



SIMONS OBSERVATORY

A STATUS UPDATE

SIMONE AIOLA

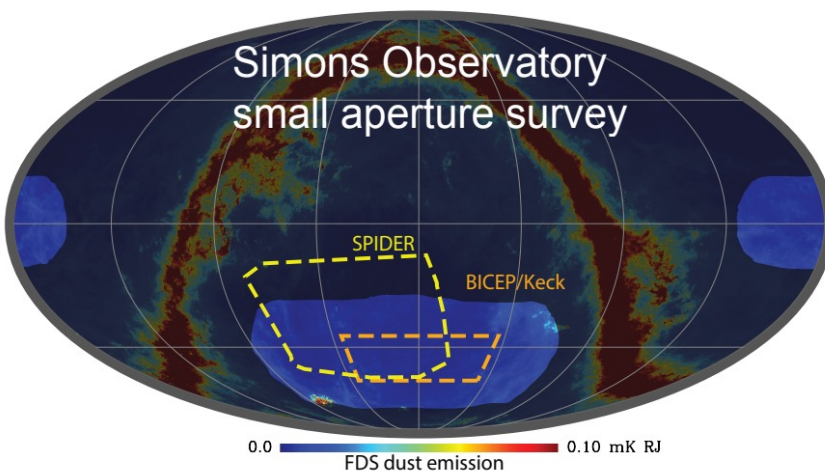
(CENTER FOR COMPUTATIONAL ASTROPHYSICS, NY)

SA3CC 04/19/2022

SIMONS FOUNDATION



SIMONS OBSERVATORY (SO) — MULTIFREQUENCY 5YR SURVEY AND SCIENCE GOALS

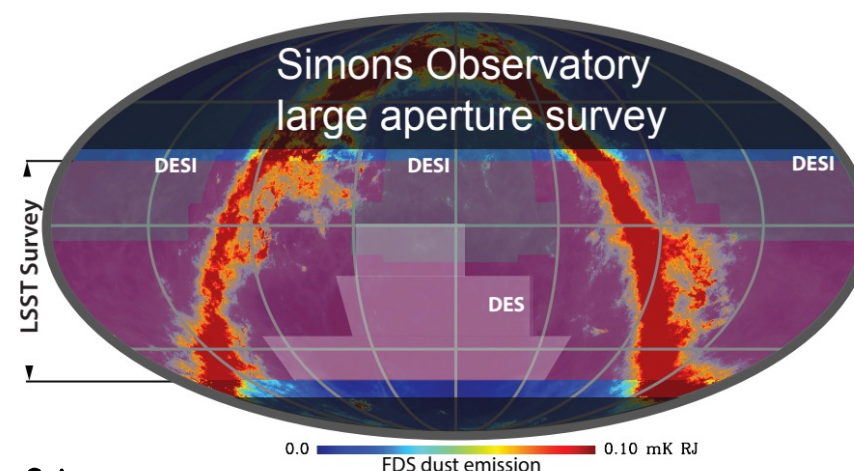


Science:

- high-risk, high-reward
- Signature of inflation

SAT Survey:

- low-dust 10% of the sky
- Large-Scale polarization, B-mode



Science:

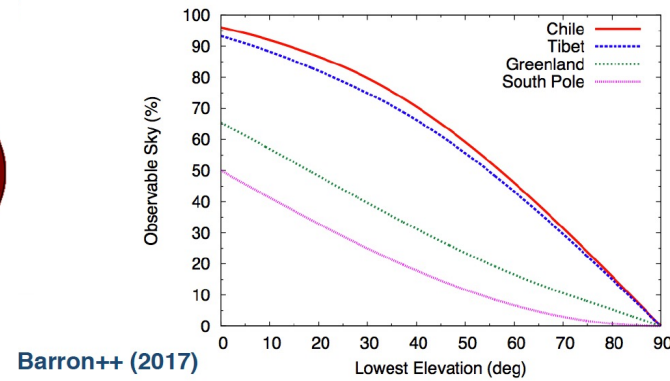
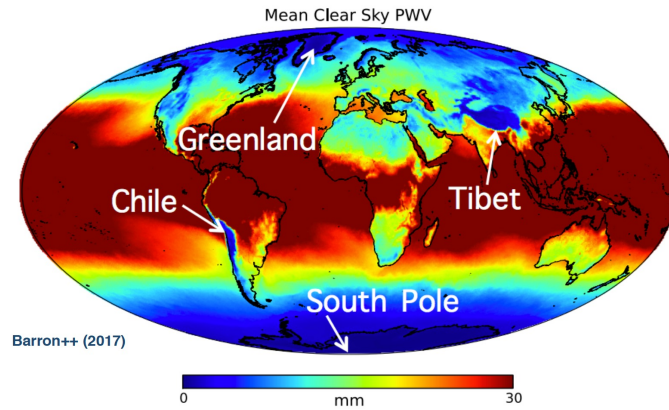
- Primordial perturbation
- Neutrino mass
- Relativistic species
- Reionization
- Dark energy
- Galaxy evolution
- Transients

LAT Survey:

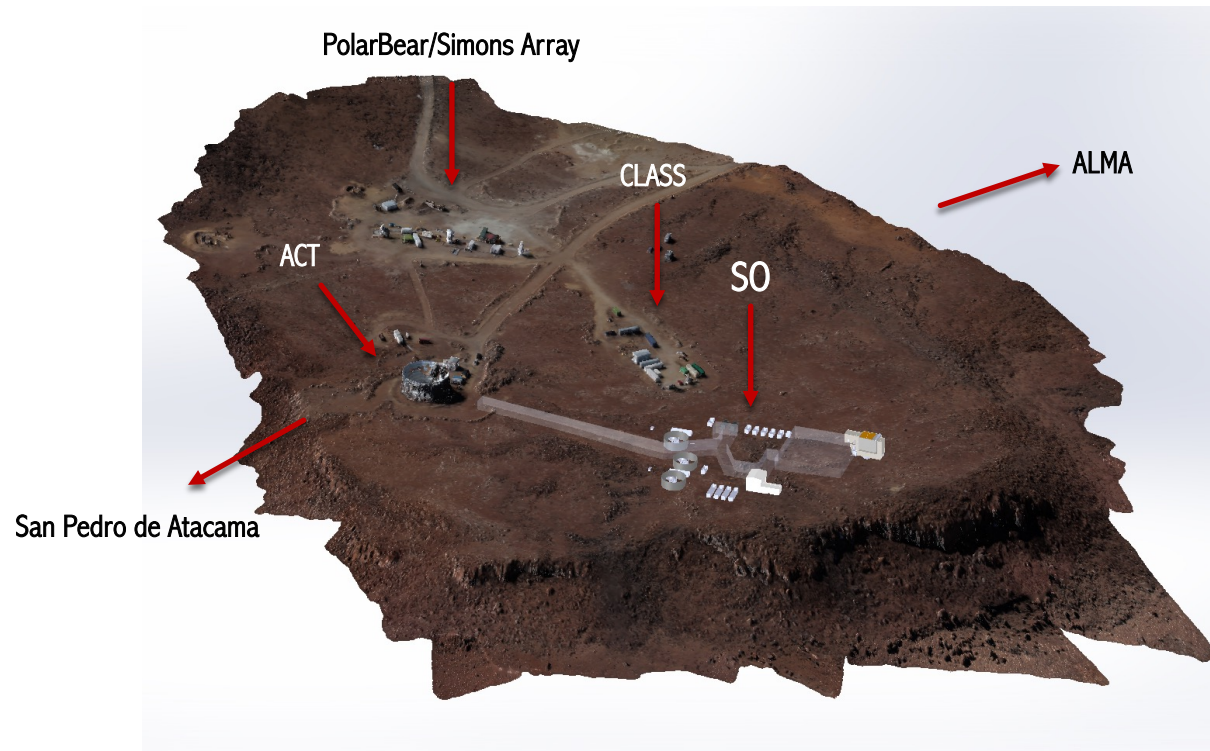
- 40% of the sky
- Overlap with Rubin Observatory/LSST and other LSS

Periodic data releases: CMB, lensing maps, source and cluster catalogs, transient events

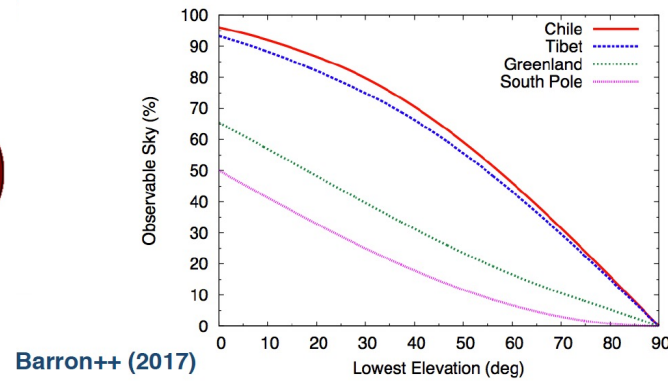
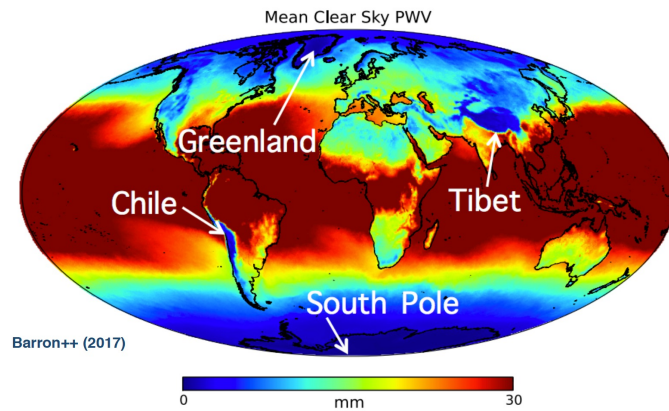
SIMONS OBSERVATORY (SO) — SITE



- Chajnantor plateau, Atacama Desert, Chile @5,190m a.s.l.
 - Ideal for ~half-sky measurements
- Median precipitable water vapor ~0.8mm
 - Ideal for 20-280 GHz measurements



SIMONS OBSERVATORY (SO) — SITE



- Chajnantor plateau, Atacama Desert, Chile @5,190m a.s.l.
 - Ideal for ~half-sky measurements
- Median precipitable water vapor $\sim 0.8\text{mm}$
 - Ideal for 20-280 GHz measurements



SAACC 2021 → SA3CC 2022

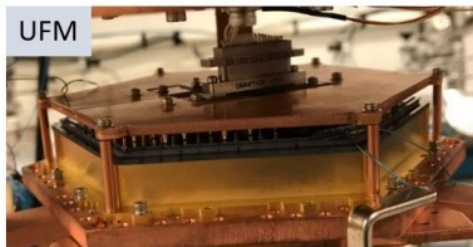
- SATs and LAT foundations are poured
- Computers at the site with connection by end of summer 2022



SIMONS OBSERVATORY (SO) — INSTRUMENTATION

Detectors:

70,000 dichroic detectors operating at 100 mK
Two different technologies



Large-Aperture Telescope (LAT)

6m primary mirror, 8deg FOV, 1.5' resolution @ 150 GHz
Largest cryogenic camera ever built for CMB experiments, 27-270 GHz detectors



LF (27/40 GHz), MF(90/150 GHz),
UHF (220/270 GHz)

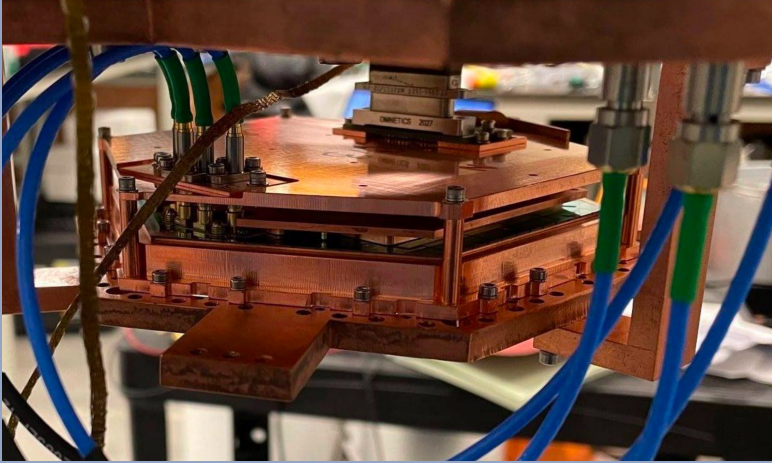
Small-Aperture Telescopes (SATs)

3 telescopes, 42-cm aperture, 35deg FOV, ~0.5deg resolution @ 150GHz
Cryogenic Half-Wave Plate to modulate polarization, 27-270 GHz detectors

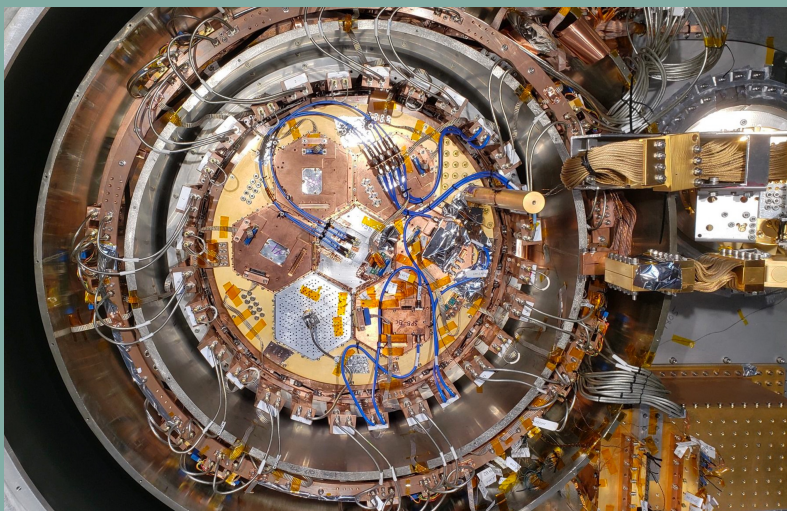
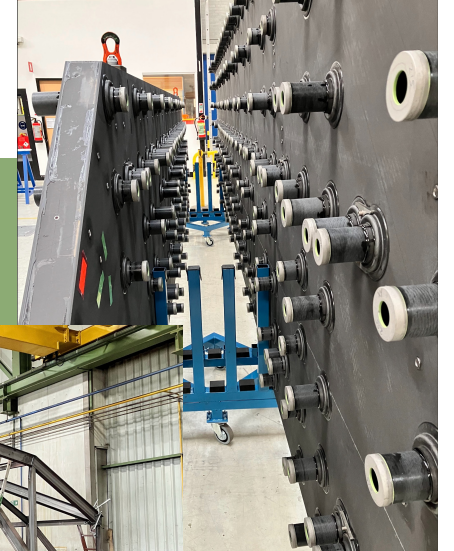
SIMONS OBSERVATORY (SO) — INSTRUMENTATION

SAACC 2021 → SA3CC 2022

Detectors:



Large-Aperture Telescope (LAT)

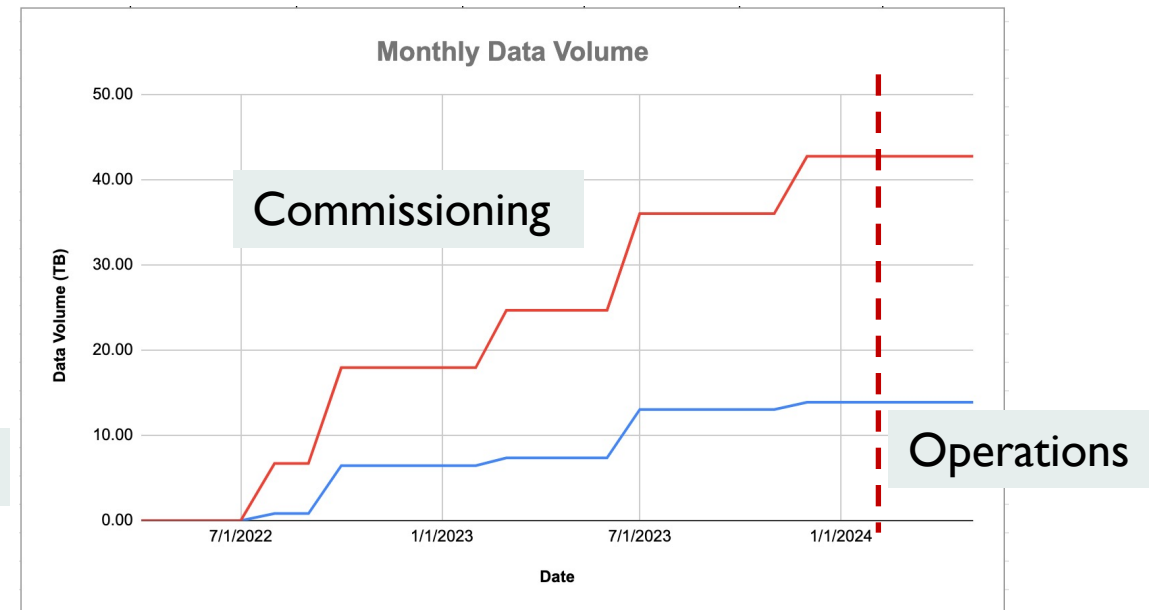
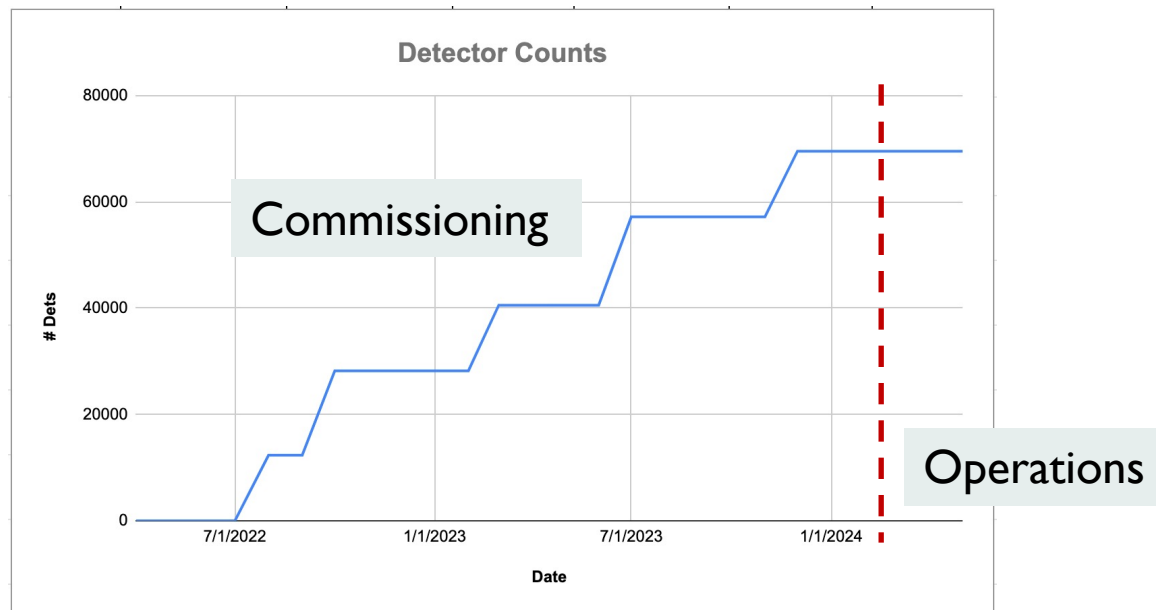


Small-Aperture Telescopes (SATs)



DATA RATES AND DATA VOLUME

- The data rate is dominated by detector time-streams (69,546 detectors) → 132 Mbps
 - SATs: 37,044 detectors, sampling [min, max]: 27-200 Hz (all frequencies same sampling, HWP dominating factor)
 - LAT: 32,502 detectors, sampling [min, max]: 30-340 Hz
- We baseline the higher data rate (red curve), but we could reduce it during operations depending on the instrument characterization
 - At current baseline rate, ~3PB of raw data for 5yr survey

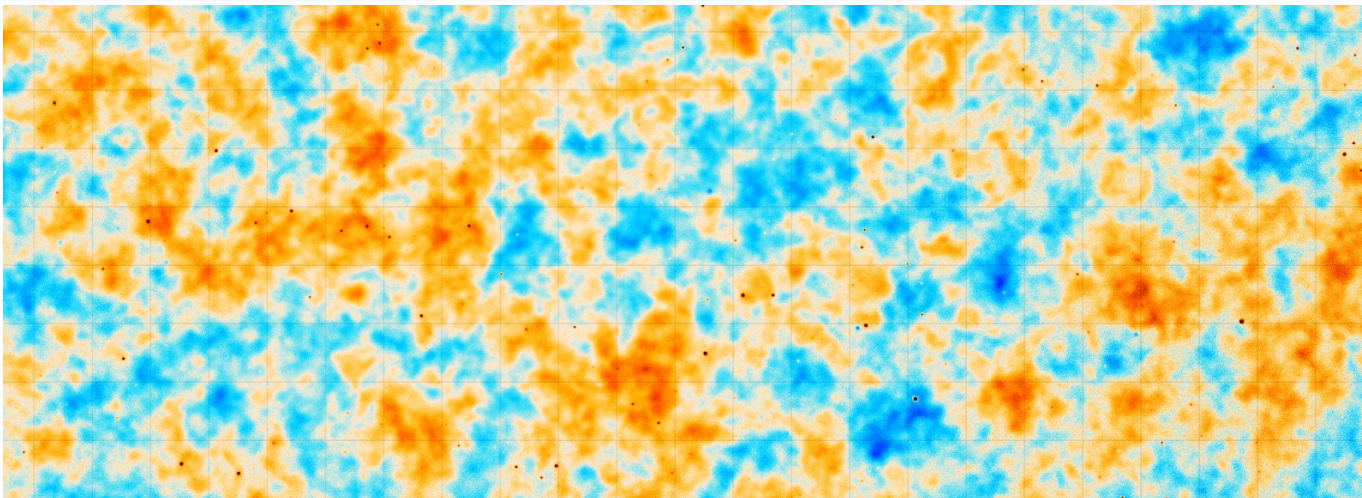
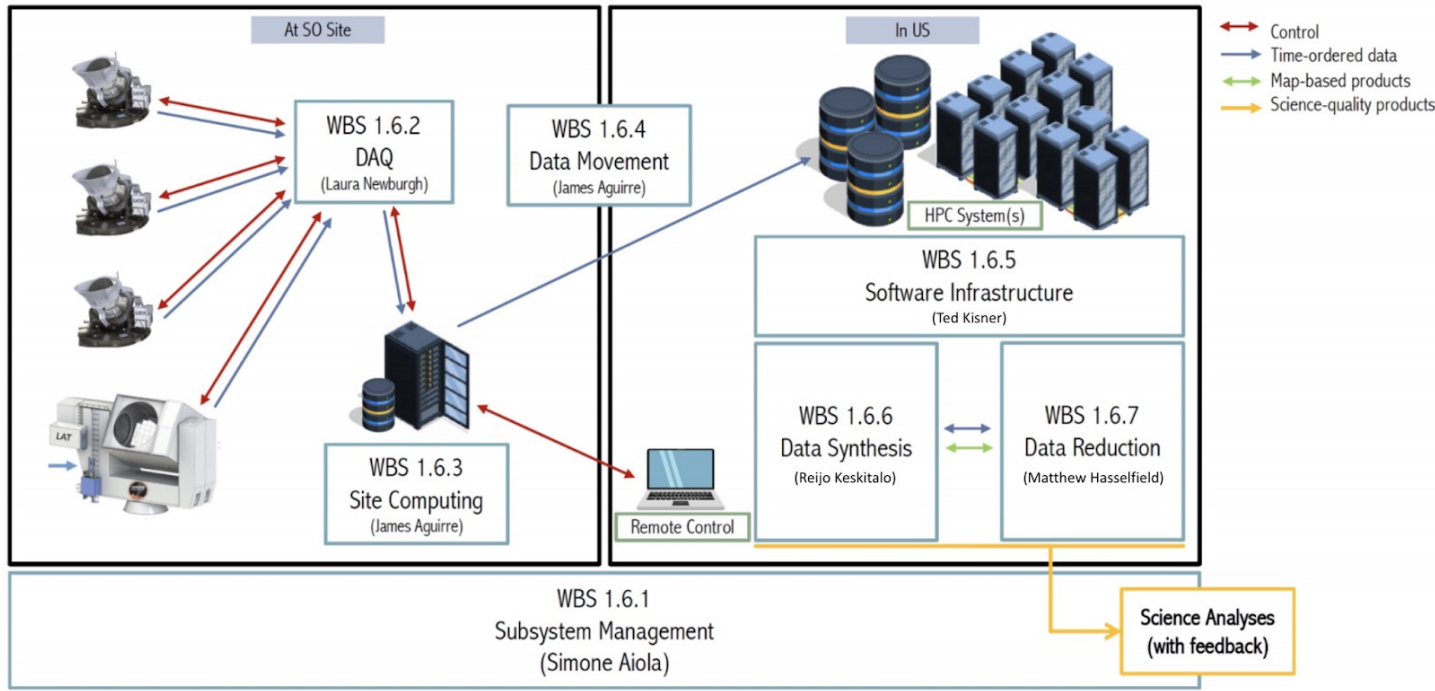


SIMONS OBSERVATORY (SO) — TIMELINE

Early '21	Mid '22	Early '23	Mid '24
Testing and integration, optical validation	First light for both SAT + LAT	First science observations expected	Full science observations expected

- SO Construction Project: 2016 - 2024
- SO Operations: 2024 – 2029/2030 (5yr survey + 1/2yr to finalize data reduction)

DATA MANAGEMENT



Open source philosophy. Most software is public on the 'simonsobs' GitHub account; Software Developers' Guide.

- An observatory control system to monitor and acquire data; software for live data viewing.
- Hardware infrastructure for computing at the SO site, and use of CMB community resources at NERSC.
- A software library to process raw time-ordered-data.
- A simulator of time-ordered-data, and simulations of observed sky maps.
- Software to perform quality cuts and calibrations.
- Software to turn time-ordered data into maps.

DATA MANAGEMENT

Observatory Control System + Data Acquisition (DAQ) system:

- *Current status:* [OCS](https://arxiv.org/abs/2012.10345) Fully developed (general + SO specific hooks), tested, documented and public on GitHub
- Adopted as DAQ baseline for CMB-S4
- Used in SO labs for testing and soon deployed at the site
- Includes: control and monitoring of hardware and site, data aggregation and collection, real-time visualization

The Simons Observatory: Overview of data acquisition, control, monitoring, and computer infrastructure
<https://arxiv.org/abs/2012.10345>

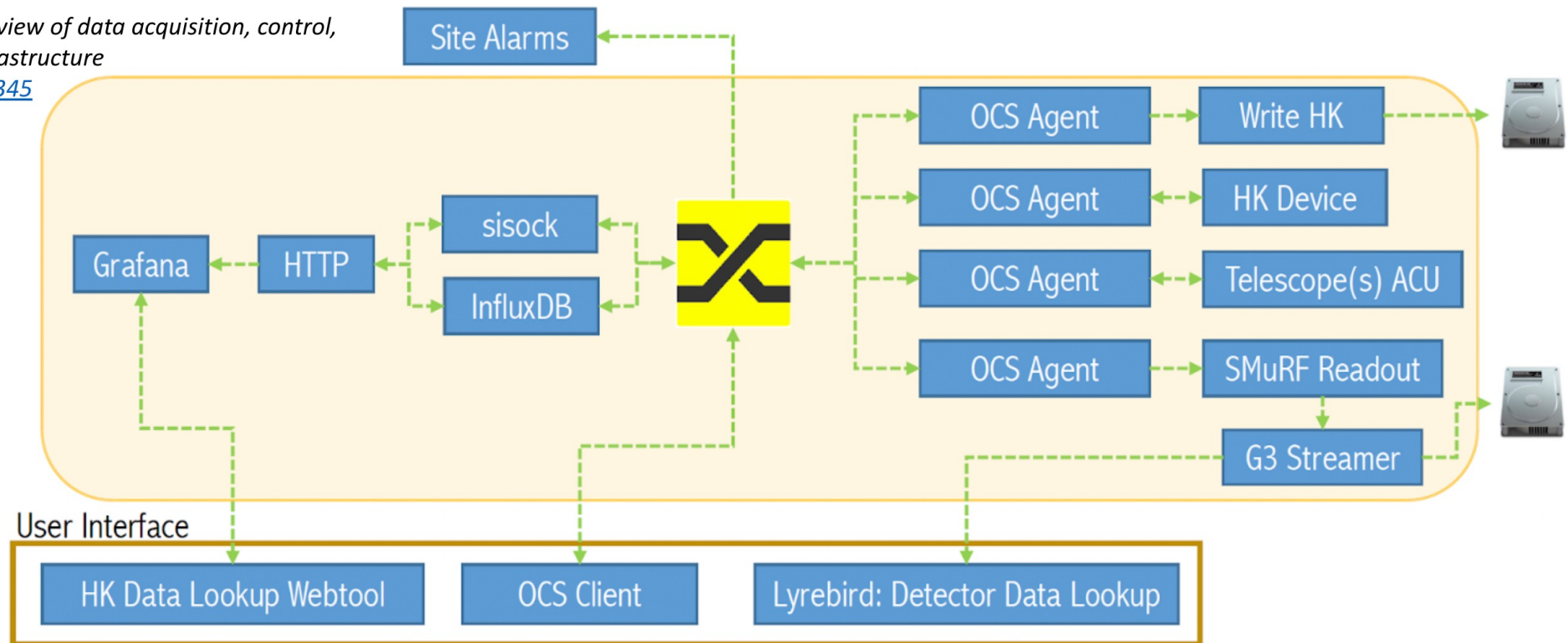
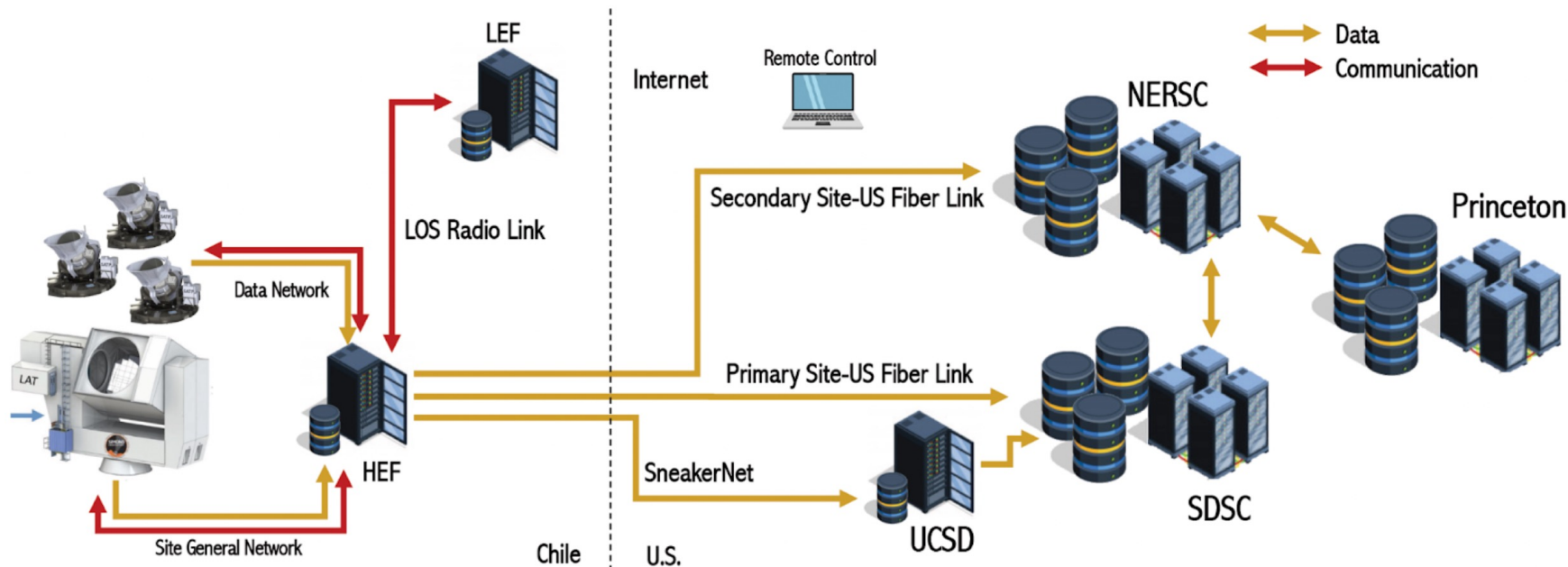


Figure credit: inspired by B. Koopman

DATA MANAGEMENT

Data collection, data registration, and data transport

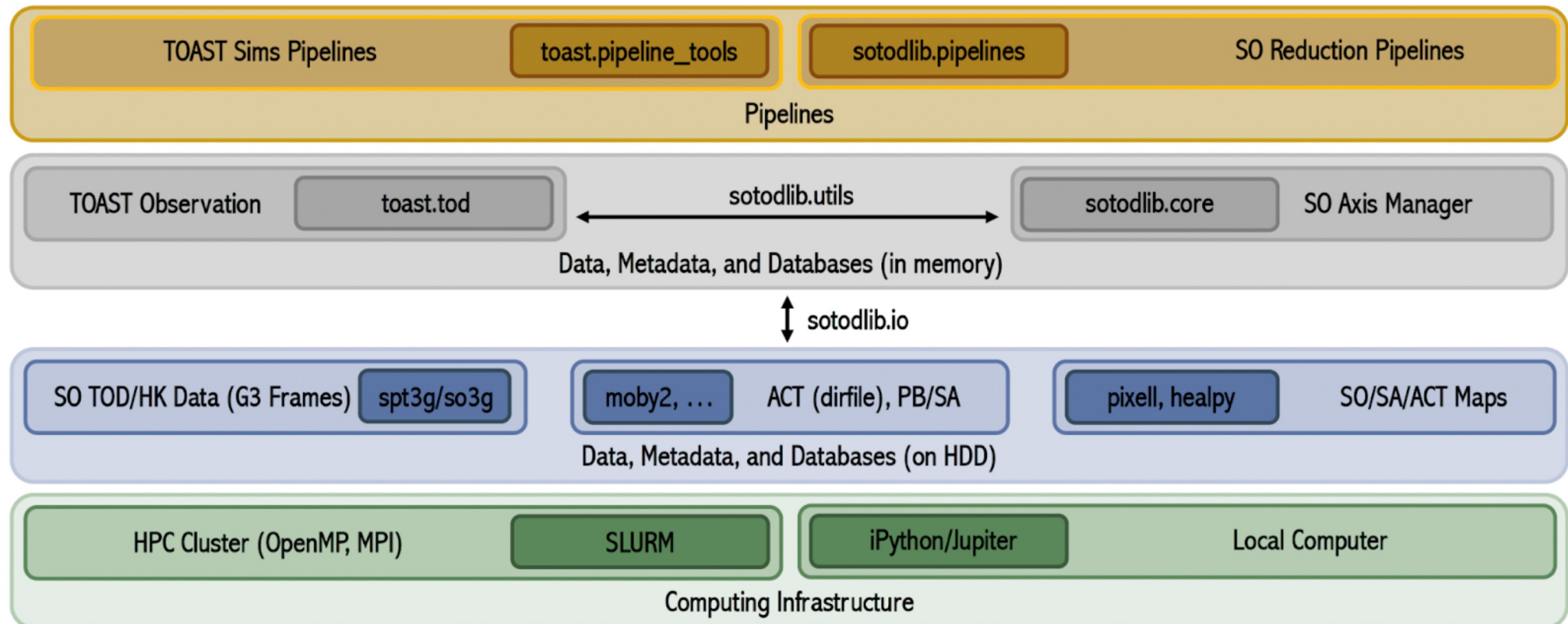
- *Current Status:* data transfer manager software into testing phase ([Librarian](#) on SO GitHub).
 - Will manage: two 1-month copies at the site, three full copies in US, transfer from Site to US and US to US.
- Implemented SneakerNet (manual transport of disk) and also transfer via fiber. All handled by the same software
- Cross-development group with CMB-S4 who will need a scaled version of this implementation.



DATA MANAGEMENT

Data reduction and simulation unified framework

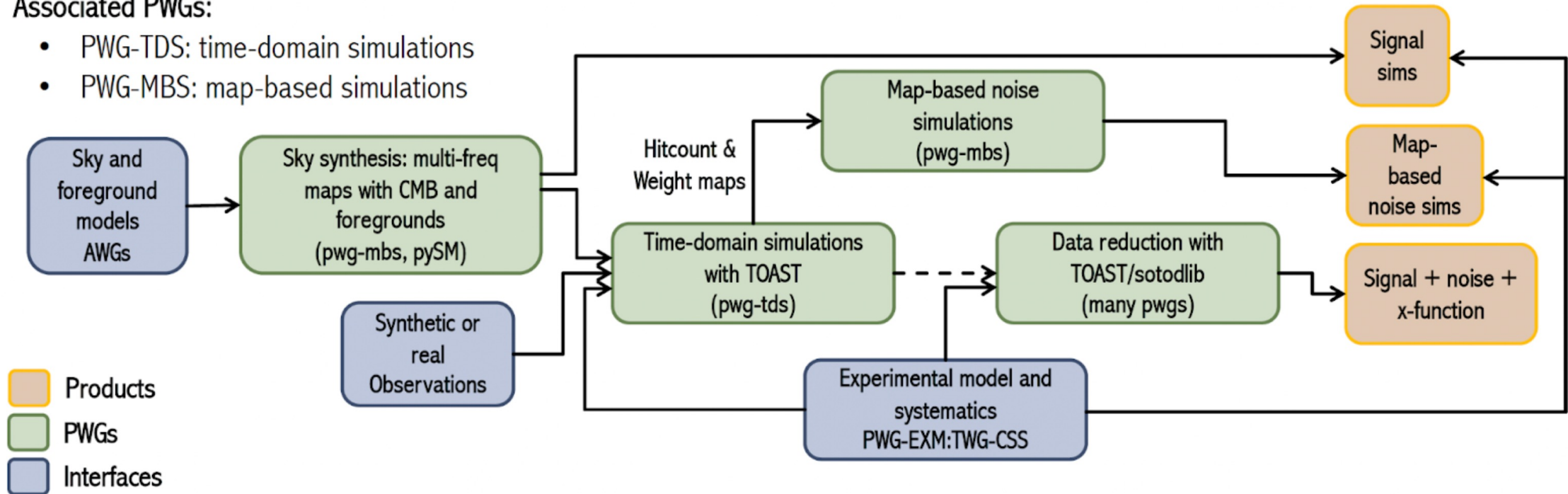
- [SOTODLIB](#): Public library to characterize and reduce real and simulated data. Also used in labs for data manipulation
- [TOAST](#): suite of simulation and reduction pipelines optimized for HPC
- Unified framework to simulate+reduce data on-the-fly



DATA MANAGEMENT

Simulations

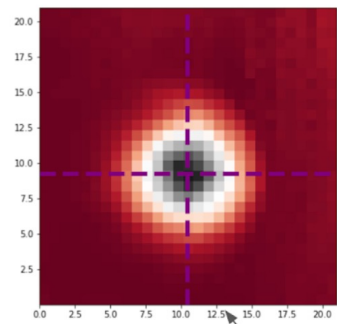
- Two methods implemented: map-based and time-domain simulations
- Used to test/benchmark reduction pipelines and deliver SO-like data to AWGs (science groups)
- Planned released before end of SO project
- *Current Status:* pipelines are mature and should deliver products in 2022-2023
- Associated PWGs:
 - PWG-TDS: time-domain simulations
 - PWG-MBS: map-based simulations



DATA MANAGEMENT

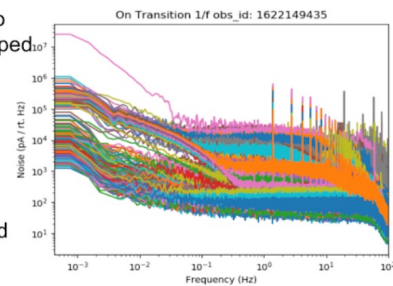
Reduction to maps (some highlights)

- *Current Status:* Developed low-level pipelines to characterize data, used also in labs, and beam and focal plane pipelines very advanced
- For LAT, developed a map making maximum-likelihood pipeline

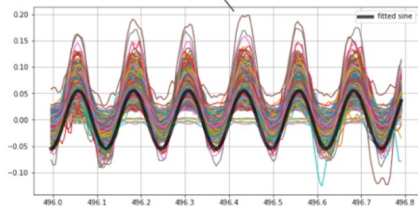


sotodlib filtering to demodulate chopped beam map measurements

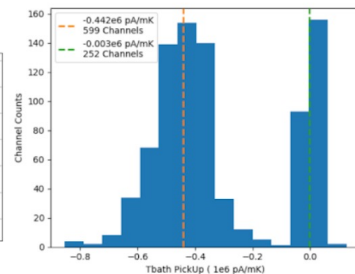
sotodlib PSD and noise calculator



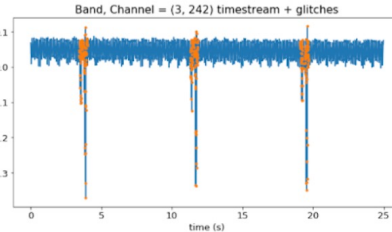
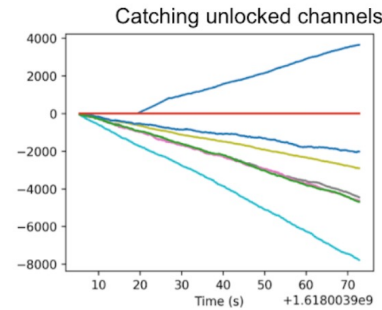
Plot from Jack Lashner



Plot from Tommy Alford



sotodlib PCA tools to characterize bath temperature pickup



Flagging Glitches
Plot from Tommy Alford

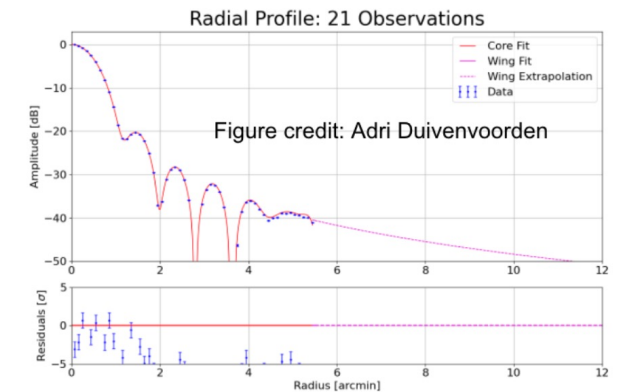
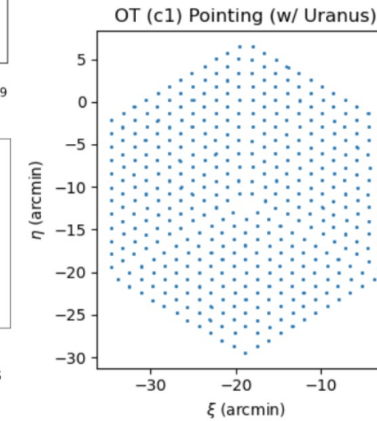
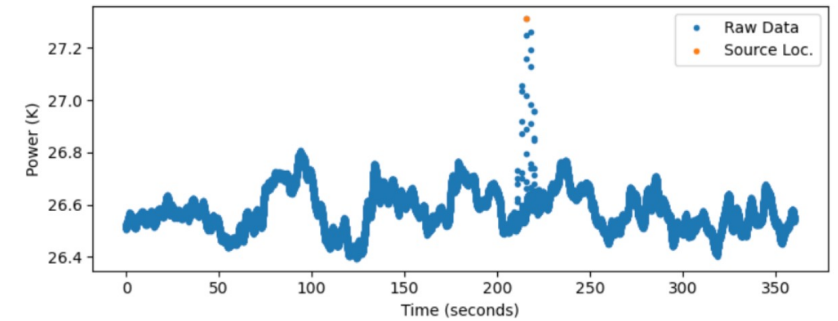


Figure credit: Adri Duivenvoorden

HEF-WORLD COMMUNICATION AND DATA TRANSFER

- Communication and remote access to site computing via line-of-sight radio links
 - Two redundant radio links/routers to ensure constant communication with site crew
 - Not meant to move data, but used for webcam streaming/frames
 - All communication hardware is on UPS
- Data transferred via fiber connection
 - Data will reach North American within 24hrs
 - Fiber connection should be operational before June 2023. For commissioning and to mitigate possible delays we have also implemented a “SneakerNet” plan
- We adapted the Librarian software as Data Transfer Manager to be used for SO data:
 - Will run it at the site and all US data hubs: for Site-US and US-US data movement
 - Also support SneakerNet with US-endpoint at UCSD
 - Data stored at the Site (2 copies) until 3 copies appear in US

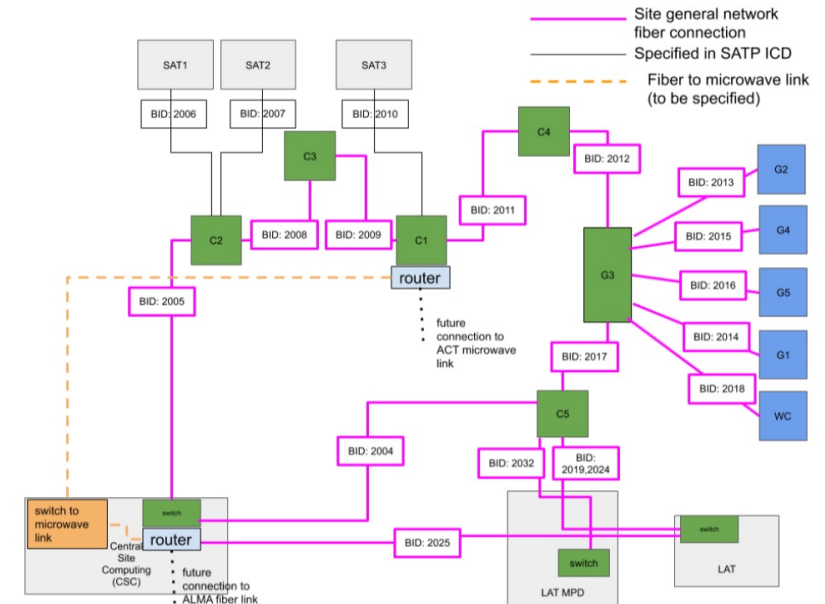


Figure 4: General network layout

The general network has a “circular” topology whose rationale is explained in Section 4.2.2. Magenta indicates single-mode fiber bundles, with bundle ID (BID) as specified. Green indicates IEEE-1588 compliant managed switches, and blue switches which are not currently IEEE-1588.

SO Site-Data ICD

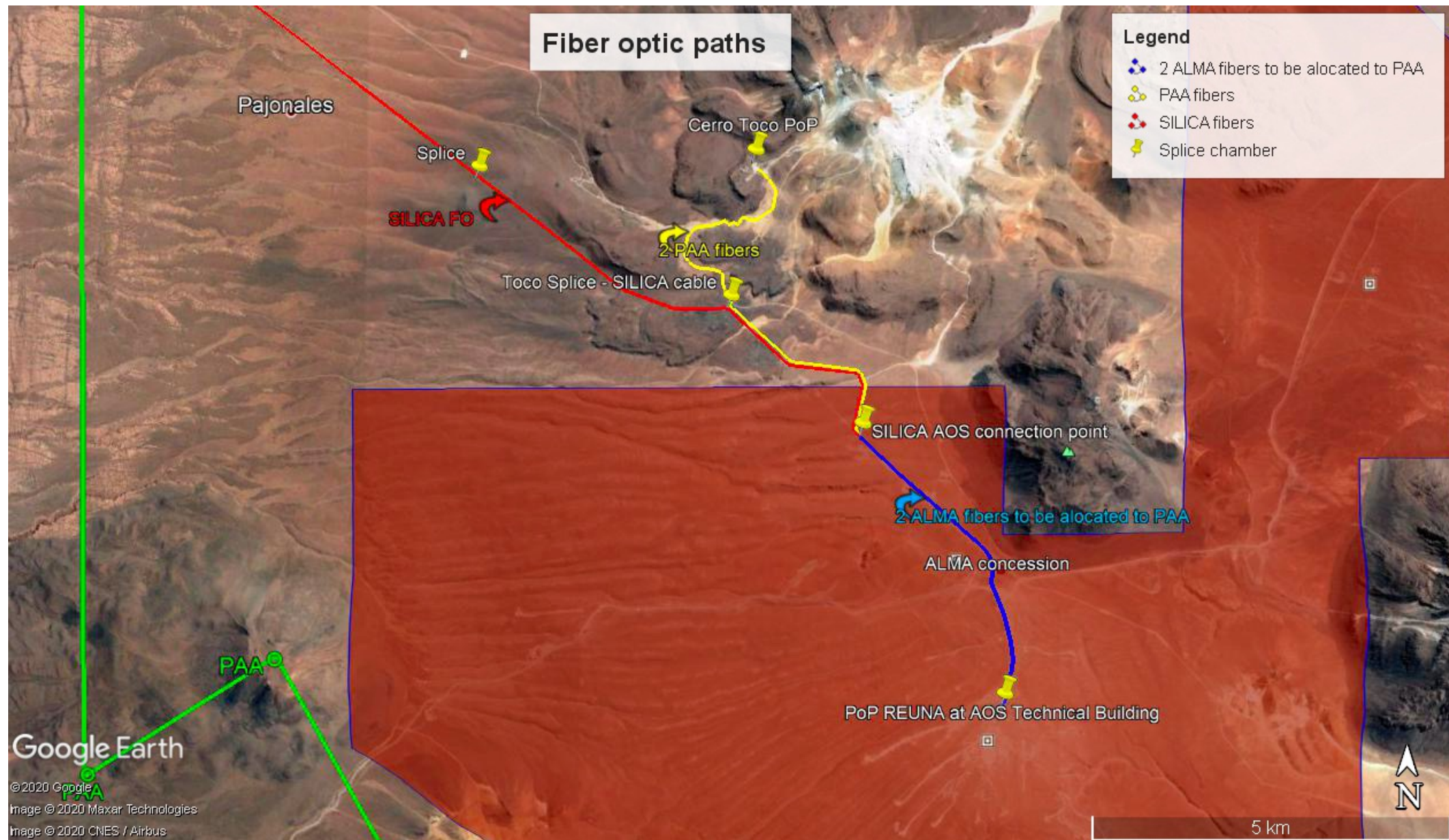
External Reviewer: Paul Wong (SF)

DATA MOVEMENT — SO SITE TO U.S.



- Design of Site network is completed and under review **[DONE]**
- ~~SO funded fiber connection from SO site to ALMA REUNA PoP~~
 - ~~Connection near pad W208~~
 - **[UPDATED]**: PAA will provide fiber connectivity from ALMA to the Site
- MoU between SO and ALMA to allow fiber connection is written and under preliminary revision
 - **[UPDATED]**: PAA x ALMA MoU. SO x ALMA kept as risk mitigation
- MoU between SO and REUNA to utilize the service needs to be finalized

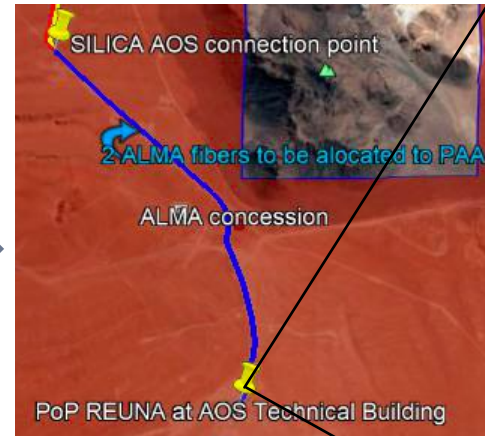
DATA MOVEMENT — SO SITE TO U.S.



DATA MOVEMENT — SO SITE TO U.S.

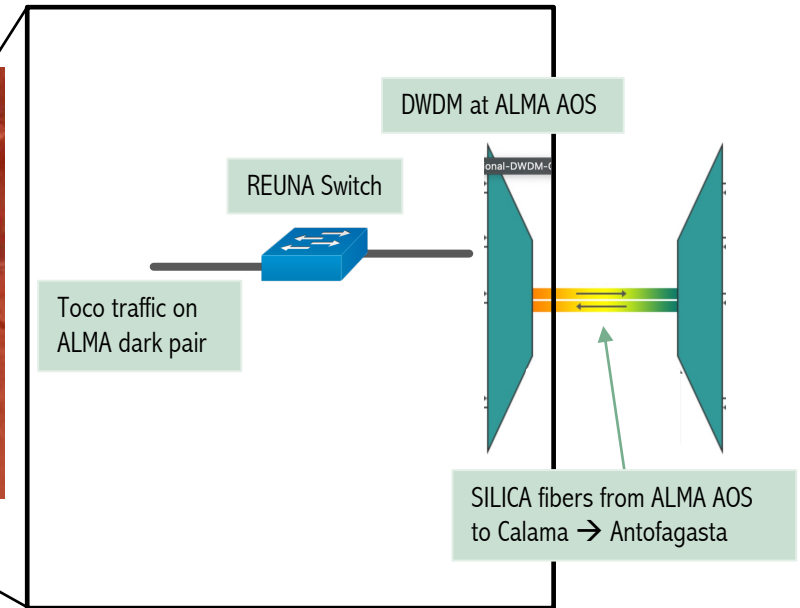


SILICA will install a new fiber under PAA contract. Part of the connection will use existing SILICA fibers (red) to SILICA PoP



PAA fibers will patch into ALMA dark fibers from SILICA AOS to REUNA PoP @ ALMA AOS.

PAA working on MoU with ALMA



Toco traffic will travel on a separate OUT2 from ALMA traffic but same fiber

REUNA working on MoU with ALMA (we heard from Jorge Ibsen)



REUNA will mediate between SO and providers (redCLARA, AMLIGHT, ESnet...) to reach North America



BACKUP

DATA MOVEMENT — SO SITE TO U.S.

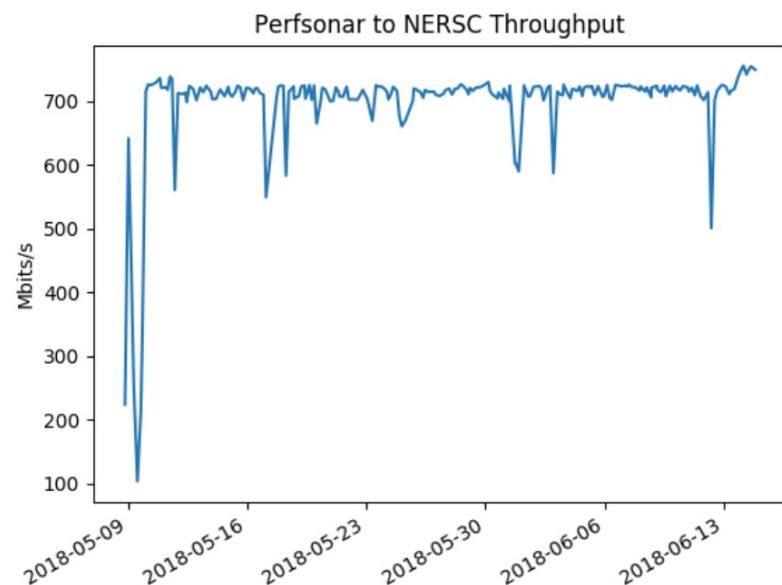


Fig. 6 - Network throughput test (Simons Observatory to NERSC) showing sustained high performance over a month.



James Aguirre
(U Penn)



Eli Dart
(ESnet)

- 1GB connection between ALMA PoP and NERSC tested
 - Performance: >700 Mbps
 - Reliability: stable over ~1 month
 - Performance exceeds SO requirements by factor 2-5
- Great collaborative work:
 - R&E Networks:
 - ESnet and REUNA
 - help from RedCLARA and AMPATH/AMLIGHT
 - Science facilities: ESO, ALMA, and SO