Sites Breakout: Chile Infrastructure & I&C

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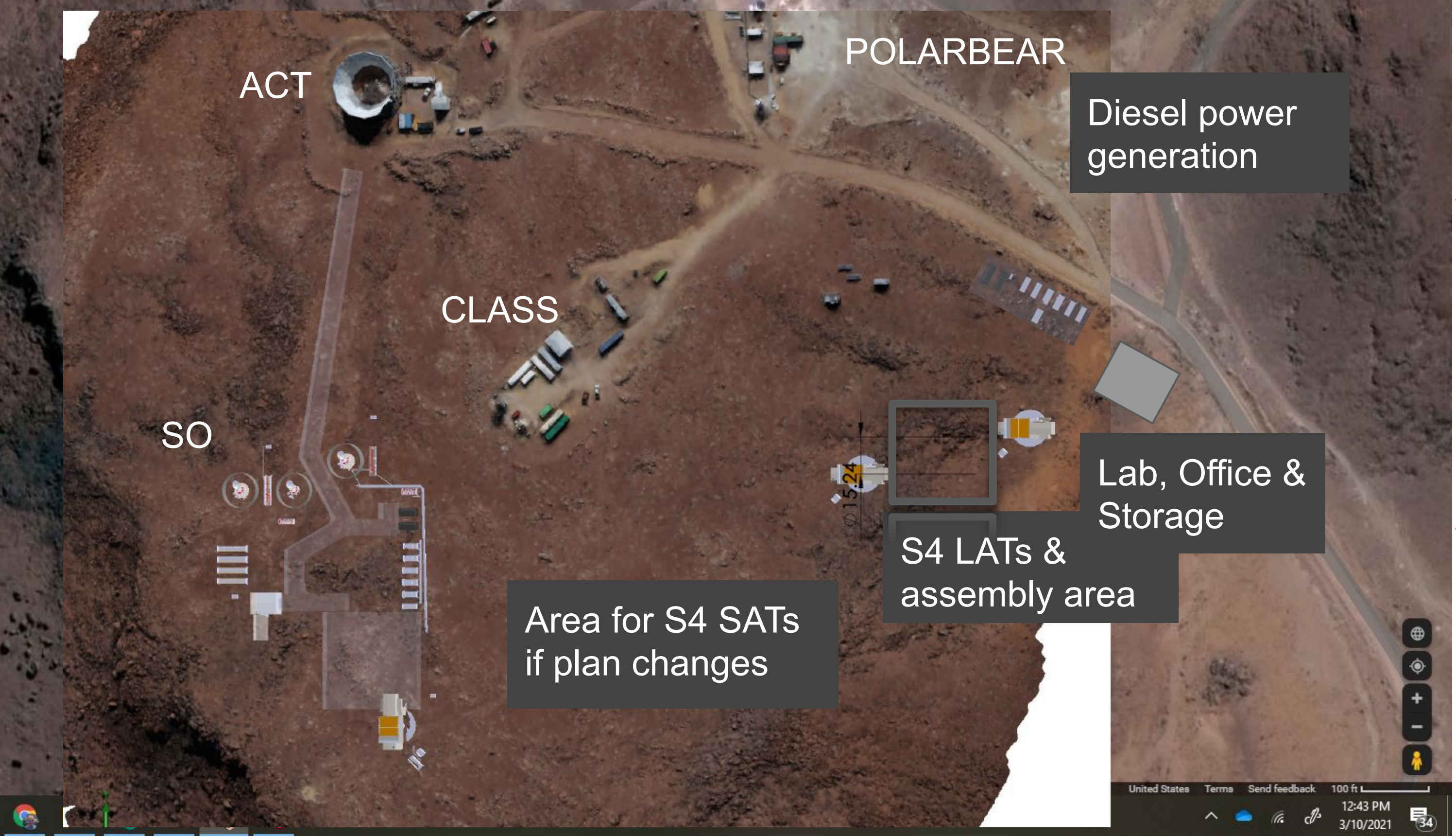
CMB-S4

Outline

- Technical details of site systems
- Power generation
- Chile Project Office: Legal & Operations Support

Facility layout (pre-conceptual)



Contract with Chilean architect firm to produce the conceptual design is executed; they are waiting for our input requirements to develop a conceptual design.

This layout satisfies the requirements listed on the next slide.

As stated in the past slide, we are currently evaluating the possibility of power from a PV array coming up from the south (bottom) of this image

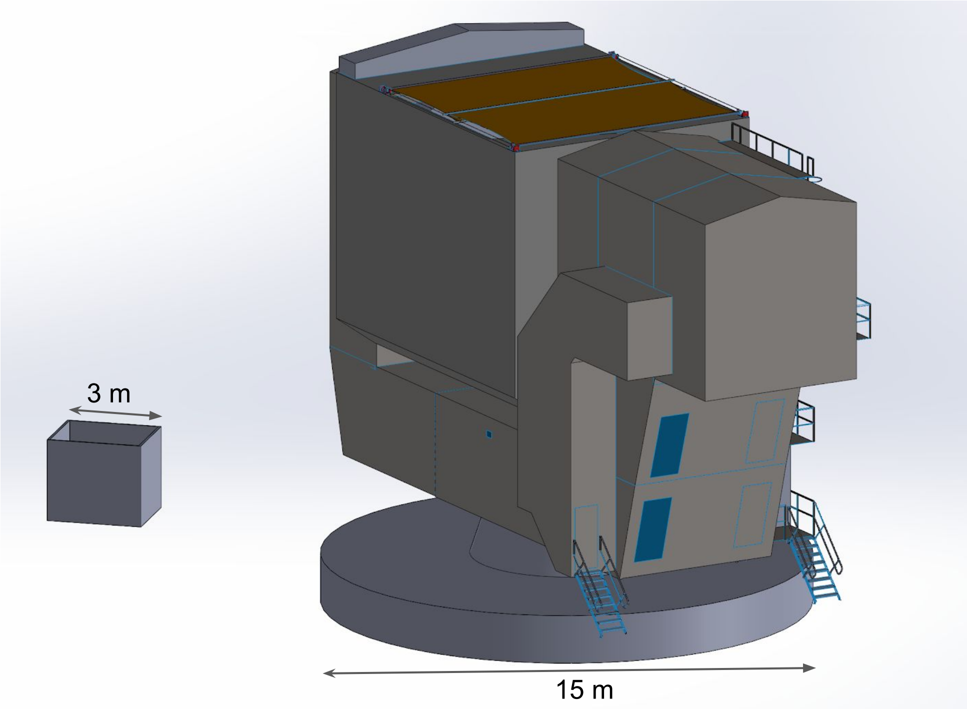
LAT & LAT interface containers

The LAT preliminary baseline design is based on the SO LAT Design.

A trade study for the foundation design, between a poured-in-place design (like SO) and a partially pre-fabricated design (like CCAT-p) will be conducted after concluding a geotechnical study at the foundation location and receiving preliminary foundation requirements from the LAT vendor.

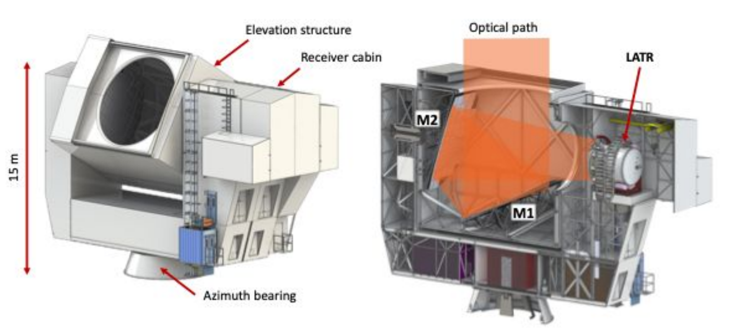
The preliminary baseline design is the poured-in-place SO design. This is 380 m3 of concrete.

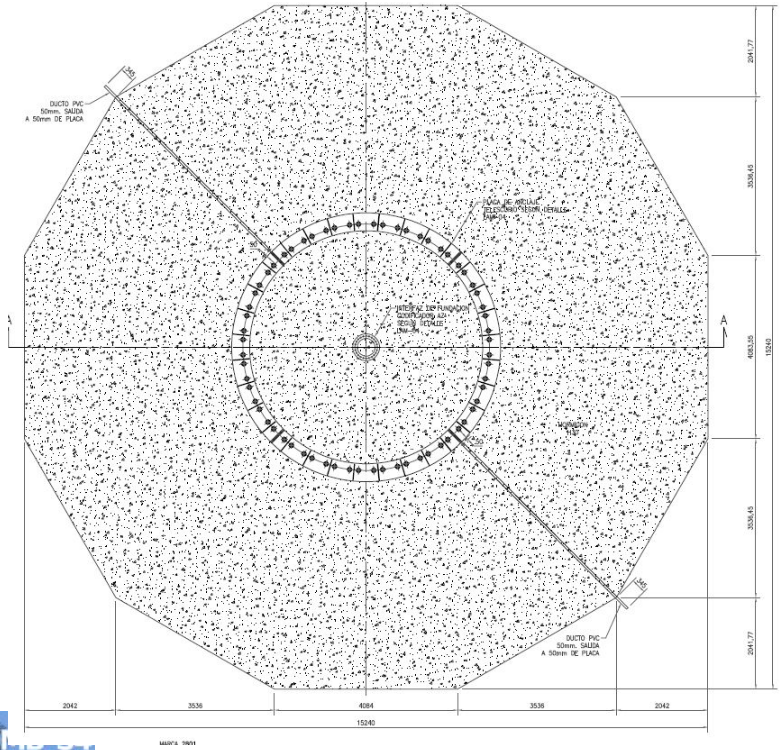
There are 2 interface containers associated with the LAT, one provided by the vendor and one by S4, which is primarily for cooling loop control

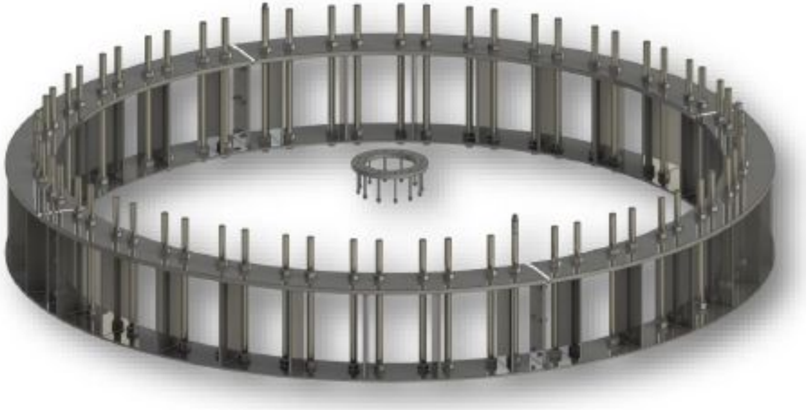


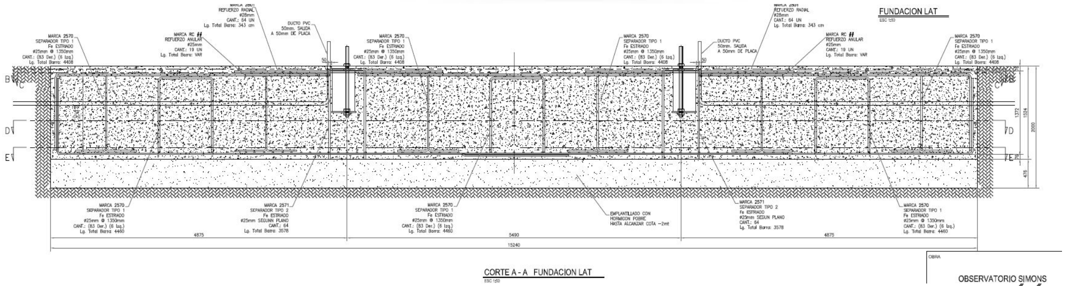
S4 LAT PDBR model based on SO LAT, with foundation and Vertex "MPD" interface point container. A 2nd 10-ft container will be near the LAT to contain the cooling control.

Chile LAT: Foundations based on SO design



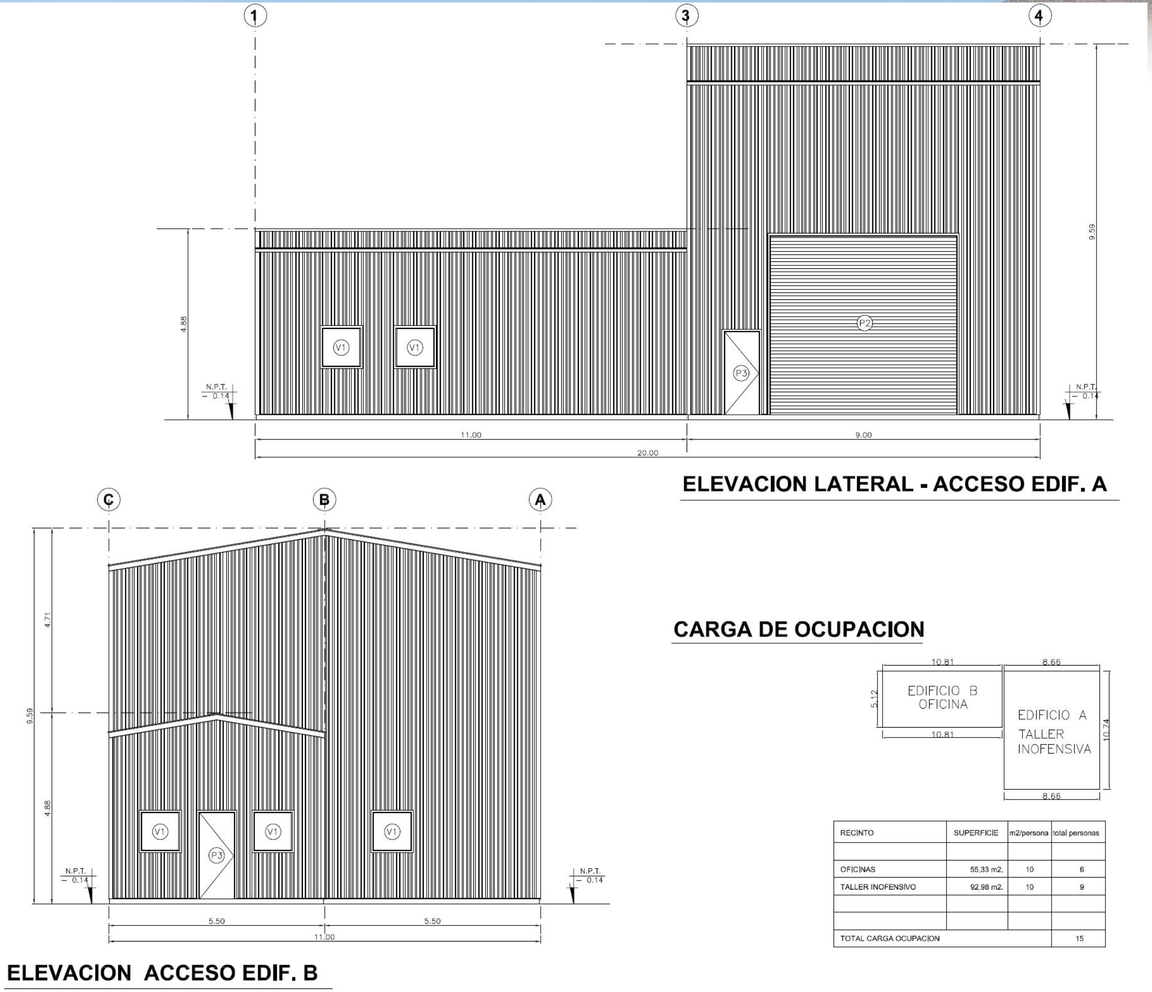






High-Bay Lab

- At least 960 sq ft (88 sq m) of lab area
- Includes an 8-ton x-y crane
- Provides for assembly and cooldown of the receiver
  - Baseline plan will be to pump down and leak check the receiver in the high bay, then transport it to the LAT and cool it down in the LAT
  - However, if necessary, the high-bay will support cooldown of the receiver
- Office with 660 sq ft (60 sq m)
  - Office includes space for all central site computing
- Reference design is the Simons Observatory building



RECINTO	SUPERFICIE	m2/persona	total personas
OFICINAS	55,33 m2.	10	6
TALLER INOFENSIVO	92,98 m2.	10	9
TOTAL CARGA OCUPACION			15

Communications

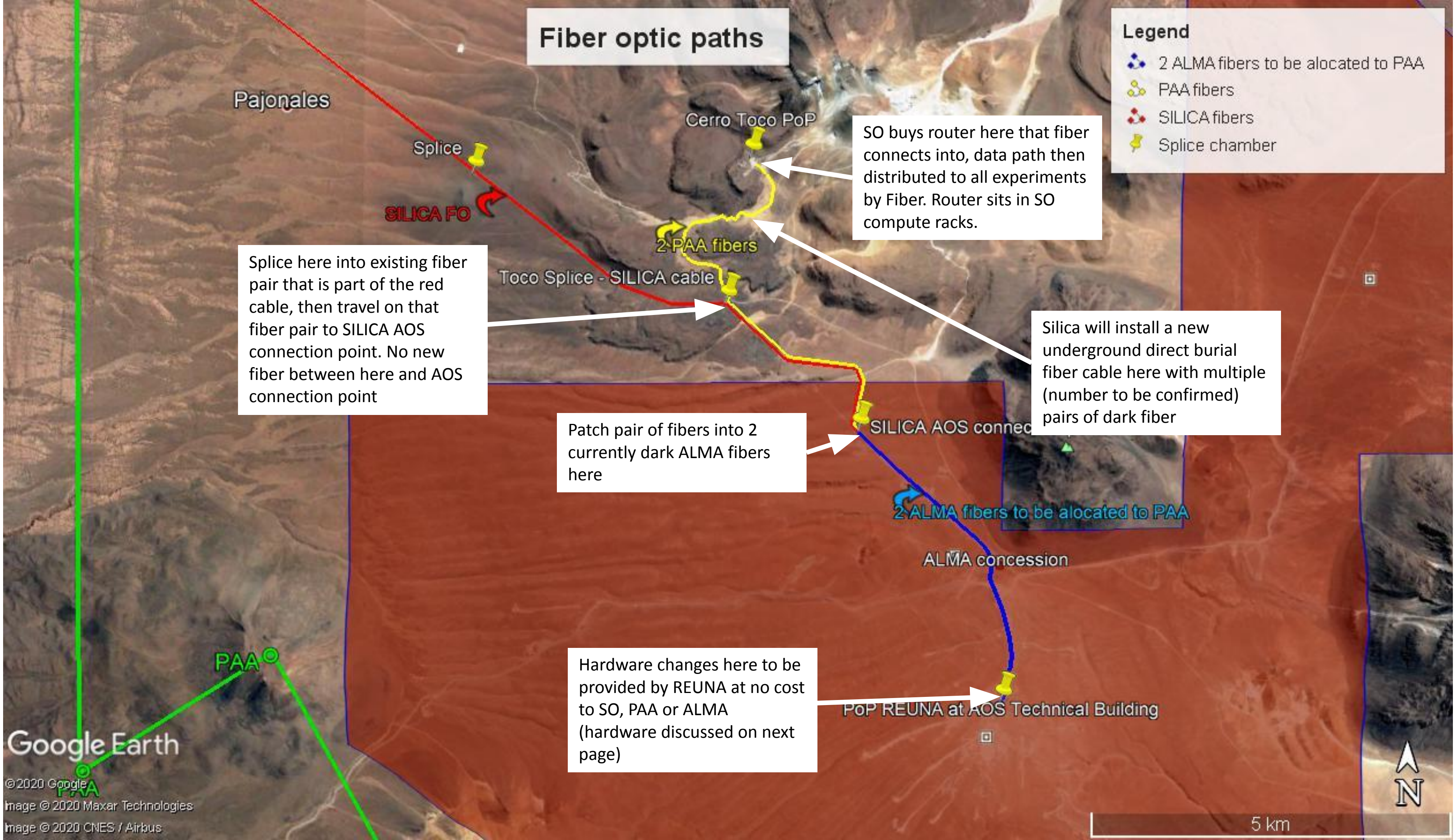
Summary of requirements:

- Redundant communication for remote control and monitoring of observatory operation
  - Low-bandwidth redundant connection via radio link to low-elevation facility, which is connected to the world by a commercial ~50 Mbps connection
- High-bandwidth connection for data transfer to the US with less than 1 minute latency.
- Support average achievable bandwidth of 1.2 Gbps

Implementation of high-bandwidth connection:

- Fiber connection to REUNA point of presence at ALMA AOS. REUNA then manages connection to North America, where the data is picked up by ESnet

External ID	Communication Requirement Description	Basis / Rationale
Chile-0255	Local network connectivity to each instrument and facility will be provided by fiber network	
Chile-0260	All intra-site communication outside of buildings shall be on optical fiber	Lightning is brought in to instruments on copper, lightning strikes have often destroyed equipment connected to copper in the past
Chile-0265	There shall be two separate connections to the outside world for control and monitoring of the observatory that achieve a >10 Mbps connection to the site.	
Chile-0270	Data transfer capability to North America with an average achievable bandwidth of 1.2 Gbps Site -> North America, and with ability to execute control functions North America -> Site.	Support data from two LATs
Chile-0275	Site shall provide a place for the housing of hard drives provided by DM. Hard drives must have capacity for 2 weeks of data, be redundant against hardware failures, and be appropriate for use at 17,000 ft (helium-filled or solid state)	
Chile-0280	The high-bandwidth connection will be up for control functions more than 95% of the time, and will maintain average transfer requirement by having a peak transfer capability exceeding the average transfer requirement by at least 10%	
Chile-0285	The low-bandwith connection will be accessible from the LEF and the world. Note that there is no requirement for high-bandwidth connection between the LEF and the HEF or the LEF and the world.	


Fiber optic paths
Legend
2 ALMA fibers to be alocated to PAA
PAA fibers
SILICA fibers
Splice chamber
Pajonales
Splice
SILICA FO
Cerro Toco PoP
SO buys router here that fiber connects into, data path then distributed to all experiments by Fiber. Router sits in SO compute racks.
2 PAA fibers
Toco Splice - SILICA cable
Splice here into existing fiber pair that is part of the red cable, then travel on that fiber pair to SILICA AOS connection point. No new fiber between here and AOS connection point
Silica will install a new underground direct burial fiber cable here with multiple (number to be confirmed) pairs of dark fiber
SILICA AOS connec
Patch pair of fibers into 2 currently dark ALMA fibers here
2 ALMA fibers to be allocated to PAA
ALMA concession
PAA
PAA
Hardware changes here to be provided by REUNA at no cost to SO, PAA or ALMA (hardware discussed on next page)
PoP REUNA at AOS Technical Building
Google Earth
©2020 Google
Image © 2020 Maxar Technologies
Image © 2020 CNES / Airbus
5 km
N

Cooling

- Heat from compressors and readout water chiller exhausted through a utility cooling loop to the air outside the LAT
  - Requirements do not currently capture the readout water cooling requirement
  - The design will be modified to assume that a chiller inside the LAT provides constant-temperature chilled water for readout cooling, and will exhaust that heat into the utility cooling loop
- Current requirement in Jama (needs to be updated):
  - The site shall provide 50%/50% glycol/water coolant to each LAT at a 2" NPT connection near the MPD. The coolant will be between 7 and 27 °C, with temperature varying depending on ambient temperature, and with flow capability of 21 GPM, heat extraction capability of 46 kW, and pump driving pressure capability of 69 psi. Numbers contain some margin, to be revisited in detailed design.
- The cooling loop design is based on the SO AquaCooling design:
  - “Dry Coolers” are blowers over radiator units that exhaust heat to the atmosphere
  - SO schematic on following slide

LAT Utility Cooling Loop Diagram (adapted from SO)

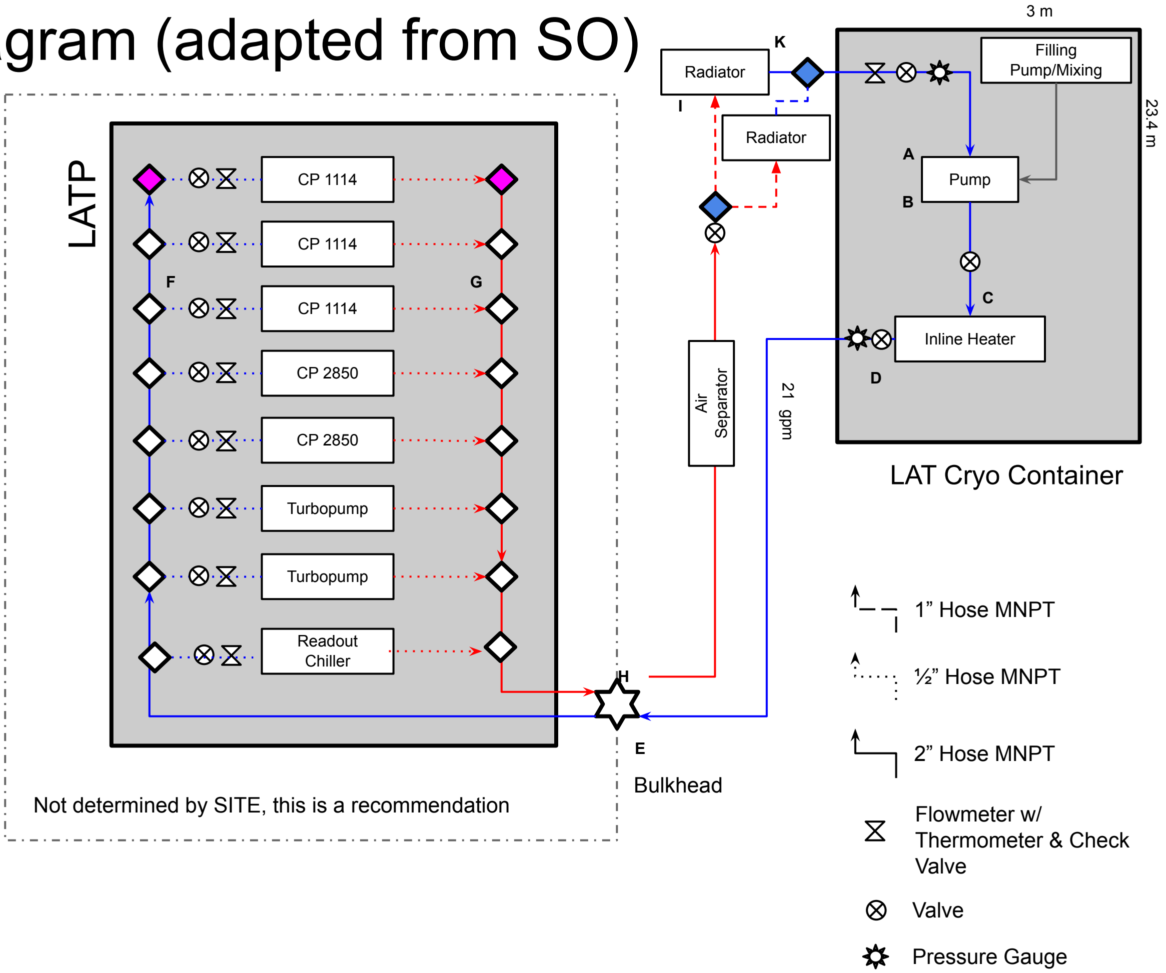
Distances, Equivalent Flow/Diameters, and Pressure Drops (+40% psi glycol)
A-B: >
B-D: 12 meters, 2” @ 21 gpm, 0.3 psi
D-E: 30 meters, 2” @ 21 gpm, 0.7 psi
E-F: 16 meters, 2” @ 21 gpm, 0.3 psi
F-G: 48 psi minimum (110psi max)
F-G: 4 meters, ½” @ 4.4 gpm, 3.6 psi
G-H: 16 meters, 2” @ 21 gpm, 0.3 psi
H-I: 50 meters, 2” @ 21 gpm, 1.1 psi
H-I: 0.5 psi (air separator)
I-K: 13 psi
K-A: 20 meters, 2” @ 21 gpm, 0.4 psi

Total 2” hose length: 12 + 30 + 16 + 16 + 50 + 20 = 144 meters

Total ½” hose length: 7x4 = 28 meters

Total Pressure Drop: 0.3 + 0.5 + 0.7 + 0.3 + 48 + 3.6 + 0.3 + 1.1 + 8 + 0.4 = 68.2 psi

Total Coolant: 71.3 gal + 1.4 = 72.7 gal
(1” hose length + ½” hose length cylinders)



32F tee with 32M-16F bushing with 16M-8F bushing

32F-16F reducer with 16M-8F bushing

4F-8M bushing to 8F-16M bushing to 1" ball valve 16M nipple to 32F-16F reducer to 32F nipple to 32F tee

For 1” NPTF flowmeter with 2” hose: 2x 32F-16F reducer with 16M nipple
For 1” NPTF flowmeter with ½” hose: 2x 32F-16F reducer with 16M-8F bushing

32F tee with two 32M-16F reducers

See Slide 11 for Junction Details

Parts List

Compressed air

- The dilution refrigerators need compressed air to actuate valves
- For operations, there is no requirement for the site to provide compressed air. This is entirely within the LAT scope, and the compressed air system is entirely within the LAT
- The site needs to provide compressed air in the lab to allow for the possibility of cooling the receiver in the lab if necessary
- Compressed air requirements:
  - Provide regulated dry air or nitrogen between 70 and 100 PSI
  - Connector to the GHS is a female series-25-type with G1/4 threading (BSPParallel)

Power Generation

Power generation will be optimized to supply ~320 kW continuously, capable of providing 400 kW continuous power.

Configuration:

- Prime power: 4 Perkins generators, each in its own 6-meter modified shipping container, with the plan to have two operating at the same time to supply the full load
- Utility power: a 50 kW small generator for site utilities when no compressors are running

All generators able to synchronize to each other, and synchronize to incoming grid power or another power source as necessary

Requirements from Jama on the following pages

External ID	Description	Basis / Rationale
Chile-0180	Electrical power generation and distribution shall comply with Chilean code and follow the guidance of PAA	
Chile-0185	Site will provide 400V 50 Hz 3-phase power to all instruments and facilities (this means a single phase is 230 V)	Following SO-LAT Standard and SO power generation
Chile-0190	The power generation shall have the capability of a future connection to an outside source of power if one exists. In this future case, the S4 planned prime generation may become the back-up generation and the outside source of power would be the prime generation	PAA may provide power in the future, or there may be a future connection to the power grid
Chile-0195	Site power generation will be able to satisfy an average consumption of 304 kW (number without margin). Including margin, the prime generation capability shall be more than 400 kW.	Power budget document within preliminary Baseline Design document
Chile-0200	Site is responsible for distribution of electrical power to all instruments and facilities, with the appropriate breakers per Chilean code	
Chile-0205	Power will be provided by multiple synchronized generators to allow flexibility of generation depending on load, and redundancy mitigating the effects of generator failure	
Chile-0210	The electrical power generation will be continuous with no more than 5 shutdowns per year	
Chile-0215	The site will be able to remotely monitor safety and security issues with enough clarity to determine if a remote power restart in the case of power failure is safe. If it is, the site will be able to perform a remote restart. All instrument control and communication must be such that this remote restart can be achieved without damage to instruments	Generator failure during weather events may mean that a power restart within a few hours could keep the cryogenic instrumentation from warming up

Chile-0220	Electrical power generation at full load will be possible without fuel delivery for at least 2 weeks	Observing efficiency: experience is that after weather events site access is almost always restored within this time.
Chile-0225	The site will supply uninterrupted power (battery-based UPSs) for subsystems: compute, network, and all remote access for at least 120 minutes, for other subsystems to be defined	
Chile-0230	Voltage and frequency fluctuations will be less than plus or minus 5%	
Chile-0235	All outlets will be 16A rated, outlets will be provided that are both Chilean standard and Schuko F	Both 230 V standards useful for European and Chilean tools
Chile-0240	Some US-standard outlets with 120 V / 50 Hz power will be provided. A warning about the non-US frequency will be placed on or adjacent to these outlets	

These requirements do not yet include anything about a photovoltaic plant. See the next slide.

Note that full diesel generation will require approximately 190 diesel deliveries (in 5000-liter-trucks) per year. This strongly incentivizes either a photovoltaic solution to reduce the reliance on diesel or a road improvement that allows delivery in 20,000-liter-trucks.

Photovoltaic Plant

Kraftwerk pre-feasibility study: A PV plant with 2.0 MegaWatt-peak (MWp) of PV generation capability and 8.8 MWh allows for operation at 380 kW while only requiring diesel generation 55 days/year.

We are currently getting proposals from other companies to compare

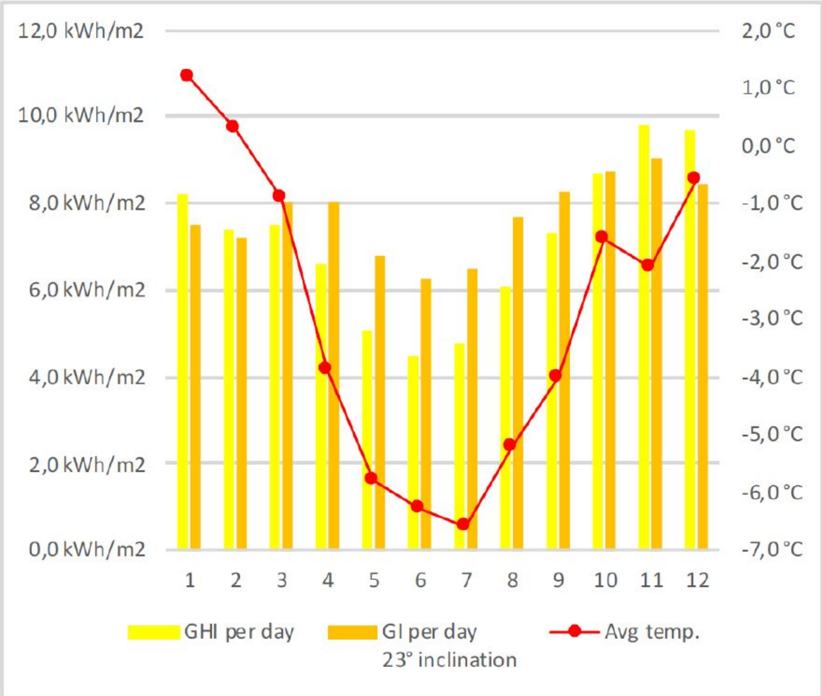


Figure 4: Average daily irradiation at the site. Note that while there is less irradiation in the austral winter, the colder temperatures are a benefit to the solar panels. Tilting the solar panels at 23° (the latitude) evens the annual variation out, and leads to maximum total power being generated over the year. Note that in the austral summer (January and February, shown here as months 1 and 2) the generation is not as high as you might expect since that is the cloudiest time of year at the site (the so-called "antiplanic winter.") The yearly average irradiation on a 23° surface is greater than 2.8 $\mathrm{MWh/m^2}$.

CMB-S4

Existing PV panels on-site

Operating with batteries for more than 5 years with no sign of degredation

Long-lead infrastructure & logistics

(From Plenary)

- Power generation:
  - Diesel generation is straightforward and not a long-lead issue. Design can be launched in 2023
  - Diesel generation will be designed to allow synchronization with incoming power from another source
    - If desired, diesel generation can synchronize with the SO diesel generation to create a single more robust power plant
    - If desired, diesel generation can back-up or be backed up by a PV/battery array
- Communication:
  - Fiber initially capable of 1 Gbit and easily expandable to 10 Gbit planned for connection to central location on Cerro Toco by 2022. This is happening as part of existing funding.
- Road improvement
  - Construction traffic can go through ALMA roads, as is done with current experiments
  - Supply of diesel to generators cannot be regularly transmitted through ALMA roads
  - An engineering study on modification of the road to allow 20,000-liter trucks of diesel If Toco is fully powered by diesel
- Legal & Bureaucratic:
  - Environmental studies
  - Agreement between U. Chicago and U. Chile, taking into account the Chilean astronomical community
  - State Department decree signed by the President of Chile
  - Agreement between U. Chicago and government entity with authority over land use
  - The framework for all of this is being worked on currently as part of the MSRI-DP1 scope, with final land use agreement signed after the award of an MREFC.

Power generation facility

- **Baseline:** diesel generators. Same as SO, which has a 5-generator 380 kW load plan, and 2 x 30,000-liter diesel tanks
- **Opportunities:**
  - Atacama Astronomical Park (AAP, land administrator) is evaluating installation of communal power generation that could include a renewable component. In this case, the S4 diesel generators can become back-up generators
  - Working with SO to join “power” and consolidate needs during overlapping years of operation
  - In discussion with power companies interested in building or building/operating a solar or combined solar/diesel power plant

2030-2035 funding is not secured yet

	Nominal [kW]	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037
Simons Observatory	340	10%	30%	50%	80%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%		
CMB-S4	324				10%	30%	50%	80%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Simons Observatory	340	34	102	170	272	340	340	340	340	340	340	340	340	340	340	340		
CMB-S4	324	0	0	0	32.4	97.2	162	259.2	324	324	324	324	324	324	324	324	324	324
Total	**664**	**34**	**102**	**170**	**304**	**437**	**502**	**599**	**664**	**664**	**664**	**664**	**664**	**664**	**664**	**664**	**324**	**324**

Documents being drafted for 2021 reviews

- Construction Plan
  - Chile Project Office Structure
  - Staffing, including for integration and commissioning
  - Shipping
- Facilities/Site Layout
  - Site selection documentation
  - Connection to requirements
  - Conceptual plan by architect
- ES&H Plan
  - Lay out that we know the scope and resources needed for such a plan
- Operations plan
  - Focus on operations readiness plan draft
  - Need draft of operations plan
- Environmental Impact Statement
- Cost Estimates

Chilean Project Office Responsibilities

The legal entity in Chile will establish a project office in Santiago that has the following responsibilities. It will report to the L1 project office as required on all of these responsibilities.

Note that this is in addition to the general project control requirements within the WBS element.

- Regulatory compliance (US and Chile)
- Legal administration & support
- Representation in Chile
- Chile human resources
- Support of international staff
- Chile safety & health management
- Local budget management and control
- Travel administration
- Accounting, including payroll and taxes
- Language support
- Insurance services
- Physical security
- Chile contracts & procurement
- Logistics: import/export, receiving, shipping, storage
- Property management
- Inventory management
- Physical plant non-technical operations and maintenance
- Manage low-elevation facility contract
- Site access management
- Transition from project to operations
- Education & public outreach
- IT support

CMB-S4 Chile Project Office

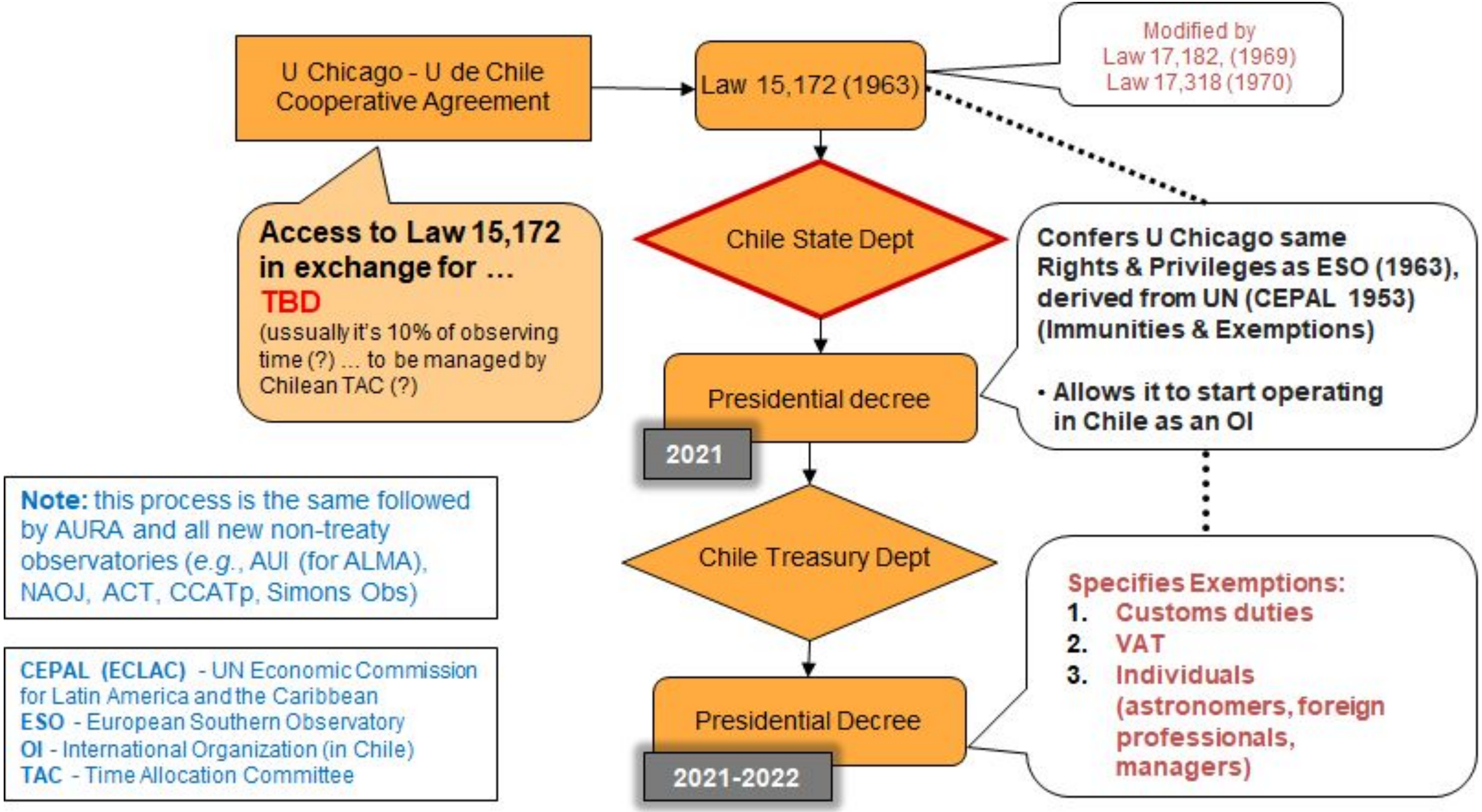
- Scope of the operation in Chile
  - Operation in Chile will be solely for CMB-S4 activities
  - Will be under the auspices of Law 15,172 that grants international astronomy organizations privileges and immunities to build and operate their facilities in Chile
    - Immunities apply and operates similar to an “embassy”; applies to facilities and accredited staff
    - Provides exemption from taxes (VAT, fuel) and customs duties
    - Waives Chile income tax payment to accredited international staff members
- Legal framework
  - Has standard risks from operating a company in Chile
  - Safety, health & environmental compliance
    - Remote site, 5200 meters above sea level (17,000 ft)
  - Application of local building standards and codes
  - Application of L1 rules rules and regulations
  - Land protection
- Commercial matters
  - Leases, contracts, property management
  - Import/export management (application of customs privileges)
  - VAT management

CMB-S4 Chile Project Office Roles

Responsible for legally conducting business in Chile and making binding commitments.

- Is the OI's link to:
  - **Government of Chile:** State Dept, Congress**,** Science Dept, Health, Labor, Environment, Treasury, Police, Municipalities, Regional Authorities
  - **Chilean institutions:**
    - Other observatories in Chile, universities
    - Atacama Astronomy Park
  - **Embassies**
- Maintains strategic oversight of Chilean community & legislation changes
  - "Senses" strengths, threats, weaknesses & opportunities
- Oversight of Chile operations
  - Operate the Site, Low Elevation Facility (in San Pedro de Atacama), and Santiago Office
  - Follow Chile rules and regulations, and L1 policies
  - Oversight on safety, health & environment
- Legally responsible in Chile for local & international staff
  - Follow Chile labor legislation
  - Accreditations/relocations of international staff members

Establishing the CMB-S4 legal presence in Chile



CMB-S4