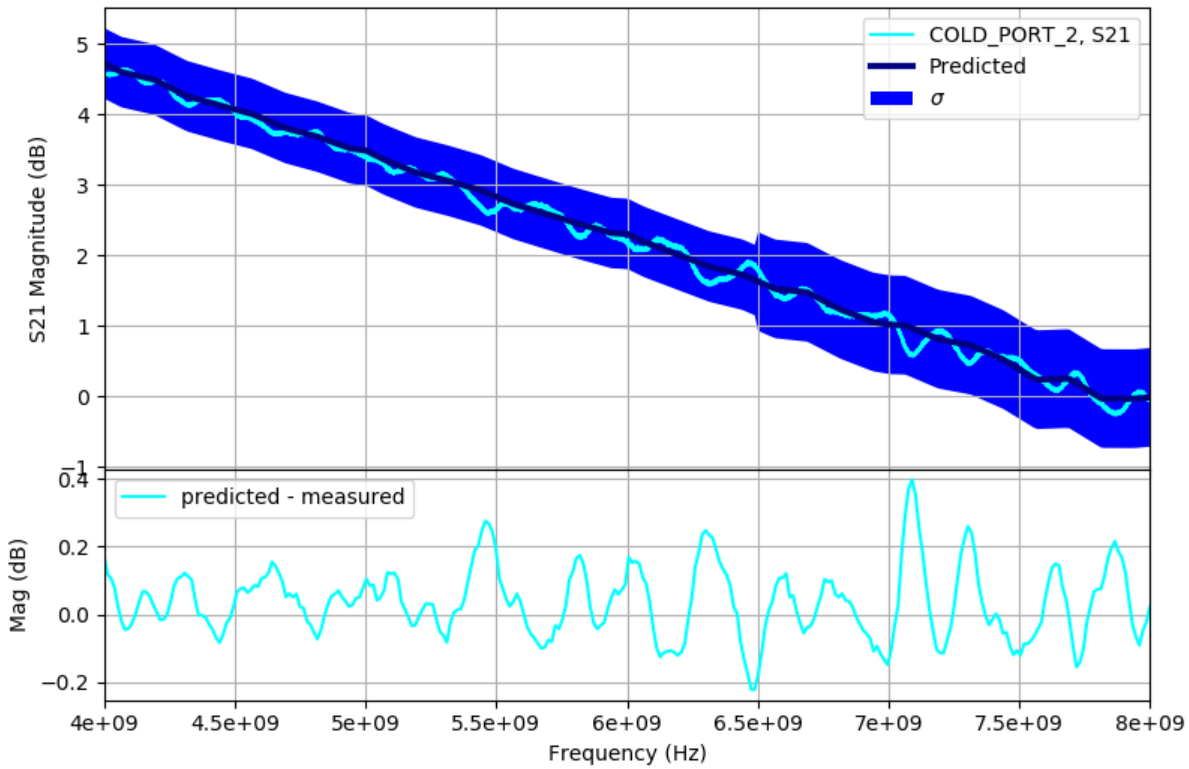
- Developed a radio frequency (RF) transmission model to predict the SAT readout chains' performance.
- Used model to health check the RF system.
- Set pass/fail criteria and established it as standard for testing at UCSD and within the collaboration, spanning various receivers.

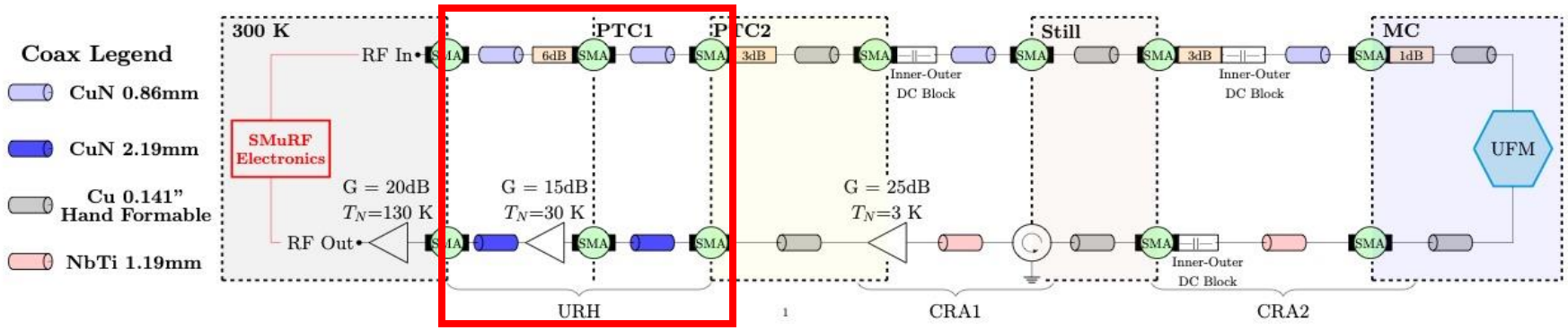
Universal Readout Harness (URH) on the benchtop



Tested model on the entire readout chain inside the SAT and measurement aligns well with prediction. All the readout chains worked as expected.

URH cold transmission: measurement vs prediction

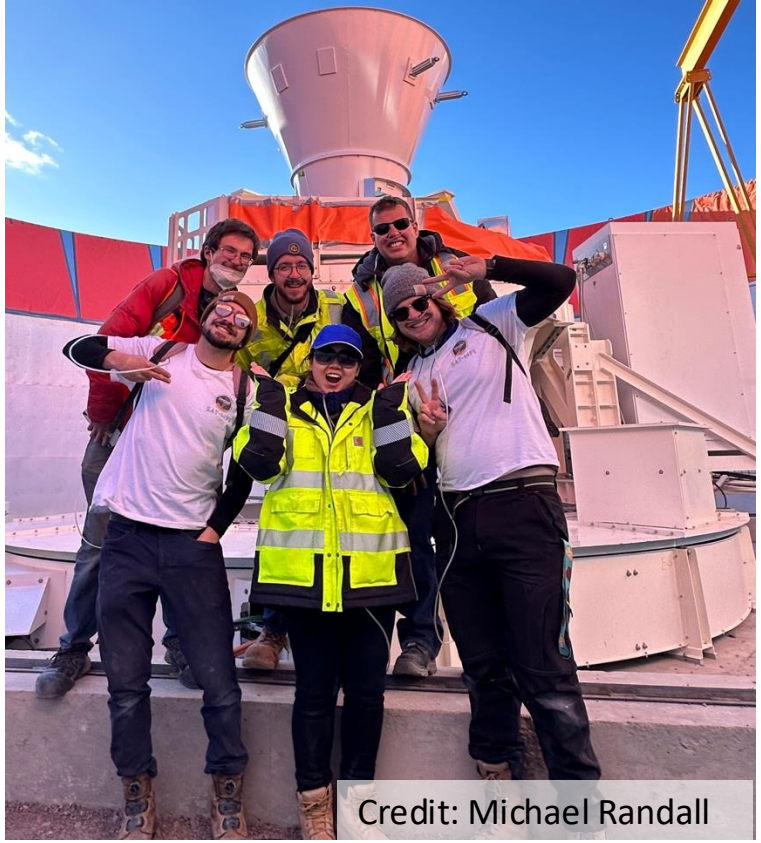




Credit: N. Galitzki, T. Tsan, et al. (2024)

Site Deployment

Credit: Katie Harrington



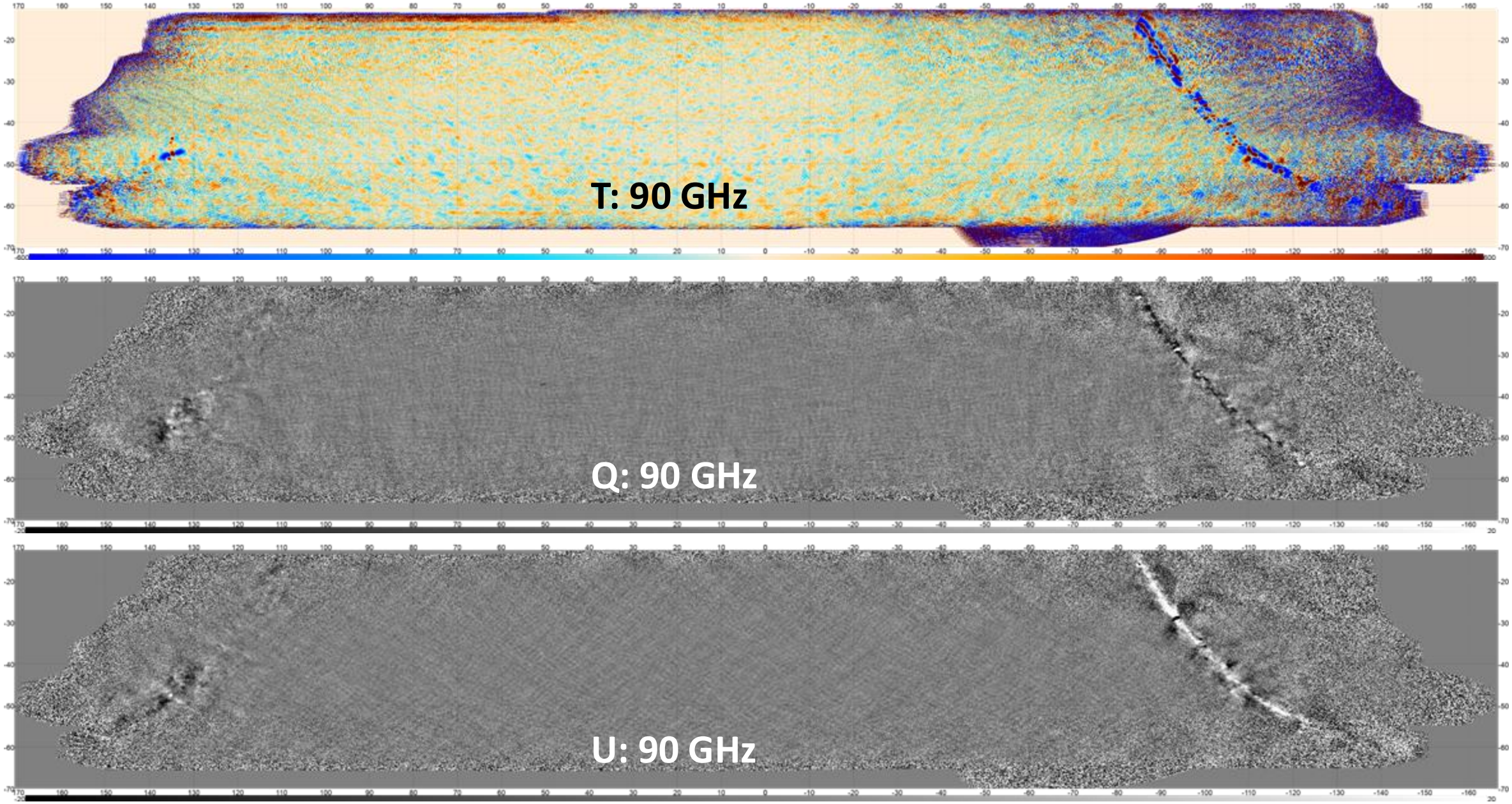
Credit: Michael Randall

SAT-MF1's Installation Onto Its Platform

- Completed integration onto the platform (SATP) and operation to test SATP in elevation, azimuth, and boresight rotation.
- SAT-MF1 achieved its first light in October 2023.
- All three SATs are deployed and operating, moving toward initial science operation.

Preliminary 90 GHz SAT Maps

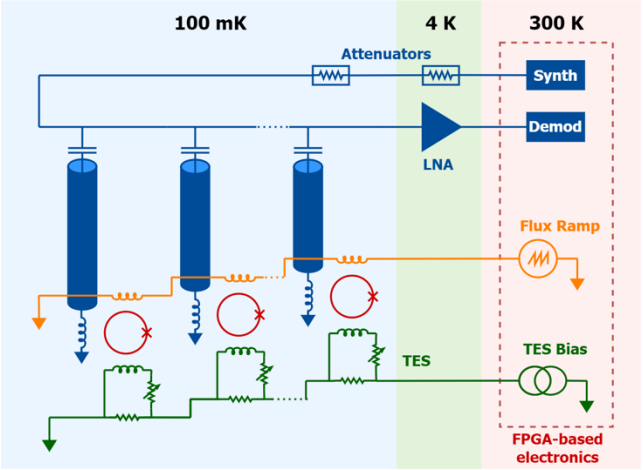
Credit: SO Collaboration

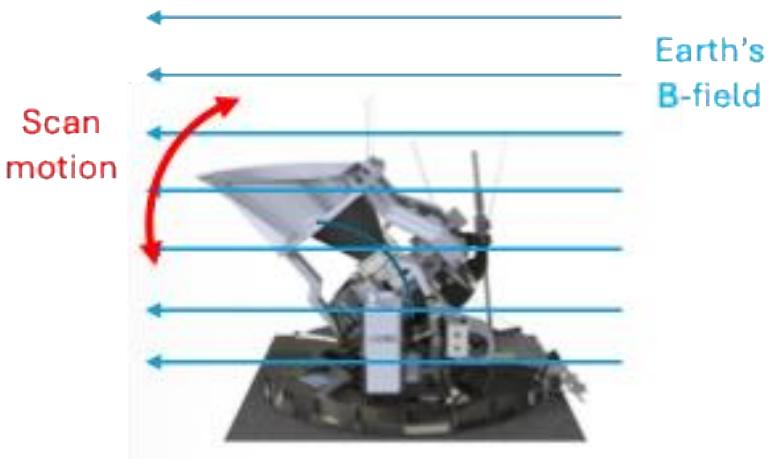


Current Projects

Investigating μmux readout systematic effects using SO data:

- Magnetic pickup
- Cross-talk
- Scan synchronous signal
- Temperature drift of readout components
- Glitches

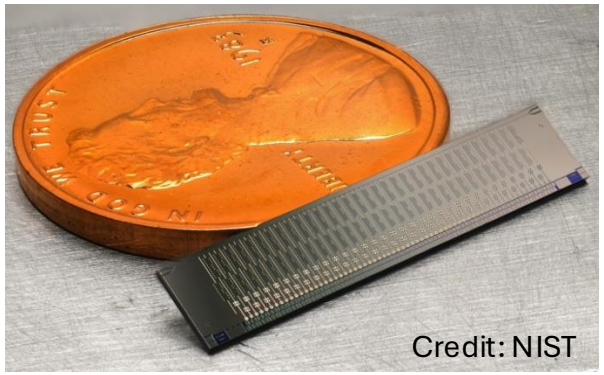




Credit: John Groh

Adapting μmux for low-mass dark matter searches:

Microwave SQUID multiplexing chip.



Credit: NIST

Testing μmux inside the dilution refrigerator.