CCAT-prime Overview and Update

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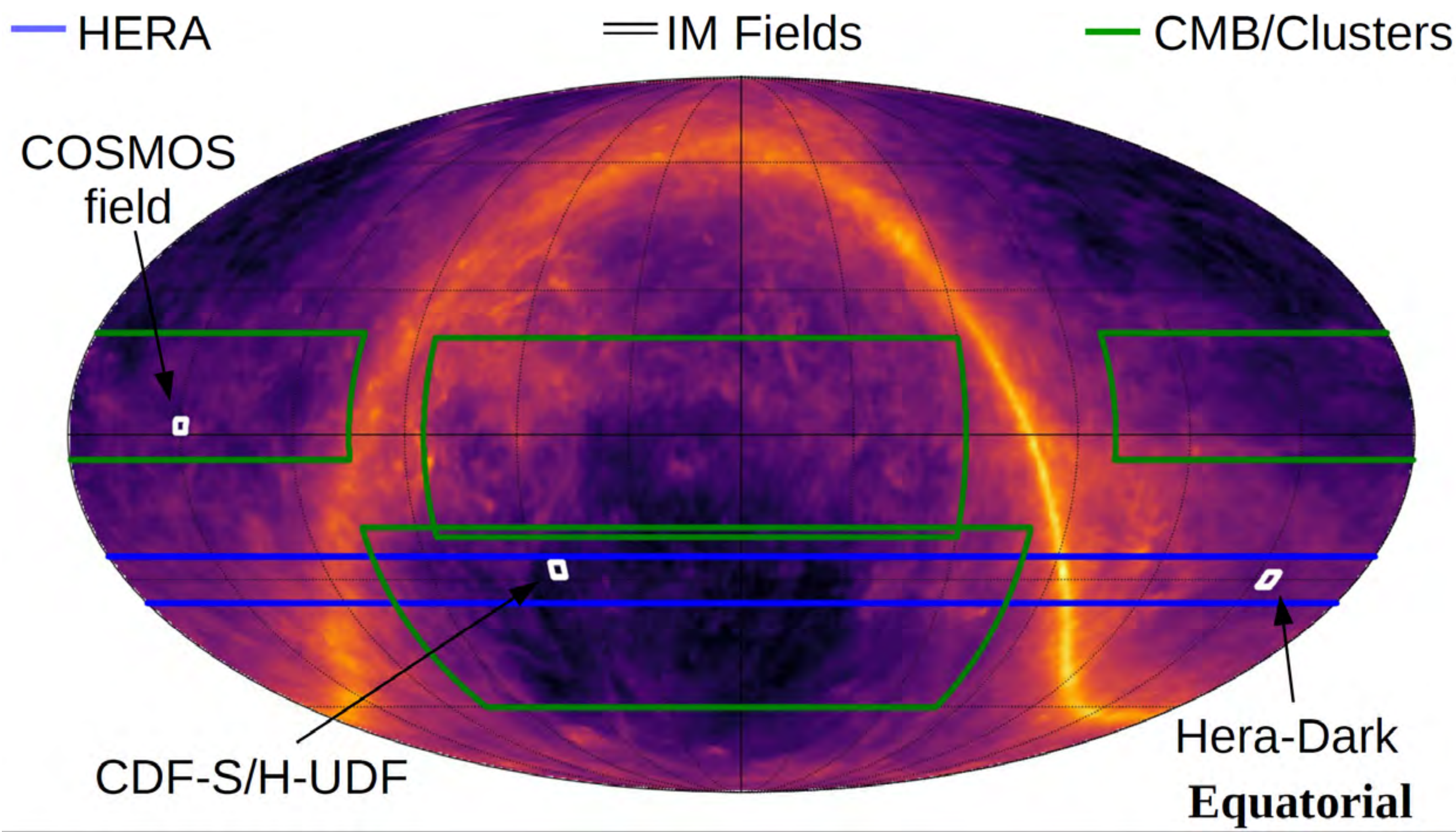
1st CCAT Collaboration Meeting 07-Apr-2020

Photo by: Alessandro Schillaci & Giulio Ercolani

CCAT-prime Observatory

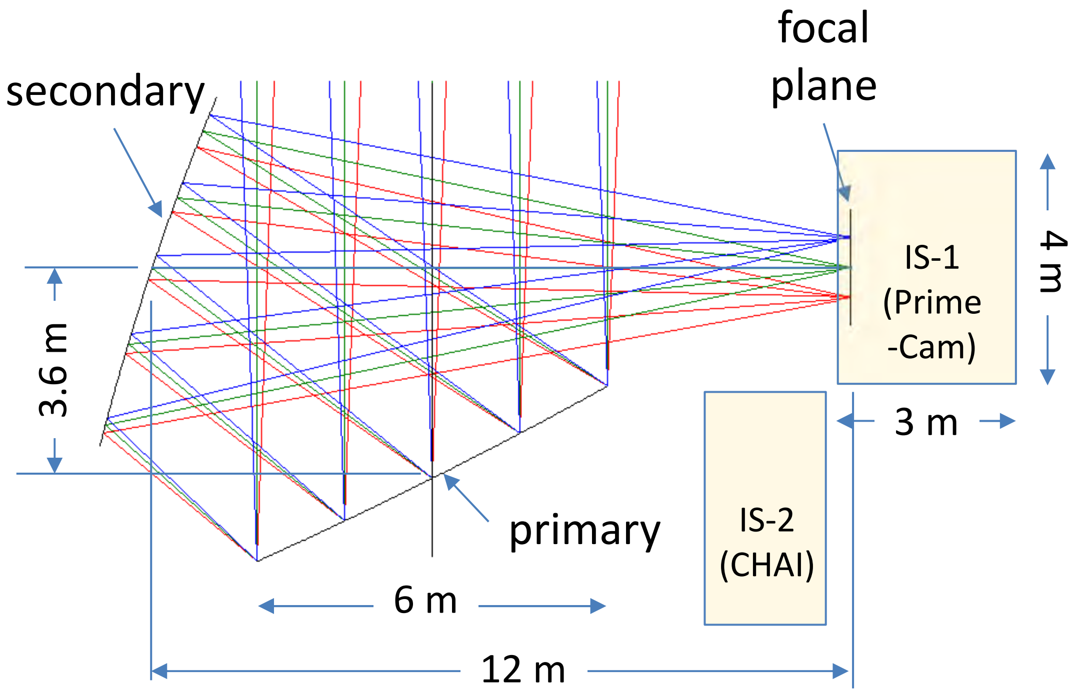
- What is it?
  - 6-m telescope design for wide-area surveys (large FoV)
  - located in high Atacama Desert of N. Chile (high trans., low ϵ)
  - Designed to address broad science questions
  - Expected first light late 2021/early 2022
- CCAT studies will range from
  - mapping of gas and dust in the Milky Way to
  - the formation of the first galaxies to
  - probing the CMB for information on new particle species, the formation of cluster of galaxies and as a lead in to CMB-S4
  - among others to be discussed here
- Links to CCAT publications: http://www.ccatobservatory.org/
  - See reports & publications under documents link
  - Astro2020 White paper on CCAT-prime with links to white papers on science themes/topics
  - Technical papers on telescope, instrumentation, etc.

Extragalactic Survey Areas



Survey fields overlaid on Planck dust map (1) Deep Subaru HSC+PSF spectroscopy (current) & COSMOS X-Ray-to-meter-wave multiwavelength survey; (2) deep Euclid grism spectroscopy (upcoming), HERA HI 21 cm (upcoming), & H-UDF/CDF-S multiwavelength surveys (incl. JWST GTO); (3) HERA HI 21 cm (upcoming), VLASS; (4) Planck, SDSS, DES, ACT (current), SO, DESI, LSST, eROSITA (upcoming).

The 6-m CCAT-prime telescope



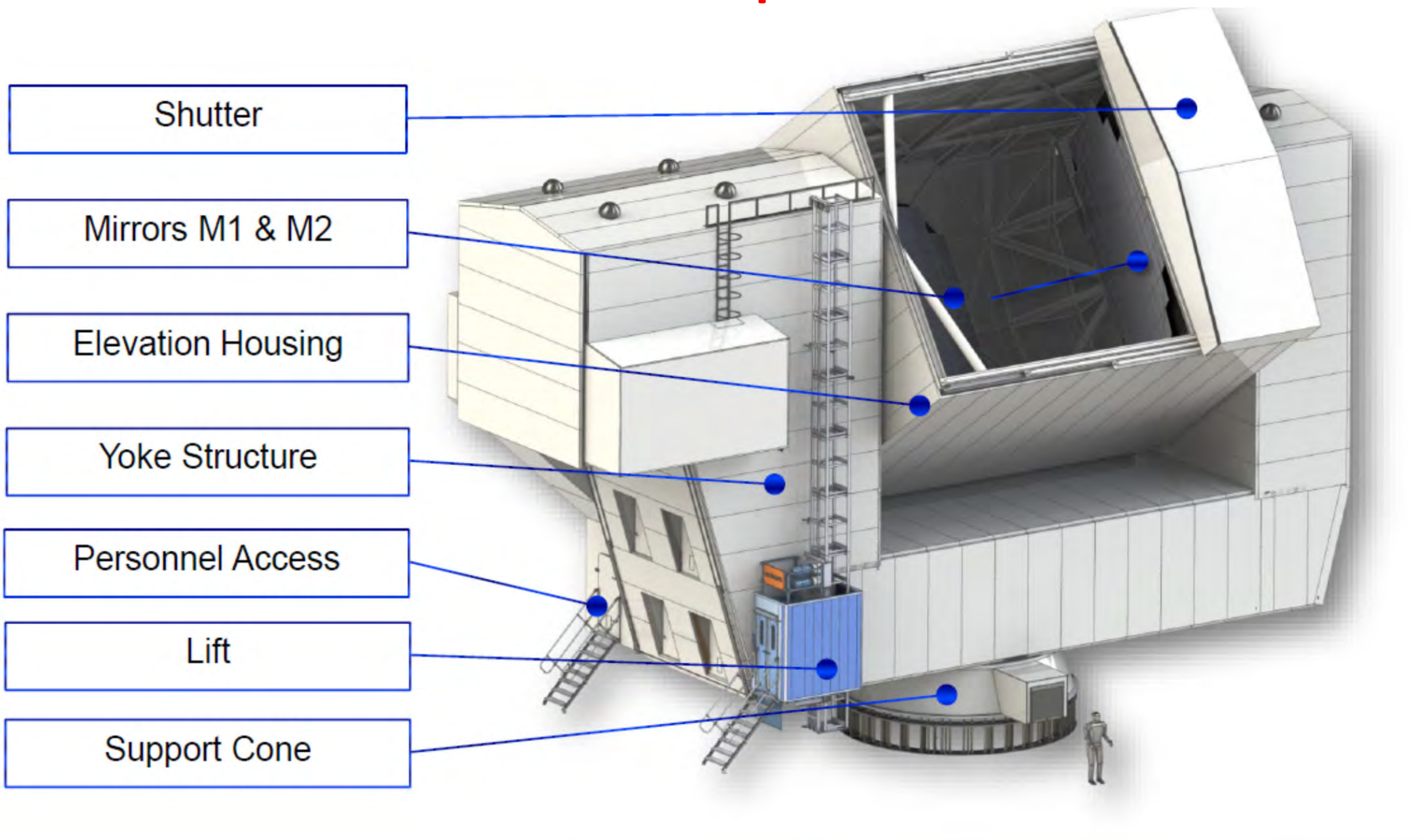
- CCAT-prime optical layout
  - See Niemack 2016, Parshley, 2018
- Ray trace shows sources -2, 0, and 2 degrees off-axis
- Locations of instrument spaces 1 and 2 are shown (IS-1, IS-2)

- Aperture: 6-m
- Large FoV: $\sim 7.3° \cdot (\lambda/3\ \mathrm{mm})^{1/2}$
- HWFE: < 11 μm
  - Half wave-front error
  - Redundant checks: laser metrology system and near-field holography
- Pointing Error: < 1.4″
- Low emissivity: < 2.8% (goal < 1%)
- Scan patterns: azimuthal
  - Typically azimuthal scans, but accelerations adequate for other patterns
- Scan speed: > 0.33° $s^{-1} \cdot (\lambda$ / 350 μm)
  - in azimuth, and half this value in elevation
- Stray light mitigations
  - Option to add baffles

Status

- Telescope under construction
- Site Preparation
  - Upgraded road nearly complete: 5-month hiatus then 1 month to finish
  - One month for site leveling after road complete
  - Foundation installation on track (Apr 2021)
- Instrumentation
  - CHAI: on schedule
  - Prime-CAM:
    - 1-tube Mod-Cam cryostat for first-light (270 GHz)
    - 7-tube Prime-Cam cryostat in fabrication

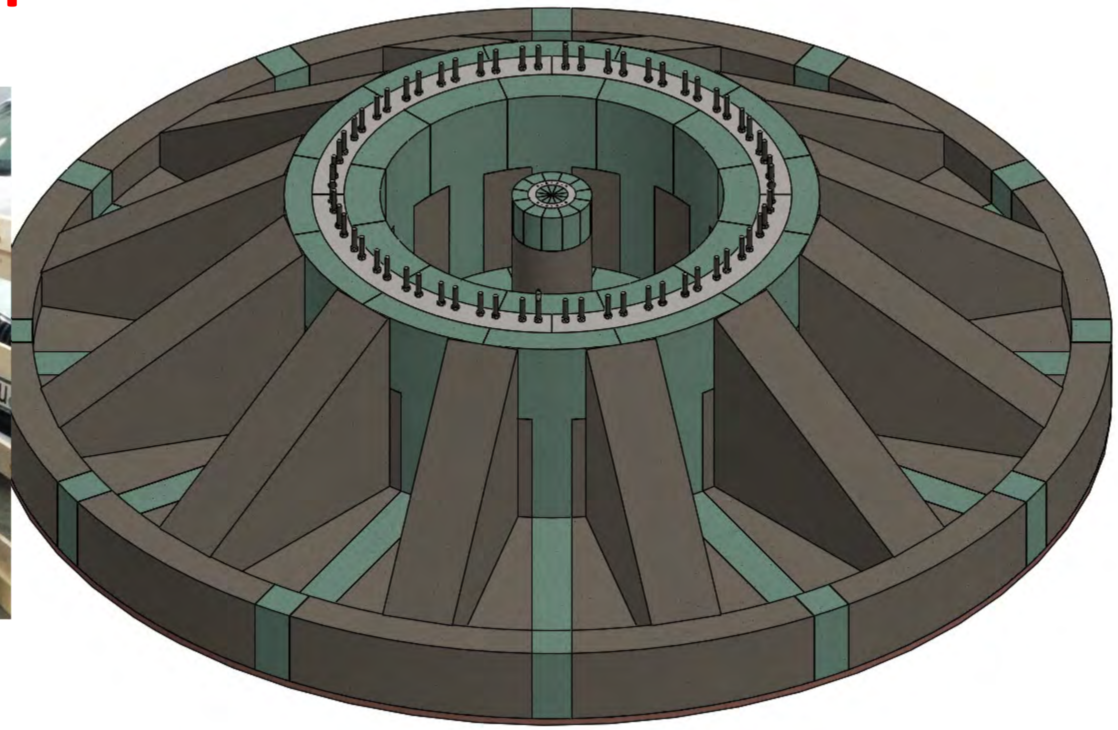
Telescope


Shutter
Mirrors M1 & M2
Elevation Housing
Yoke Structure
Personnel Access
Lift
Support Cone

Anchor Ring

- Above: Delivery to Vertex
- Left: Loading SOLAT anchor ring for shipment

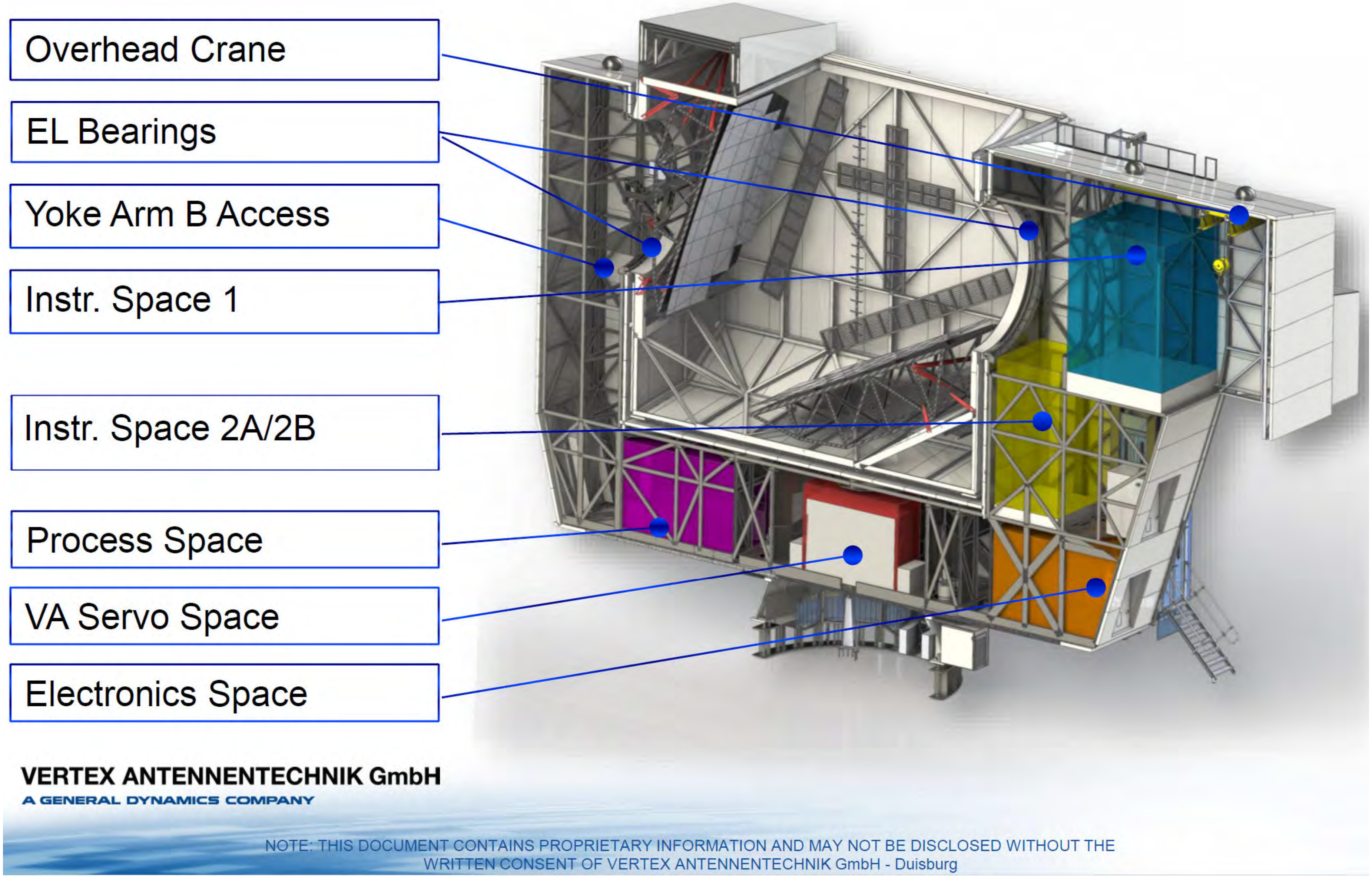
Telescope Foundation



- Vital Stats:
  - 14m diameter x ~3m tall: 13 pre-cast pieces: 1 hub = 14t, 12 radials = 27t each
  - ~ 70 cubic meters of in situ concrete to "glue" pre-cast pieces together and embed telescope anchor ring
  - ~ 12 km of rebar total in the foundation (joints contain rebar)
  - total mass ~ 500t, additional ~ 450t of backfill on top
  - supports ~ 220t telescope, reacts against ~ 200t moving in AZ

TAO Foundation

Telescope Structure



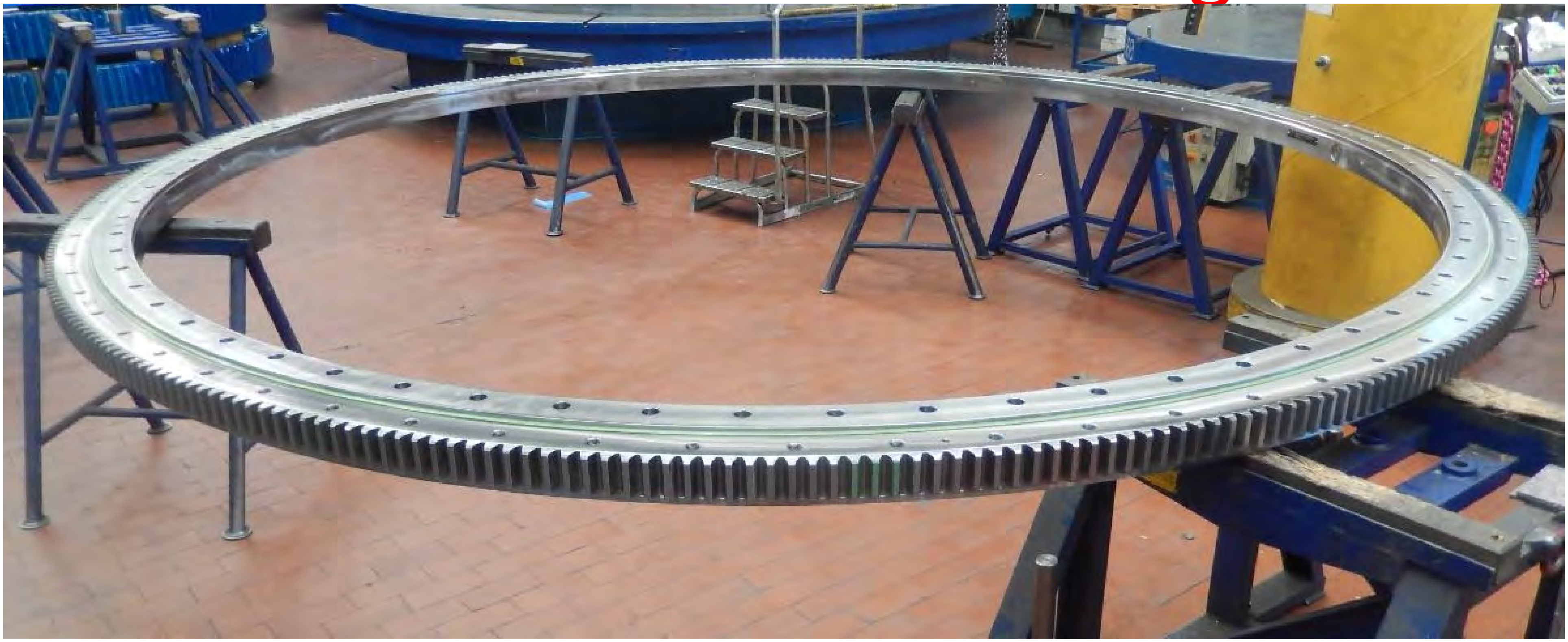
Telescope Support Cone

Steel support cone in manufacture. Finished cone will be ~ 8 tons.

Wessel

Beginning of Yoke Traverse

Elevation Drive Bearing



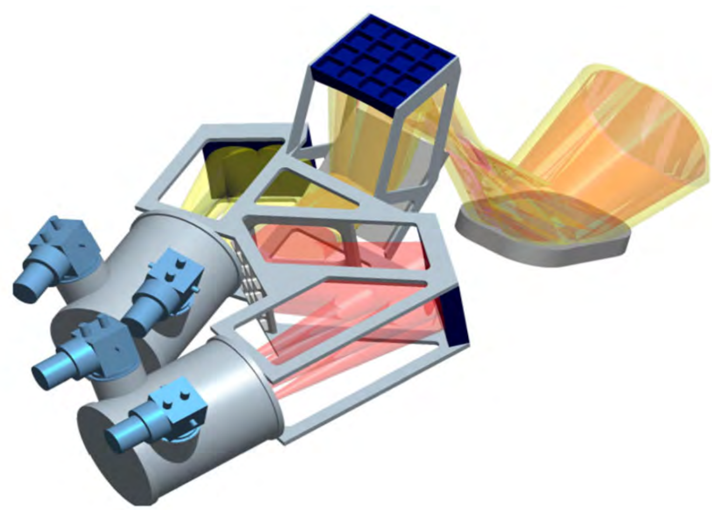
- CCAT elevation drive gear

Mirror Panel

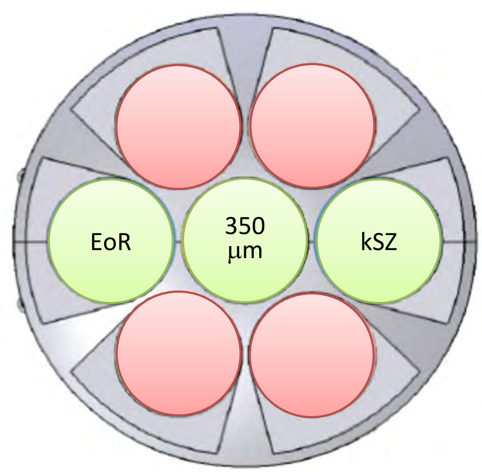
- Left: Front side of CCAT-Prime 0.7-m mirror panel. The surface RMS is approximately 2 microns.
- Right: Back side of mirror panel showing light-weighted structure, the five mounting points for attachment to the carbon fiber backing structure, and recesses for the x-y adjustment (along horizontal line in center).

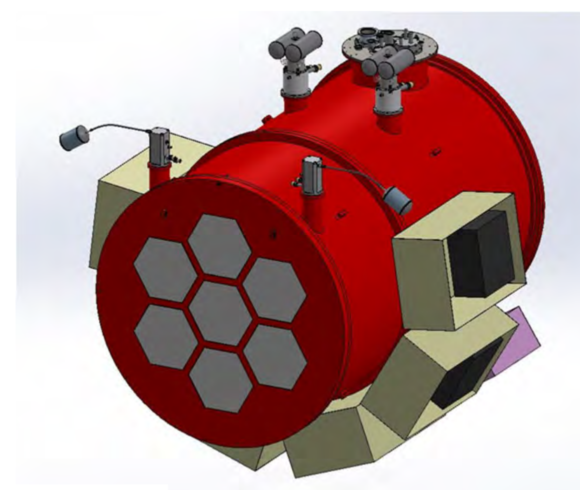
Instrumentation

Name	Primary Science	λ range	FoV	No. Pixels	1st Light?
CHAI	GEco	200 – 700 um	17’ x 8.5’	128 (256 goal)	yes
P-Cam	kSZ, GEvo	350 – 1300 um	3^o diameter	$5.9x10^4$	yes
P-Cam	IM/EOR	740 – 1300 um	--	$2.0x10^4$	yes
CMB-S4	CMB	350 – 3100 um	7.8^o diameter	$1.5x10^5$	no



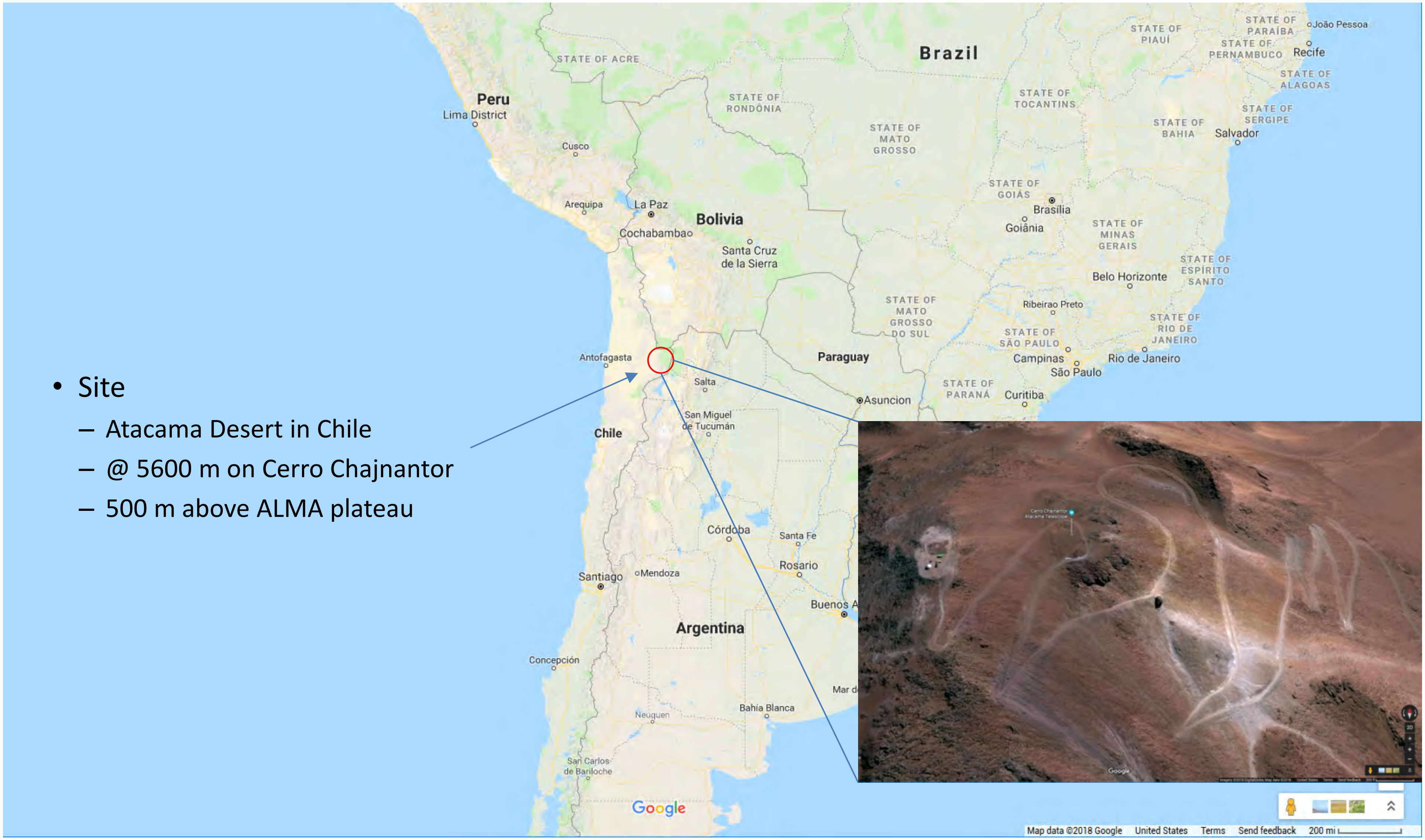
CHAI





Prime-Cam

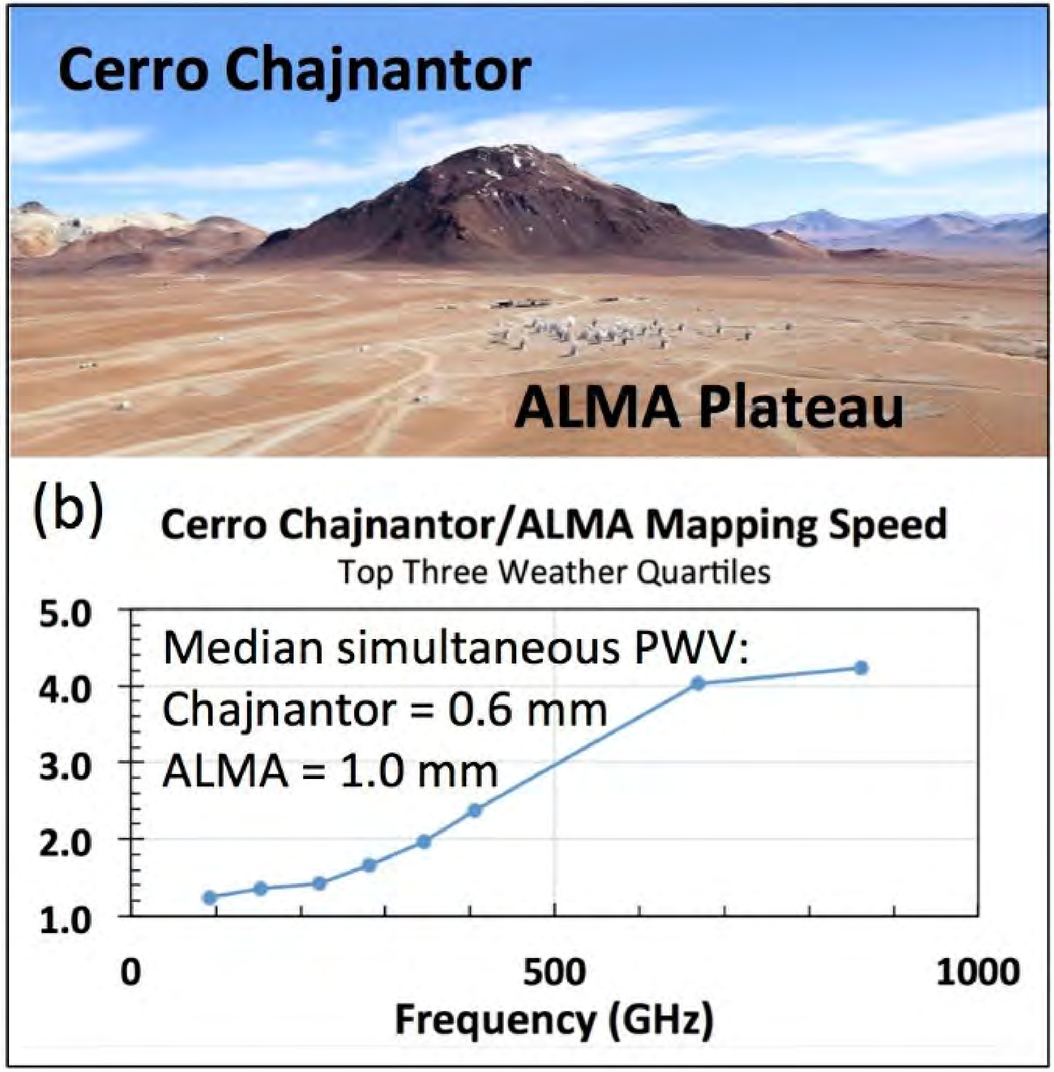
CCAT Location



- Site
  - Atacama Desert in Chile
  - @ 5600 m on Cerro Chajnantor
  - 500 m above ALMA plateau

CCAT Site

- The low precipitable water vapor (PWV) at the CCAT site offer advantages over the ALMA plateau (5500 vs. 5000 m).
- For an equivalent setup, Cerro Chajnantor is better at all wavelengths.



Road Improvements

Road Improvements

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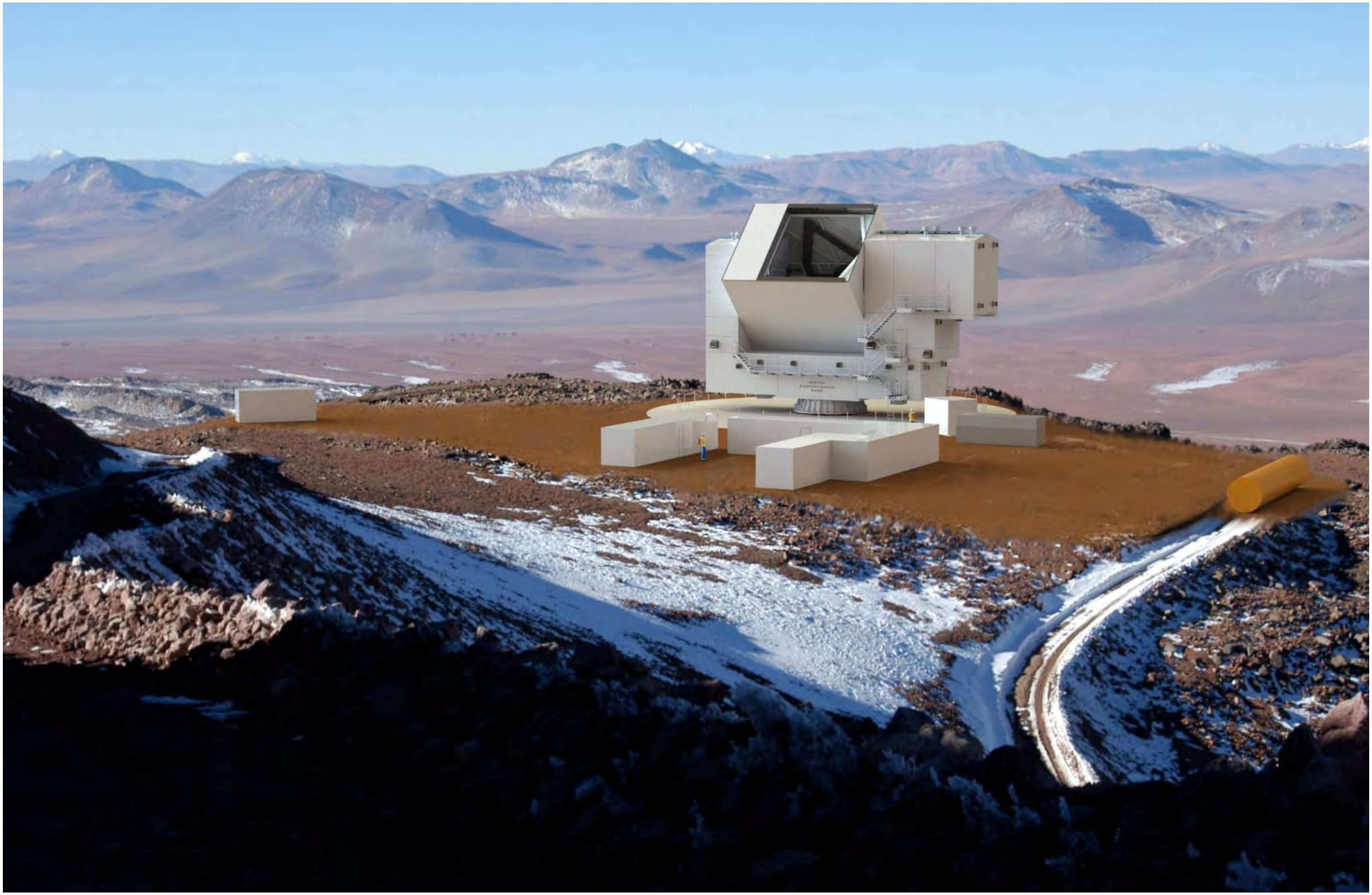
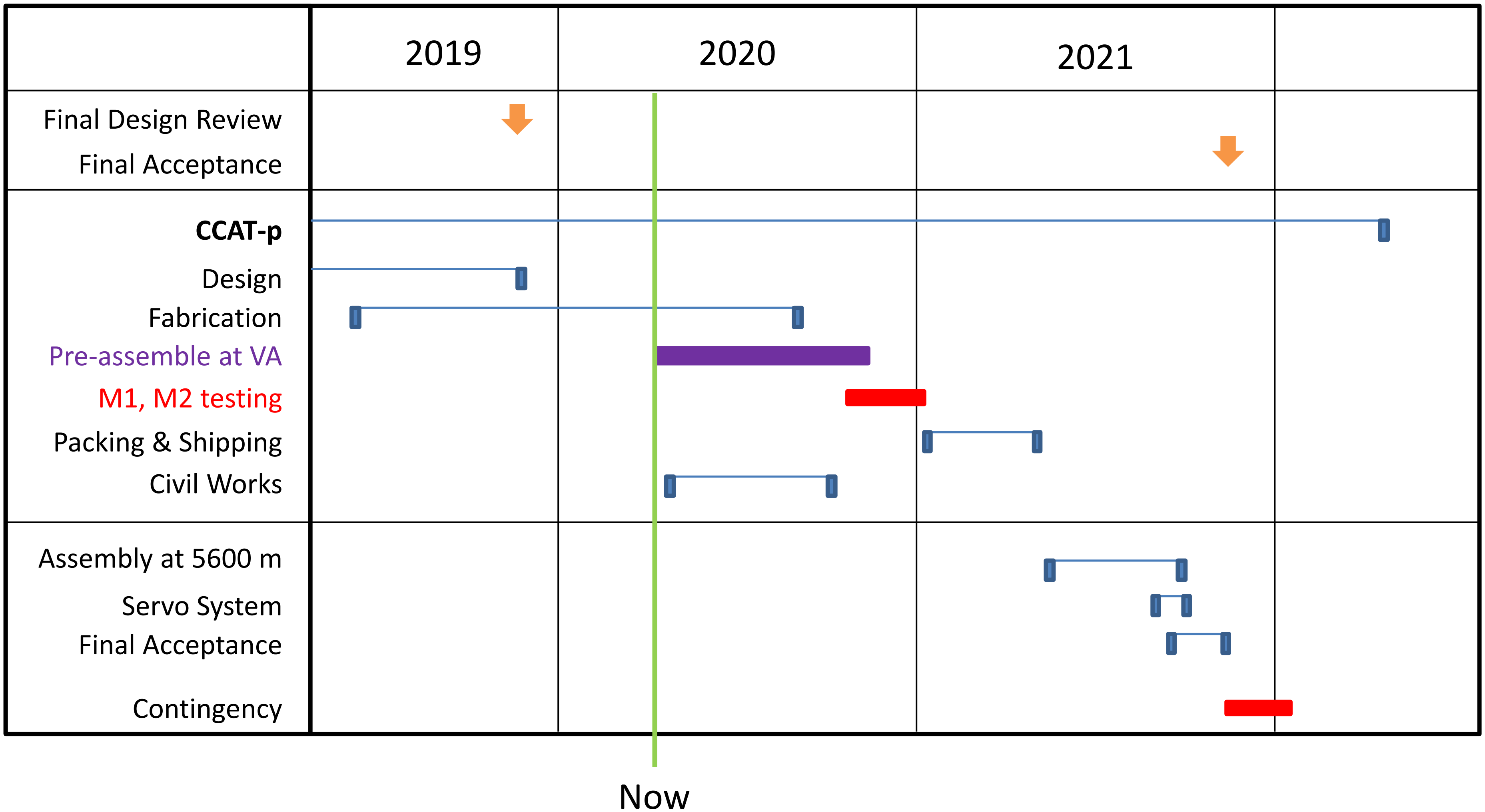


Schedule


2019
2020
2021
Final Design Review
Final Acceptance
CCAT-p
Design
Fabrication
Pre-assemble at VA
M1, M2 testing
Packing & Shipping
Civil Works
Assembly at 5600 m
Servo System
Final Acceptance
Contingency
Now

Acceptance Testing & Commissioning

- FDR / Post-FDR
  - Verification of ~150 requirements by design and analysis - ongoing
- Factory acceptance testing (FAT, pre-assembly in Germany)
  - Verification of ~40 requirements by measurement
  - Functional tests (limits, stow pins, etc.)
- Site acceptance testing (SAT, final assembly on C. Chajnantor)
  - Verification of ~50 requirements by measurement
  - Functional tests redux
  - Closes out contract with Vertex
- Holography, Laser Metrology, and IR Pointing Camera are strongly desired for FAT and absolutely required for SAT
- Commissioning:
  - Post-SAT – further telescope refinement & characterization
  - Occurs for each instrument (I&T + Commissioning)
  - Combine some early science with commissioning activities

CCAT-p

Scan Patterns

- Primary scan pattern for EoR IM, Cluster and CMB science is simply azimuthal:
  - Turn around time is ~ 2.5 s so, scanning at ~ 1° to 3°/sec ⇒ >80% efficiency for scans > 10° to 30°
  - EoR IM FoV is ~ $16^{(\circ)2}$, so 4° scan (@ 1°/s) would be only 62% efficient.
- Telescope performance will permit more sophisticated scan patterns, but not required