CMB-S4 2021 Spring Collaboration Meeting

South Pole Large Aperture Telescope (SPLAT)

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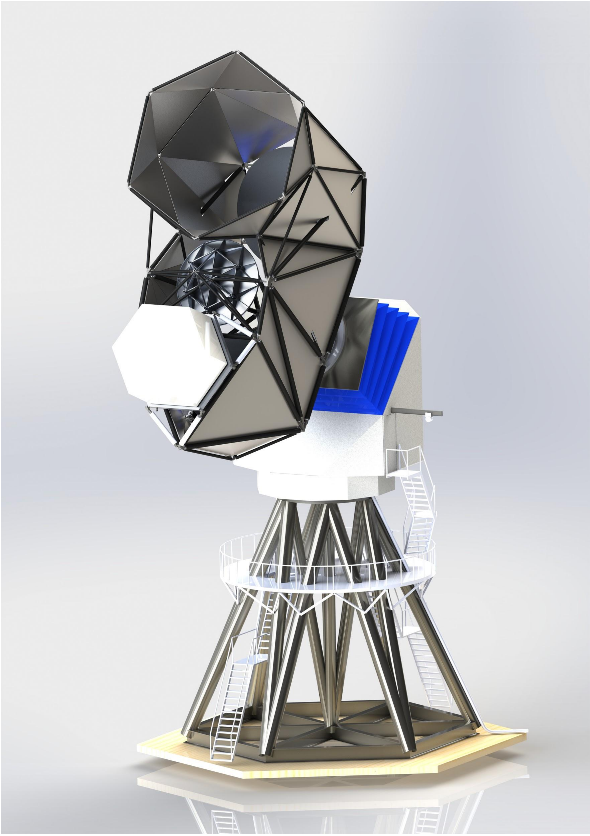
South Pole LAT Overview

Design driven by CMB-S4 delensing LAT measurement requirements, in particular to mitigate systematics, and enable cross-checks and verification for PGW science goals.

Building on concept by Steve Padin, with engineering support from Eric Chauvin and Paul Rasmussen

SPLAT has an innovative telescope design

- Large 9 deg F.O.V for high throughput
- 5m aperture giving 1.7 arcmin beamwidth at 150 GHz
- Monolithic mirrors for low pickup
- Stiff CFRP spaceframe to maintain alignment of mirrors and receiver
- Full bore-sight rotation to reduce systematics
- Full co-moving shields to minimize pickup of unwanted signals
- Engineered for South Pole - All drive components protected in warm enclosure for maintainability



SPLAT Design Specifications

Telescope Requirements

Parameter	Value	Notes
Aperture Diameter	5m	1.7 arcmin beamwidth at 150 GHz
HWFE	< 37um rms	80% Strehl ratio at λ = 1mm
Scan Pointing Knowledge	< 5 arcsec rms	< 1/10th beamwidth at λ = 1mm
Scan following error	< 10 arcsec rms	¼ beamwidth at λ = 1mm
Scan Speed	3 deg s^{-1}	~ 1 deg s^{-1} on the sky to freeze atmosphere
Scan turn around time	2s (4deg/s^2)	10% of typical 20s scan
Emissivity and warm spillover	< 0.01	Small cf. a few % atmospheric loss at mm wavelengths

Survival Requirements

Load case	Limit
Wind Speed	35 m/s
Seismic	0
Ambient Temperature	-10 C to -90 C survival
Ice	1cm

Baseline Design HWFE Budget

Contribution	error (μm rms)
Aberrations	11.9
Primary (assume 5.4m)	26.4
Secondary (assume 3.7m)	15.9
Tertiary (assume 5.4m)	26.4
Tipping structure	12.2
Telescope total (RSS)	**44 μm rms**

TMA Optics

- Design is a Three-Mirror Anastigmat to correct all major aberrations over large 9.4° FOV, better image quality than CD
- Offset design so no scattering from blockages
- Monolithic mirrors so no scattering from panel gaps

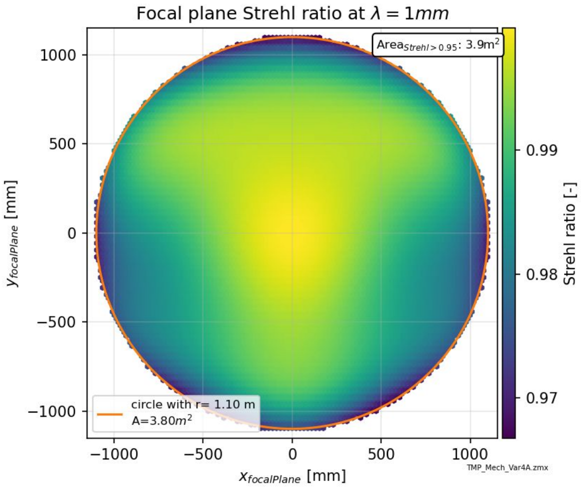
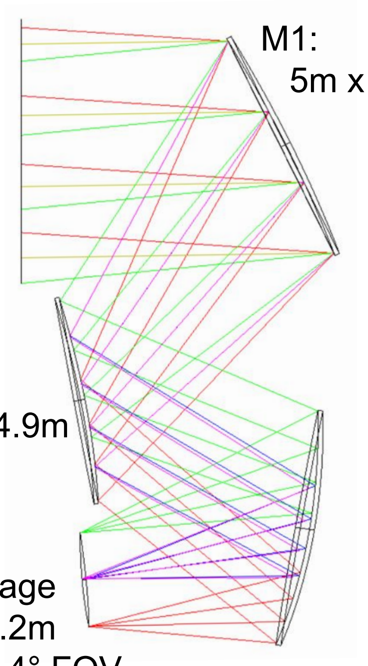
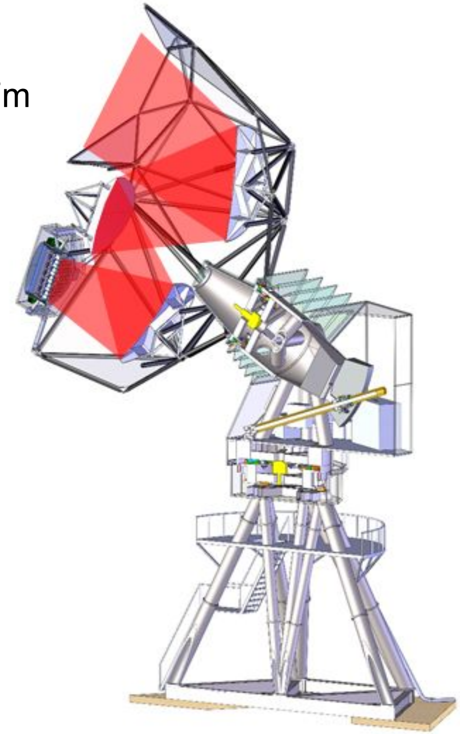


Image quality quantified using Strehl ratio

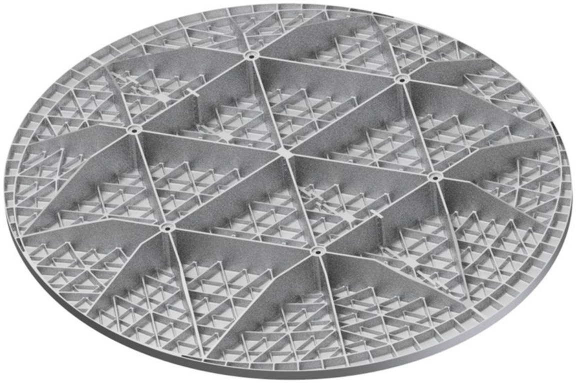


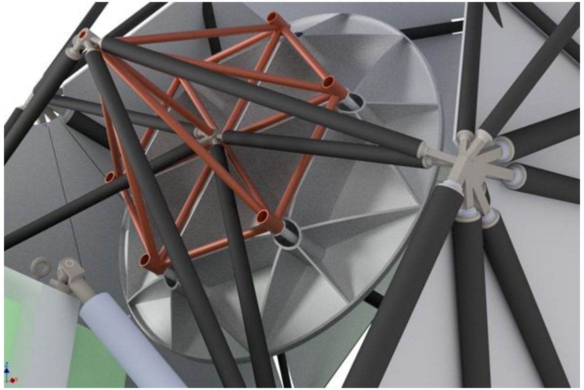


Monolithic Mirrors

- Existing telescopes of this size use segmented mirrors, which generate sharp diffraction sidelobes. Monolithic mirrors avoid this.
- Raw material of this size not available, so mirrors assembled from several segments prior to machining final surface figure
- 6 point over-constrained support allows some correction of low-order aberrations due to fabrication errors, isolates mirror from CFRP tipping structure deformation
- Mirrors must be heated to avoid icing, insulated to reduce thermal gradients
- Mirror temperature will be monitored and telescope refocused to account for bulk thermal expansion and gradients
- Metrology tools and procedures under review to validate manufacturing
    - Laser Tracker
    - Photogrammetry
    - Holography for site validation

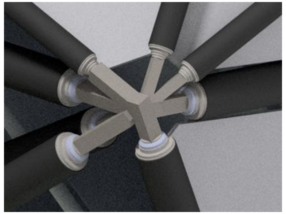
A Prototype mirror is being procured to validate the fabrication and verification methods

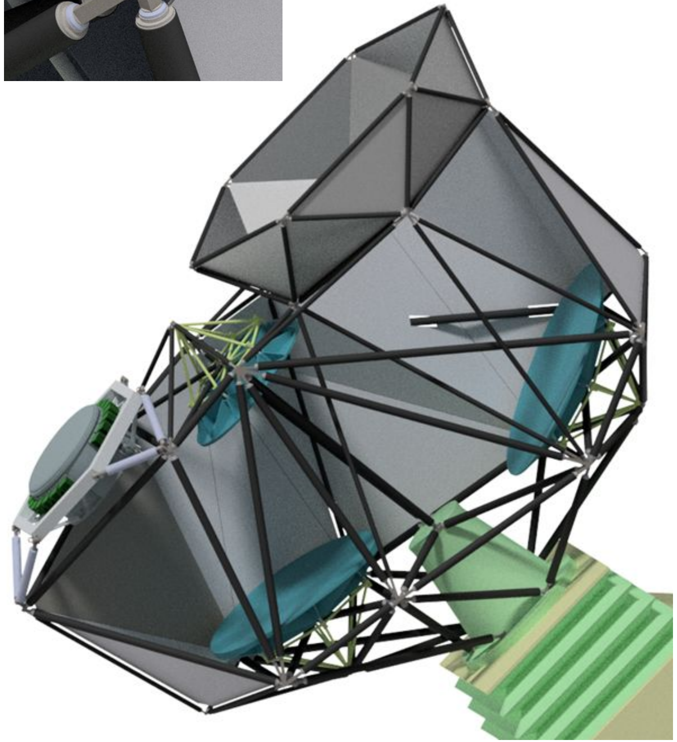




CFRP Tipping Structure and Baffling

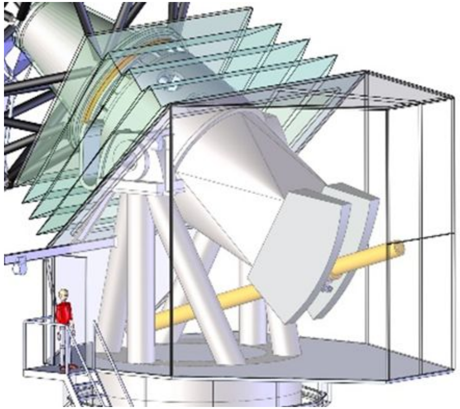
- Basic Requirement of Mirror Support System is to maintain alignment of 3 mirrors and receiver to within ~1mm at any orientation and over the operating temperature range of -20C to -60C, also in the presence of wind
- 3 Mirrors and Receiver are supported by a common CFRP space frame structure
- CFRP has very high stiffness to weight ratio, and very low Coefficient of Thermal Expansion (CTE) to maintain alignment of mirrors over large temperature changes - slightly negative in baseline design
- Nodes are nominally welded stainless steel structures, post-machined at interfaces, but a 3D printed design has also being investigated
- Receiver (LATR) supported on hexapod mechanism to enable refocusing, based on temperature measurements of the mirrors
- Tipping structure surrounded by lightweight scattering panels to control sidelobes.
- Truss connects to rolled steel cone that provides stiff support for the boresight rotation bearing and motor.

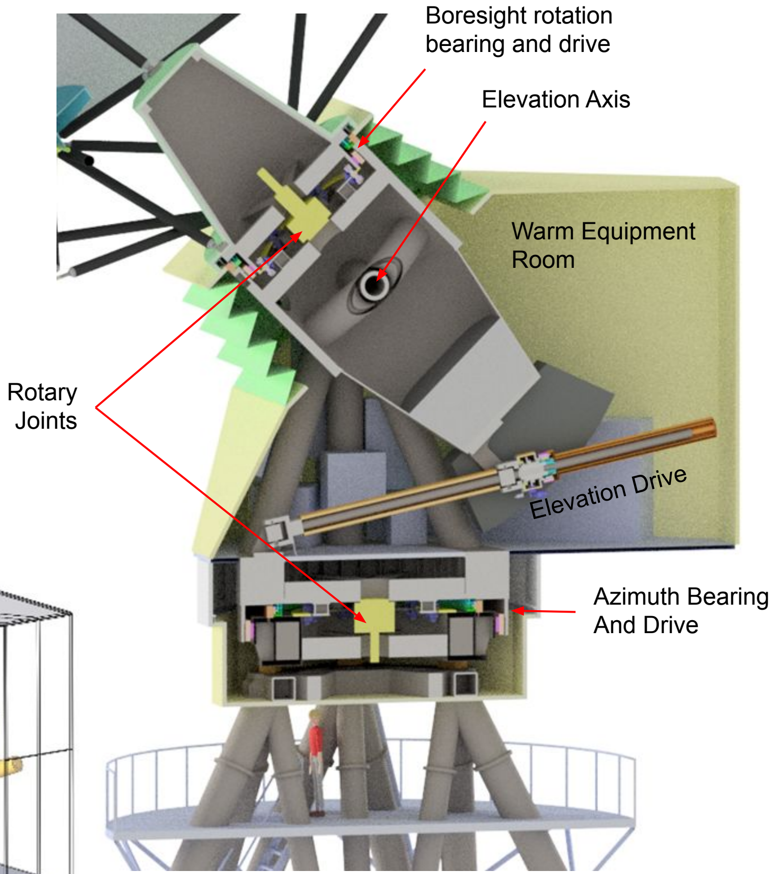




Mount

- Elevation over azimuth mount with an additional boresight rotation axis
- The azimuth and boresight rotation axes use large diameter slew bearings with direct drives for high stiffness. Both axes also use rotary joints which enable continuous rotation and removes the need for hard stops
- The spherical roller elevation bearings sit atop stiff tripods connected directly to the azimuth drive ring
- The elevation drive incorporates a 7m long drive screw and nut driven by direct drive motor
- All drive components are housed in an environmentally sealed and warm enclosure, which stretches from the azimuth bearing up to the PA cone via flexible bellows
- The warm enclosure also houses electronics cabinets, helium compressors, and heat exchangers
- The azimuth structure sits on a 10.3m tower. This is needed to keep the telescope above snow level for at least 20 years of snow accumulation





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Path Forward

Path forward to DOE CD-1 / NSF PDR

- Need to converge on optics and tipping structure mechanical layout, node design, CFRP layup
- Begin to validate monolithic mirror performance with prototype mirror fabrication contract
- Clearly define external interfaces, in particular with the LATR
- Develop Shielding and panel treatment for reflection and absorption
- Advance detail design and mechanical component selection to refine and update cost estimates