The GMT Site, Enclosure, and Facilities: 2024 Design and Construction Update

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ABSTRACT

The Giant Magellan Telescope (GMT), one of three extremely large telescopes (ELTs) in development, will be located on the summit of Cerro Las Campanas, a peak within the property of the Las Campanas Observatory (LCO) in Chile. The GMT employs seven 8.4m monolithic mirrors as segments to form a single optical surface with an equivalent diameter of 25.4 meters. Developing a new observatory for cutting-edge science operations and a 50-year lifespan poses a variety of design and construction challenges. This paper reports on progress since 2020, including the latest developments for the GMT site master plan, and work completed for the site infrastructure, telescope enclosure, and support facilities. In late 2021, GMTO selected IDOM (Bilbao, Spain) to mature the enclosure from its preliminary reference design through to final design and documents (drawings and specification) for construction. Over the last two years, the designs for enclosure structures, mechanisms, pier seismic isolation system, and related control systems have been refined as they passed through a 60% critical design review in May 2023, and the final design review (FDR) in May 2024. Construction work at the GMTO site started in 2015, and over the past four years has seen completion of the underground utility distribution systems and preparations for start of enclosure construction.

Keywords: GMT, GMTO, observatory, facilities, enclosure, construction

1. INTRODUCTION

The Giant Magellan Telescope Organization (GMTO Corp.) was formed to build and operate the Giant Magellan Telescope. Since 2015, GMTO has been engaged simultaneously in design, fabrication, and construction activities for the telescope, optics, science instruments, telescope enclosure, and related facilities. As of 2024, the GMT project is advancing in all major areas, including fabrication of the seventh 8.4m primary mirror, fabrication of the azimuth structure of the telescope, fabrication of the first adaptive secondary mirror, fabrication of components for the first-light instrument suite, and many other areas. See Burgett[1] (this proceedings) for a comprehensive update of all areas of the GMT project.

This paper provides a status report on design and construction of the GMT Site Infrastructure, Enclosure, and Facilities (SEF) since 2020 (See Bigelow[2]). The GMT project is organized and led by the project manager (PM), who delegates responsibility and authority to a group of project element managers (PEMs), who in turn are responsible for managing delivery of the project subsystems (elements). The Site Infrastructure, Enclosure, and Facility elements are combined under a single PEM, and a dedicated group of engineers who are responsible for guiding work in their disciplines, including structural, mechanical, electrical, physical plant, and controls engineering. The SEF team is responsible, in coordination with GMT Systems Engineering, to develop the subsystem architecture (effectively, the product breakdown structure, PBS), the subsystem operational concepts, requirements, and interface control documents (ICDs) for the SEF deliverables. The SEF team works with GMT Contracts and Procurements (C&P), to develop design and construction statements of work (SoW), procurement strategies and plans, and requests for proposals (RFP), to execute the design and construction contracts which deliver the final products. In this status report, we address the latest developments in the SEF elements, including the Site Master Plan, which addresses the SEF deliverables on and just below the summit of Cerro Las Campanas. The GMT observatory site includes three major construction areas (the Summit, Support Site 1 - SS1, and Support Site 2 - SS2). The Summit Site includes the GMT enclosure, the Summit Utility Building (SUB), the Summit Utility Tunnel (SUT), and the (Facilities) Summit Support Building (SSB). Immediately below the SUB, the water pad hosts summit infrastructure including the water and fire equipment buildings (WEB and FEB), the GMT water tank, and just below, the GMT dry coolers.

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SS1 (the technical support site) includes the (Facilities) Shop and Warehouse buildings, along with the site infrastructure associated with connections to external networking and electrical power (the Chilean power grid). SS2 (the personnel support site) includes the buildings and site infrastructure which provide lodging, food service, and recreation for GMT and site contractor personnel. Site Infrastructure includes the roads, parking areas, utility systems, utility treatment, and underground distribution systems which connect and support the three major construction areas. See Figure 1 for the layout of the Summit Site. In La Serena, roughly 2-1/2 hours south of the observatory site, the Facilities scope includes a Base Facility, which will include spaces for the personnel, business, and operations support functions for the observatory which are most efficiently provided in an urban environment. In the following sections, we report on the latest design and construction progress, organized by the three primary construction areas, and including the telescope enclosure, the site facilities buildings, the Base Facility in La Serena, and the site infrastructure.

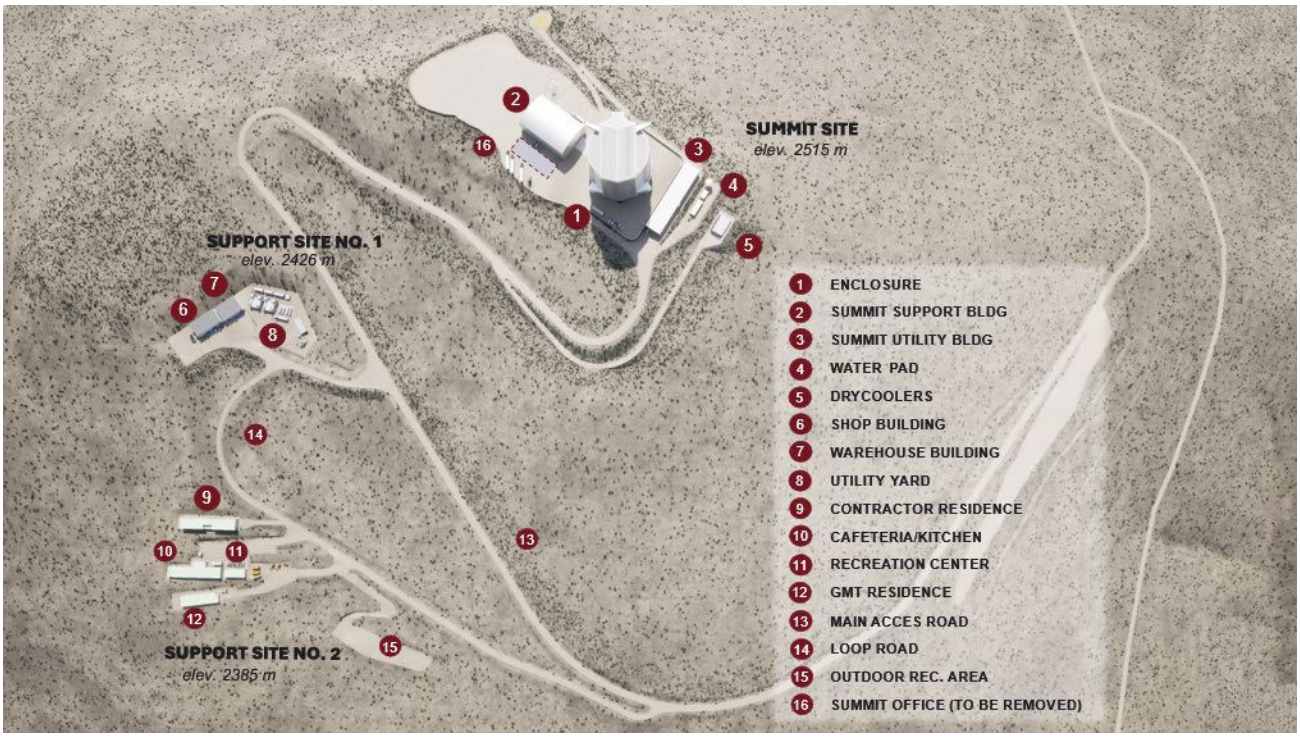

Figure 1 - The 2024 GMT Observatory Site Master Plan

2. THE SUMMIT SITE

The Summit Site includes the buildings and support infrastructure as described in the site master plan. See Figure 2 for a rendering of the site looking from the North-West. The following sections will describe the designs and status for the Summit Site improvements.

The scope of the GMT enclosure final design contract includes the foundations for the telescope and enclosure, the telescope pier, the telescope pier seismic isolation systems (SIS), the fixed lower portion of the enclosure, and the rotating upper enclosure. Although they are named individually, the Enclosure, Summit Utility Tunnel (SUT), Summit Utility Building (SUB), water pad buildings, dry cooler platform (and the Utility Yard at SS1) have all been designed together under a single statement of work.

2.1 The Enclosure

Starting in early 2022, the enclosure Architecture & Engineering (A&E) firm IDOM, supported and guided by the GMT project and SEF teams, has matured the enclosure reference design (from 2020) through a successful series of design reviews, including an initial engineering review (IER) in July 2022, 60% maturity Critical Design and Constructability

Reviews (CDR) in May 2023, a pier and seismic isolation system CDR in October 2023, and 100% Final Design Review (FDR) in May 2024.

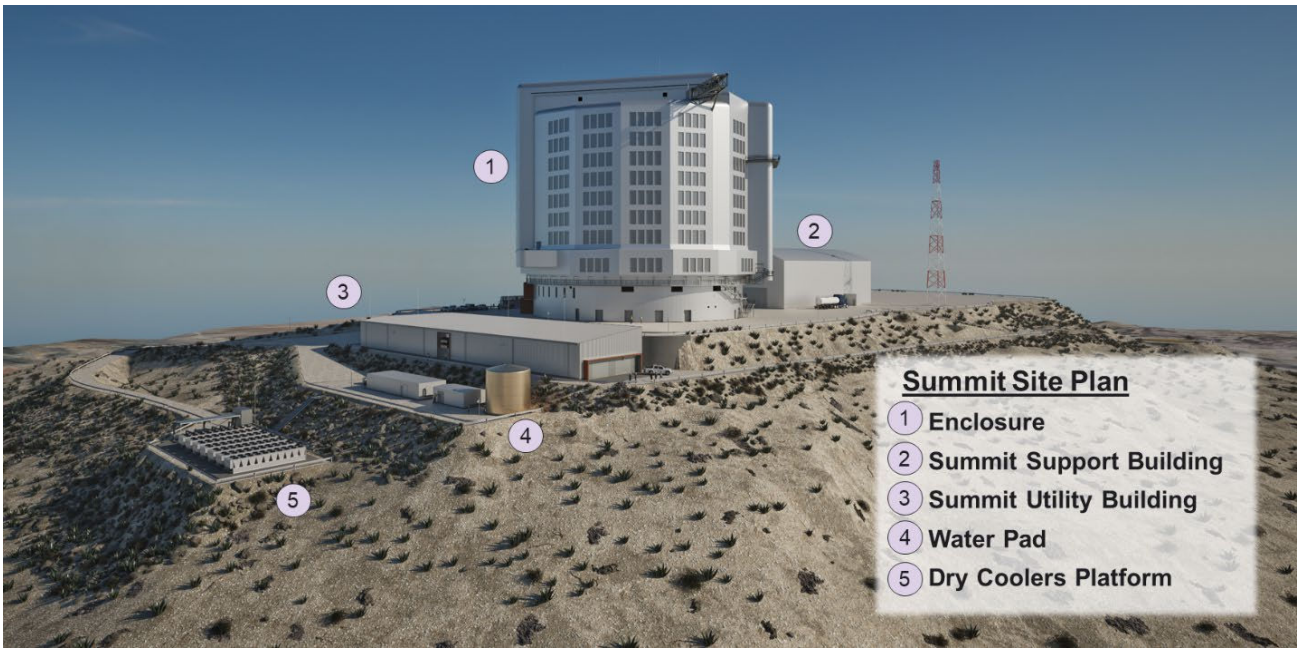

Figure 2 - View of the dry cooler platform, water pad, Summit Utility Building, Enclosure, and Summit Support Bldg.

A detailed description of the enclosure design is provided by IDOM in these proceedings (see Castro[3]). Similarly, a detailed description of the design, prototype fabrication, and prototype testing for the telescope pier and seismic isolation systems is also provided in these proceedings (see Fernández[4]). For a report on the design and construction of the Giant Magellan Telescope, in these proceedings, see Park[5]. The enclosure was designed using a Building Information Modeling (BIM) approach, based on a variety of computer-aided design and engineering tools including Autodesk Revit, Tekla, SolidWorks, Autodesk Construction Cloud (ACC), and Navisworks. Control of conventional building functions such as secure access, lighting, fire detection and protection, and heating, air-conditioning, and ventilation (HVAC), are controlled by a Building Automation System (BAS), which in turn is monitored by the Observatory Control System (OCS). See Cox[6] for a detailed description of the GMT observatory software and controls (OCS) development program.

The Lower Enclosure structure is of conventional design, composed of reinforced concrete (walls and slabs) and steel structures (control and observing floor levels). On grade, the lower enclosure provides two instrument labs, a large storage area, a shipping & receiving area, and a large electrical room for the transformers and switchgear for the enclosure and the telescope. The control level hosts the large air-handling units (AHUs) which control the daytime air temperature in the observing chamber, and provides a control room, a computer/server room, a dedicated IT network room, and additional support and office spaces for daytime and nighttime operators and science observers.

The Upper Enclosure is essentially a computer-operated environmental control system which protects the telescope from a wide range of adverse external environmental conditions (i.e., rain, snow, wind, ice), while also providing air flow control systems to modulate the effects of nighttime ambient thermal and wind conditions that can negatively impact local “seeing” and resulting telescope image quality. Key mechanisms include the enclosure rotation system (ERS), bi-parting shutters (BPS), windscreen (EWS), and wind vents (EWV), all of which are controlled by the OCS via the Enclosure Low-Level Control System (LLCS). A 75MT overhead bridge crane (EOBC) is installed at the top of the enclosure, to enable assembly and servicing of the telescope, and removal/installation of the telescope payloads. A completely independent interlock and safety system (ISS) protects personnel and machinery in the upper and lower portions of the enclosure and enables system-level safety actions by the observatory global interlock and safety system (GISS). See Figure 3 for a section view of the enclosure and general arrangement of its features. Figure 4 shows the angular relative motion of the bi-parting shutter doors. Some of the main design drivers for the mass and dimensions of the upper enclosure include the following:

- Height and diameter determined by the height of the telescope elevation axis and swept volume

- Shutter door dimensions based upon the telescope aperture diameter and elevation angle range
- 75 MT bridge crane reach spanning the width of the telescope and half of the enclosure diameter

Key design changes since 2020 include increase of the bridge crane capacity from 65MT to 75MT, revision of the size, number, and locations of the wind vents (based on system-level integrated modeling with CFD inputs and impacts on image quality, see Conan[7] and Vogiatzis[8]) refinement of the windscreen and viewing gallery designs, and strengthening of the upper enclosure structures for improved seismic performance.

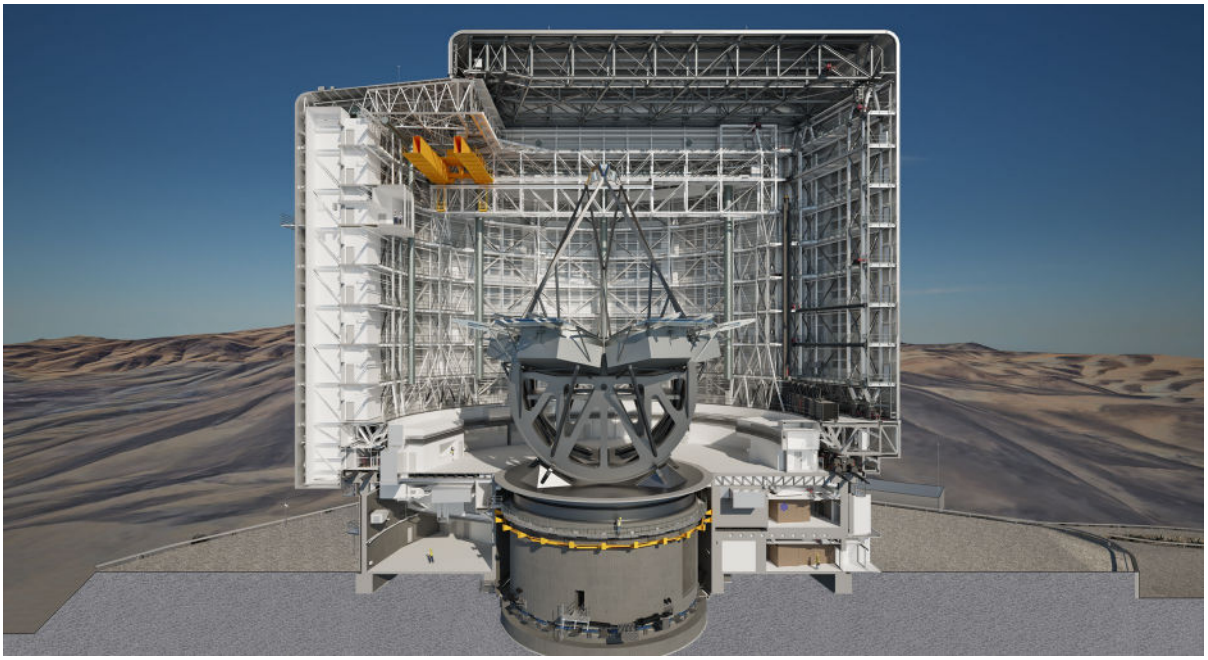

Figure 3 - Section view of the enclosure with the telescope.

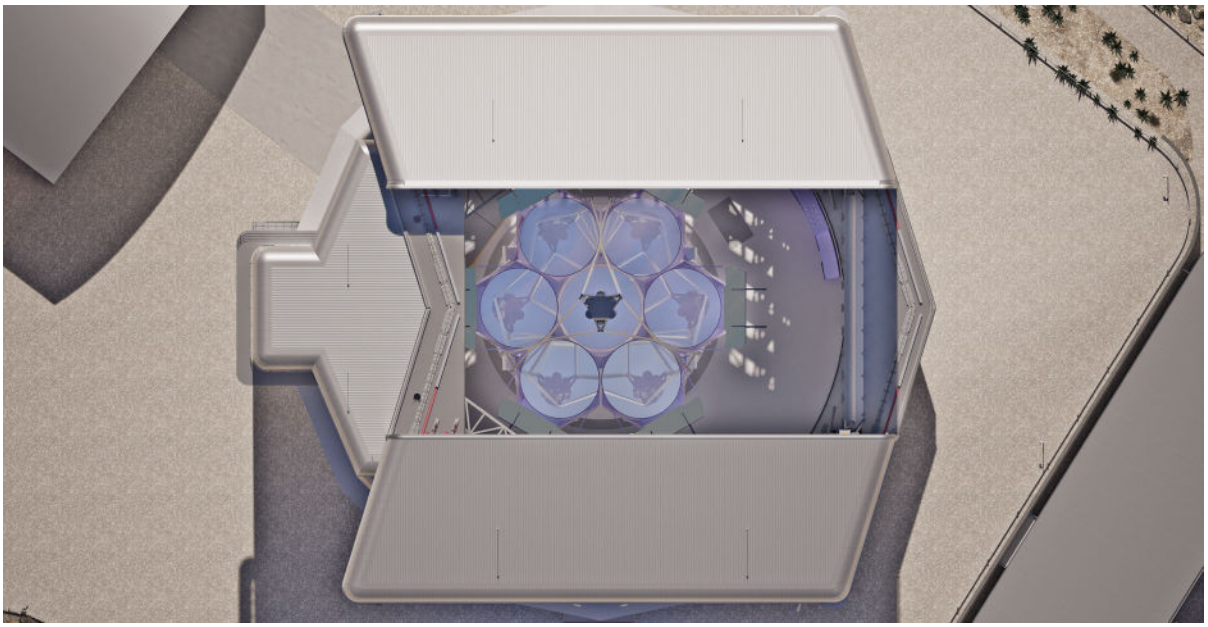

Figure 4 - Top view of the enclosure, showing the angular motion arrangement of the bi-parting shutter doors.

2.2 Enclosure Dynamic Modeling

The GMT observatory will be much larger than its predecessors. With the increase in size of the telescope and enclosure comes increased difficulty and complexity in the planning and conduct of daily operations tasks. Simulation of these tasks, especially during the design process, can provide a means for assessing risk and assisting in the design of mitigations. Dynamic observatory models based on video game development engines offer an efficient way to simulate a wide variety of observatory operational behaviors. Game development tools, such as the "Unity" and "Unreal" gaming engines, allow the creation of integrated 3D virtual observatory models which can be animated with motion and basic physics. A key advantage of the game-based models is that they can be shared with observatory operations users who have no knowledge or experience with the underlying 3D design tools. Models created during the design process with computer aided design (CAD) tools including Revit, SolidWorks and Navisworks can be imported directly into the gaming engines to simulate operational behaviors.



Figure 5 - Graphics from an integrated gaming model including the telescope, enclosure, and personnel lift.

GMTO is currently experimenting with multiple gaming engine products, and simulating simultaneous motions of the telescope, enclosure, and operational tools such as personnel lifts and the enclosure overhead bridge crane, to develop procedures for installing and removing the primary mirror segments on the telescope. In addition to the ability to dynamically simulate observatory operational tasks, virtual models developed with the gaming engines can also be used to generate high quality graphics which are difficult and/or very time-consuming to create using the 3D CAD tools. An image of an operation including positioning of a personnel lift and independent rotations of the telescope and enclosure can be seen in Figure 5.

2.3 The Summit Utility Tunnel

The Summit Utility Tunnel (SUT) provides an underground pathway for conduits carrying electrical power, fiber-optic network cabling, and piping for liquid and gaseous heat transfer fluids (water/glycol, CO2, compressed helium, compressed air, and high-pressure hydraulic oil for the telescope hydrostatic bearings). The SUT also serves a duct for the pier forced ventilation system, which collects waste heat from the enclosure rotation system and sources in the pier chamber and rejects the heated air via a fan wall on the far side of the SUB. Construction of the SUT is composed of a cut-and-cover trench and a concrete box section tunnel 33m long, 4.7m high and 5.2m wide. See Figure 6 for a section view of the SUT, from its starting point in the lower enclosure to its ending point at the SUB.

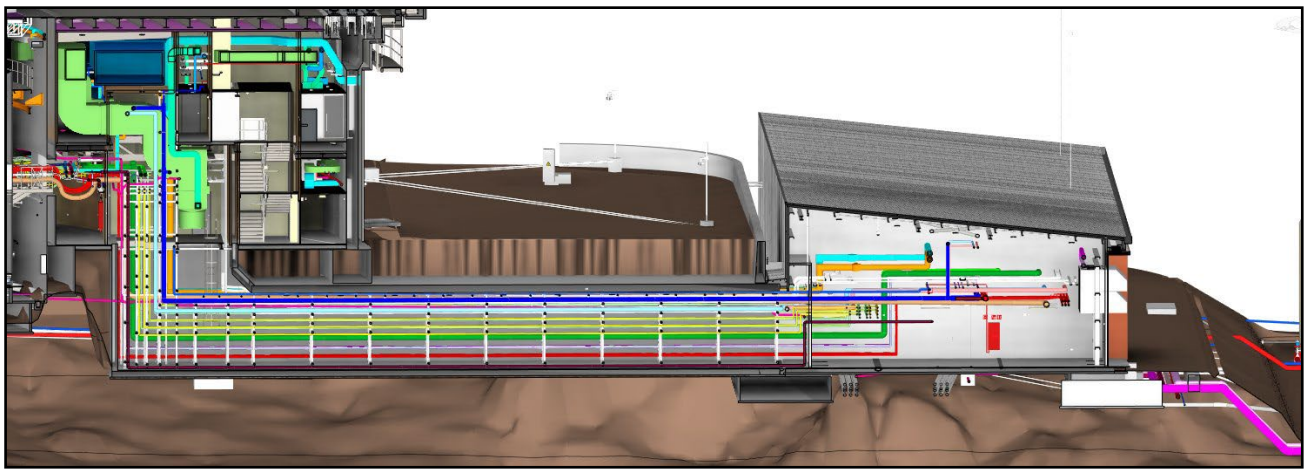

Figure 6 - Section view of the Summit Utility Tunnel, including entrances to the enclosure and Summit Utility Building.

2.4 The Summit Utility Building

The Summit Utility Building (SUB) construction includes a slab on grade and a conventional steel structure. The SUB is ~74m long, ~16m wide, covering ~1180m^2, and ~8m tall at the highest point. Separate rooms are provided for network equipment, electrical transformers and switchgear, fluid chillers, the water mist fire protection system, the hydrostatic bearing system (HBS) skid (provided by the telescope mount builder), CO2 refrigeration system, compressed helium cryogenic cooling systems, and compressed air systems. Arrangement of the rooms in the SUB are shown in Figure 7.

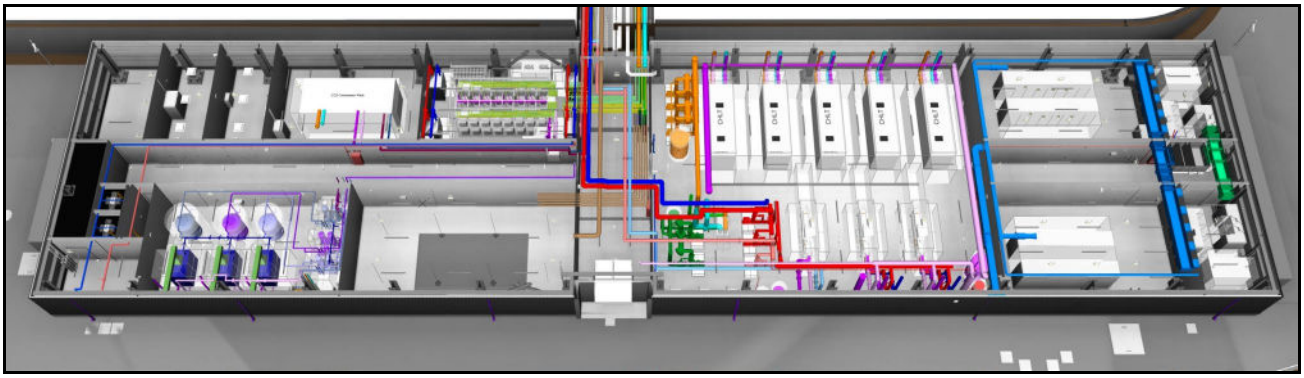

Figure 7 – Isometric view of the rooms and equipment layout in the Summit Utility Building.

2.5 The Summit Support Building

The Summit Support Building (SSB) will be located near the center of the Summit Site, adjacent to the Enclosure Building. A concrete apron will connect the SSB to the Enclosure to allow safe movement of telescope components and personnel between the two buildings. The SSB is in the schematic design phase, and an initial arrangement of the grade level floor plan is shown in Figure 8. The SSB houses critical functions associated with primary mirror initial integration, staging, washing/stripping, coating, storage, and secondary mirror assembly, alignment, and testing.

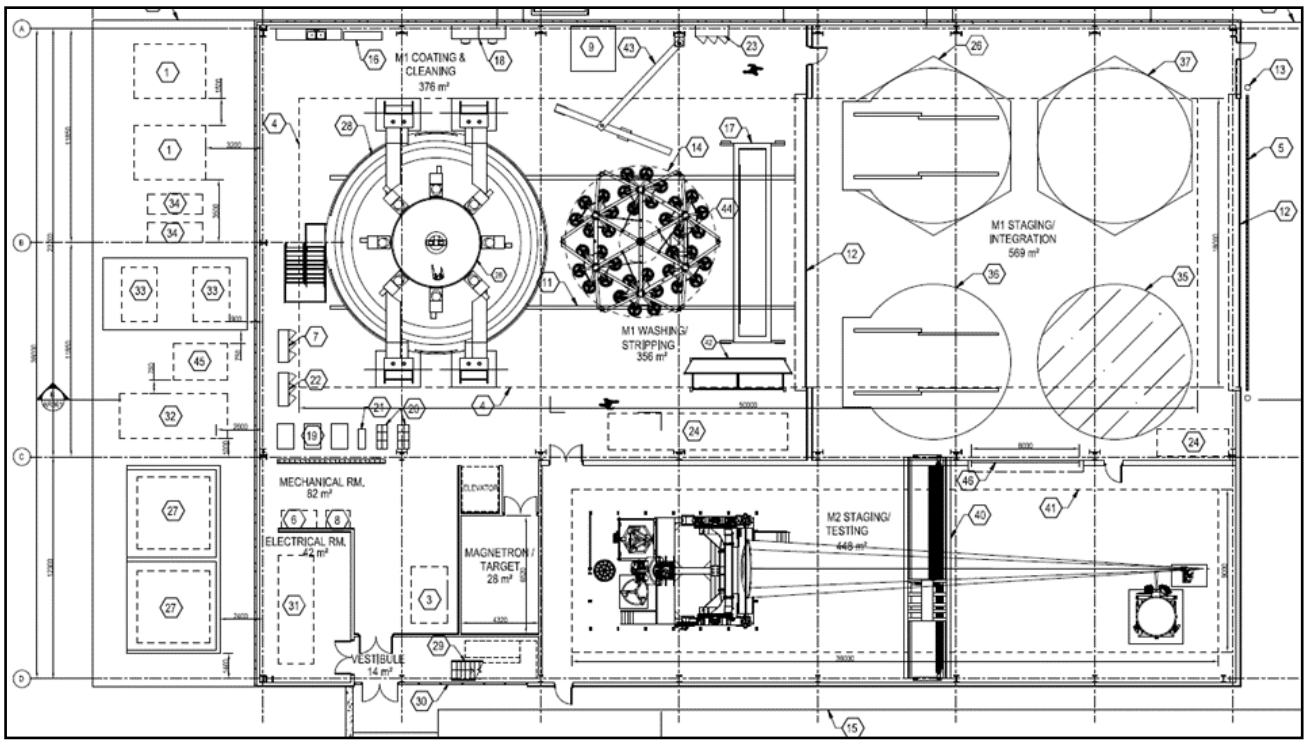

Figure 8 - The grade level floor plan for the Summit Support Building.

Floors, spaces, and functions in the SSB include:

- First floor: M1 coating, M1 coating removal and cleaning, M1 staging and integration, M2 integration and testing, Magnetron/Target integration area, Mechanical room, Vestibule and Elevator Shaft. Floor area ~1,945m^2.
- Second floor: Changing / Gowning Room, Break Room, Restrooms, Offices, IT room and Storage areas. Floor area ~640m^2
- Building exterior: Utility Yard, Neutralization Room and Tanks. Slab area ~285m^2

Requirements and interfaces development will continue through 2024. The design of the SSB has been added to IDOM scope and will proceed when project funding allows.

3. SUPPORT SITE 1

Support Site 1 (SS1) is the technical support area for the observatory site. SS1 includes the observatory facilities Shop and Warehouse building, and the utility yard. The utility yard includes the local reception points to the Chilean power grid via the GMT powerline, and the entry point for the GMT connection to the Chilean internet. The general arrangement of SS1 has evolved since 2020, and the latest version is shown in Figure 9. The SS1 construction improvements are described in the following sections.

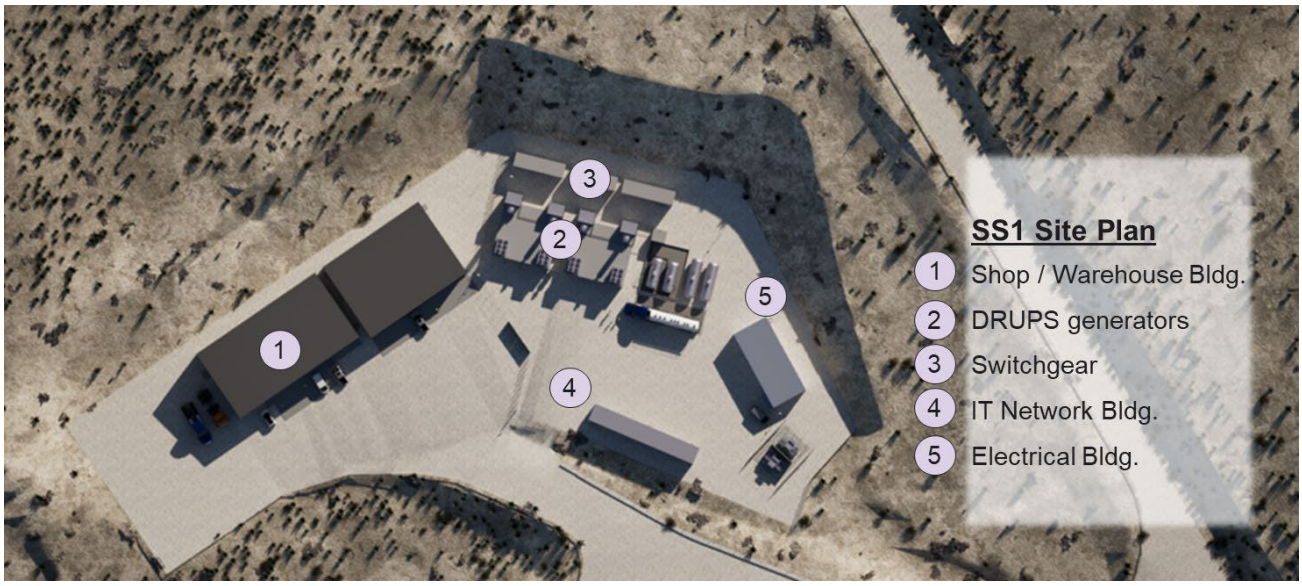

Figure 9 - Planned configuration of SS1.

3.1 The Shop and Warehouse Building(s)

The facilities Shop and Warehouse are the primary technical facilities for off-summit local support of the observatory site. The Shop building will provide space, tools, and equipment for maintenance and repair functions for the observatory. The Warehouse Building will provide storage and assembly, integration, verification, and commissioning (AIVC) space during the final site integration phase, and general-purpose warehouse space during the operations phase. The delivery method planned for the shop and warehouse will be via design-build procurement of a pre-engineered and prefabricated building. One possible realization of a single building, to provide both the shop and warehouse areas, is shown in Figure 10. The footprint of the building is ~55m long and ~15.5m deep, for a total floor area of ~850m^2. The shop portion of the building is ~15m x ~20m, or ~310m^2. The warehouse portion of the building is ~15m x ~35m, or ~540m^2.

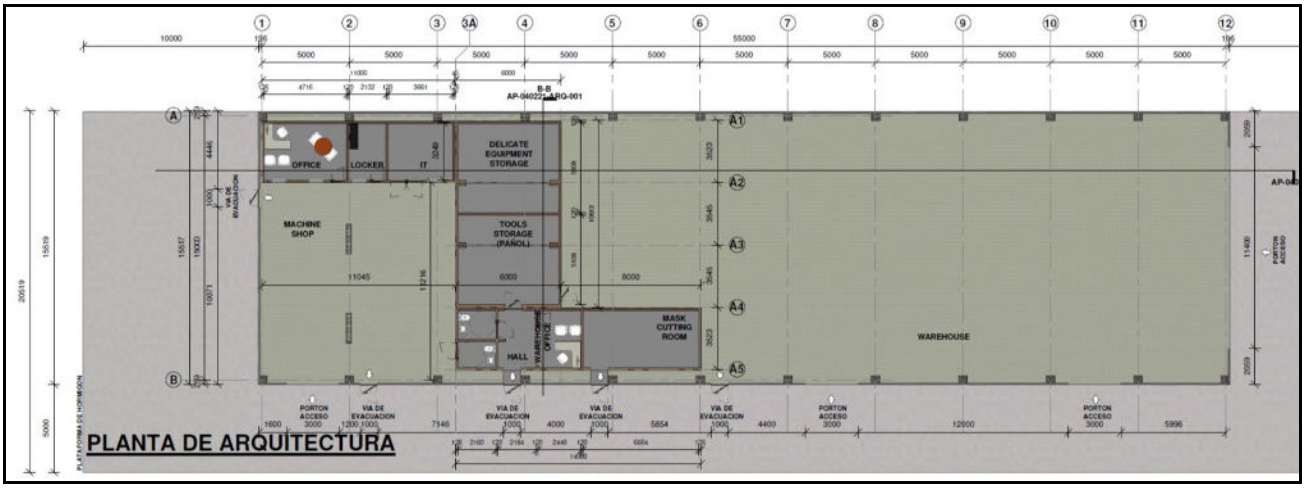

Figure 10 - Schematic design of the Shop-Warehouse design.

3.2 The Utility Yard

The Utility Yard, adjacent to the Shop-Warehouse, provides spaces for reception of the incoming commercial power connection and associated transformers and switch gear, along with the supporting equipment for the power conditioning and back-up systems. Due to the remote location of the GMT, and vulnerability of commercial electrical power delivery to the site, GMT will use Diesel Rotary Uninterruptible Power Systems (DRUPS) generators. The modular DRUPS system for GMT, which will include multiple independent DRUPS units, will provide continuous high-quality (stable frequency and voltage) electric power to the summit buildings (Enclosure, SSB, and SS1). The DRUPS installation includes the electrical switch gear, and diesel fuel tanks with a 7-day supply of fuel. Support Site 2 has a separate and independent back-up power system. See Figure 11 for the general arrangement of the utility yard.

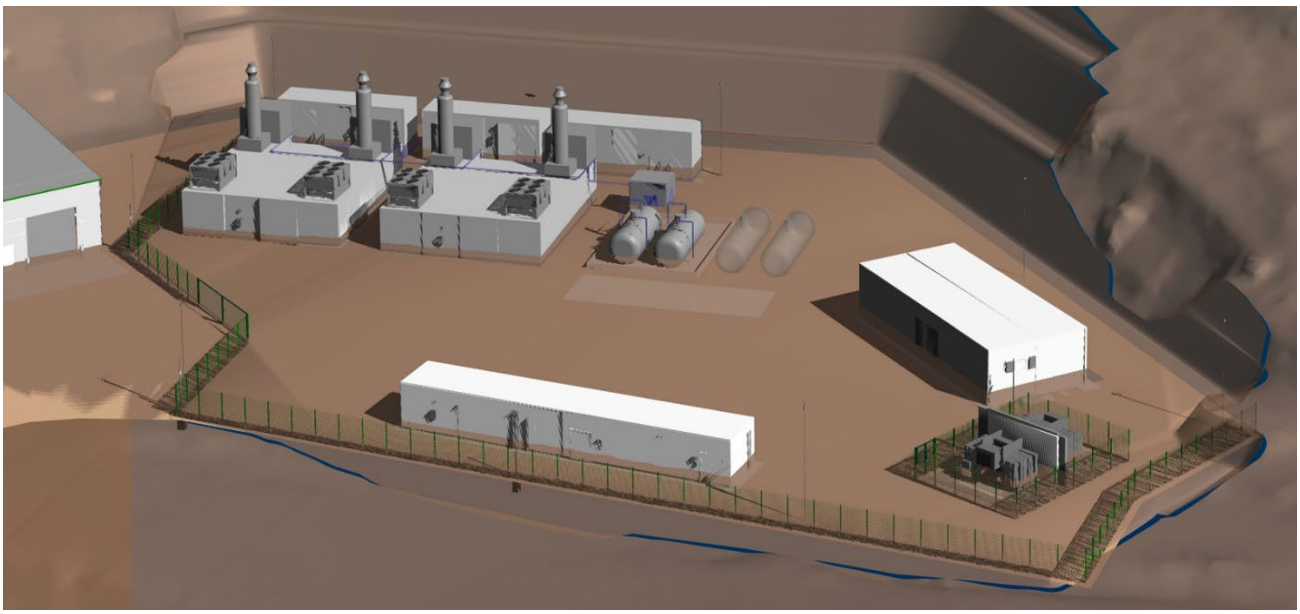

Figure 11 - General arrangement of the electrical power and IT network installation in the utility yard at SS1.

4. SUPPORT SITE 2

Support Site 2 (SS2) is the personnel support area for the observatory site. All of the buildings at SS2 make use of pre-engineered, prefabricated modules which were installed at the site in 2016. Construction at SS2 was completed in 2017 and the buildings have been in continuous use since that time. The SS2 buildings are constructed on three levels – see Figure 12. The lowest level hosts the GMT residence building, which has 24 units with separate bedrooms and bathrooms, furnished for single or double occupancy. The GMT residence area also includes a "star-gazing terrace", which is used to support VIP and fund-raising activities at the site. The middle level includes the kitchen, dining, recreation, and office buildings which support both the GMT and contractor residences.

The upper level provides the contractor residence building, which has 68 rooms. The contractor residence was originally furnished for triple occupancy, with a maximum capacity of 204 people. Following the global pandemic of 2020-2023, future occupancy will most likely include single and double occupancy, for a maximum capacity of ~136 people.

SS2 is connected to the GMT site power, internet, and domestic/fire water systems, but also has an independent electrical generator and diesel fuel supply, and back-up domestic/fire water storage systems using inflatable bladders. SS2 has its own wastewater treatment plant which treats domestic wastewater to a quality to allow surface discharge. The independent water and power systems at SS2 provide extra safety and security for the personnel site in the event of extreme weather or other disruptions.



Figure 12 - View of Support Site 2, showing (left to right) the GMT Residence, the dining and recreation buildings, and the Contractor's Residence.

5. LA SERENA BASE FACILITY

The La Serena Base Facility (BF) is an institutional 4-story building located on the grounds of the Colina el Pino, The Carnegie Institution of Washington's property in the city of La Serena. The BF will support GMT's operations 24 hours a day, seven days a week with a total occupant capacity of ~100 people. The main activities and groups served are science operations, engineering, software, information technology, administration, public relations, and community outreach. Additionally, the BF will include a small hotel for night workers and astronomical observers either observing remotely from La Serena, or in transit to or from the observatory site. See Figure 13 for a rendering of the BF conceptual design.



Figure 13 - Render of the conceptual design for the La Serena Base Facility.

The building is divided into four levels as follows:

- Underground level: For car parking and technical rooms. Floor area ~1,800 m^2.

- Science, 1st level: Primarily for science activities, with private offices, meeting rooms, and a cafeteria. Floor area ~1,900m^2.
- Operations, 2nd level: General public access. La Serena support staff for GMT operations are located on this floor. It includes a control room for remote observing, offices, meeting rooms and an auditorium. Floor area ~1,600m^2.
- Hotel, 3rd level: Located at the top of the building with 8 hotel rooms and an outdoor terrace. Floor area ~600m^2.

Operational concepts and requirements for the BF were developed by the SEF team in conjunction with GMT System Engineering and the relevant organizational units (Operations, Business Office, Software Group, etc.). The conceptual design of the BF was developed by contract with Andes Arquitectura of Santiago, Chile. Final design and construction for the BF are currently planned to occur after construction of the observatory at the GMT site.

6. SITE INFRASTRUCTURE

The observatory Site Infrastructure currently includes the entry points for the ~750KW construction-phase electrical power system and the IT network connection, both of which are operational and fed from the neighboring Las Campanas Observatory. The summit also hosts a pair of ~50m environmental monitoring towers and a MASS/DIMM seeing monitor. Distribution of construction power and networking on the Summit, SS1, and SS2 is mainly via underground conduits. Routing of the underground conduits, with construction completed in 2020, is shown in Figure 14. Future power and network connections will enter the GMT site at SS1. The following sections provide the latest updates (since 2020) for the connections to the Chilean electrical power grid and internet.

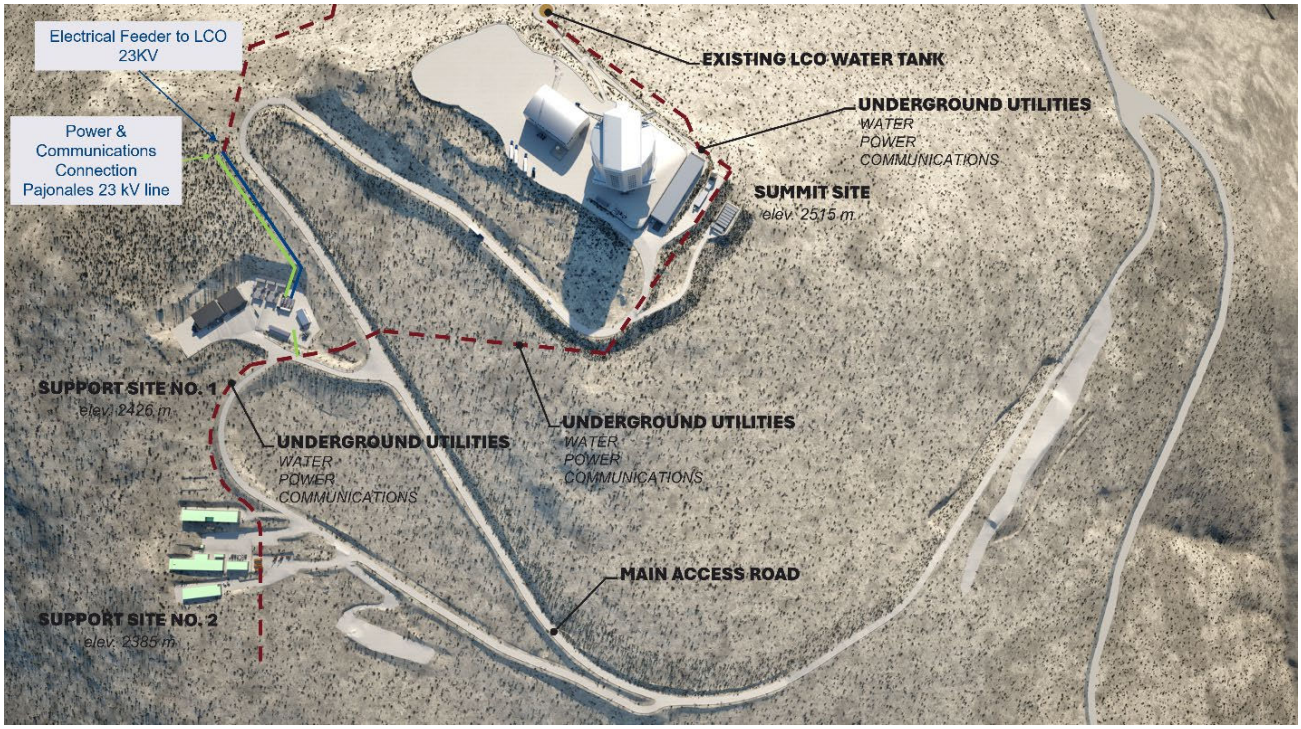

Figure 14 - Power and network connections to the GMT site and routing of the underground utility distribution systems.

6.1 Connection to the Chilean Power Grid

GMT will require an estimated ~3 MVA of power at 23 kV to meet the energy needs of the Observatory. Currently, the energy for the GMT construction site is provided through LCO, supplying ~750 kVA at 23 kV. To meet the mid-construction and operational phase needs, a new powerline from the Chilean grid to the GMT site will be required. Based on current understanding of the Chilean electrical grid, the best connection point for the GMT is through the Pajonales substation, which is owned by the European Southern Observatory, and provides power to the neighboring La Silla

observatory. Conceptual designs provided by Elequipos (Santiago, Chile) consider increasing the capacity of the Pajonales substation, owned by the European Southern Observatory (and feeding the neighboring La Silla Observatory), from 2 MVA to ~10 MVA. To achieve this, the 110/24 kV transformer will be replaced, and the high voltage panel will be modified. Additionally, new equipment will be installed, including 110 kV potential transformers, a 110 kV three-pole disconnector, 50-100 A current transformers, a 110 kV power switch, and a medium voltage cell. Conceptual upgrades to the Pajonales substation are shown in Figure 15 and routing of the new powerline from the Pajonales substation is shown in Figure 16. The length of the powerline from the Pajonales substation to GMT site is approximately 17 miles (28 km).

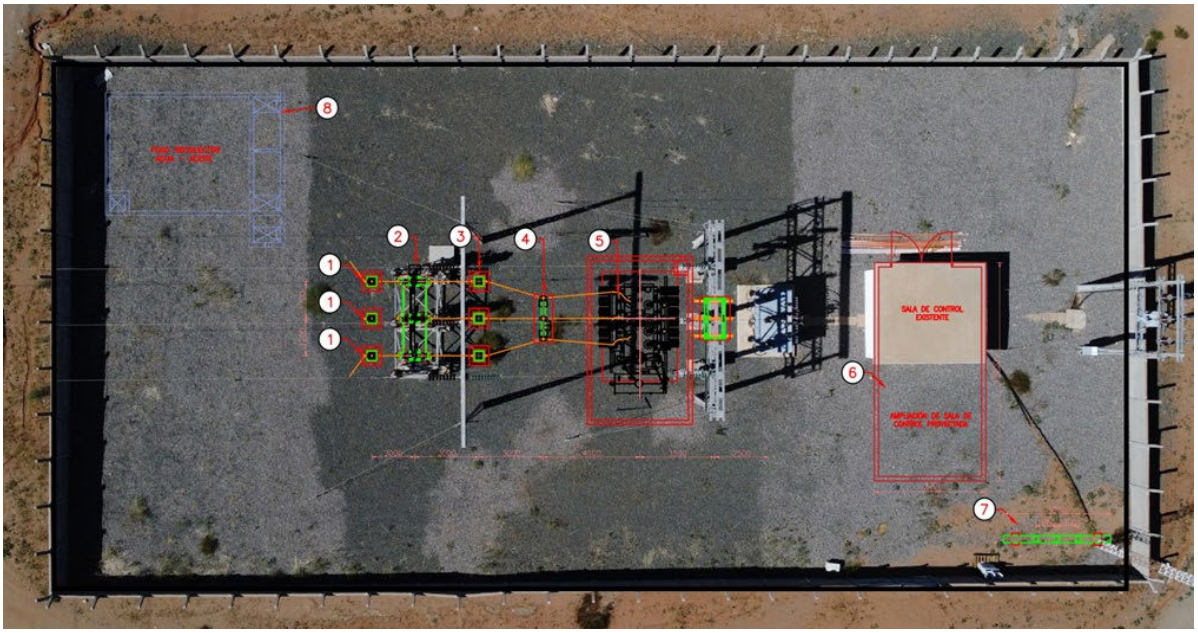

Figure 15 - Concept-phase planned upgrades for the Pajonales substation.

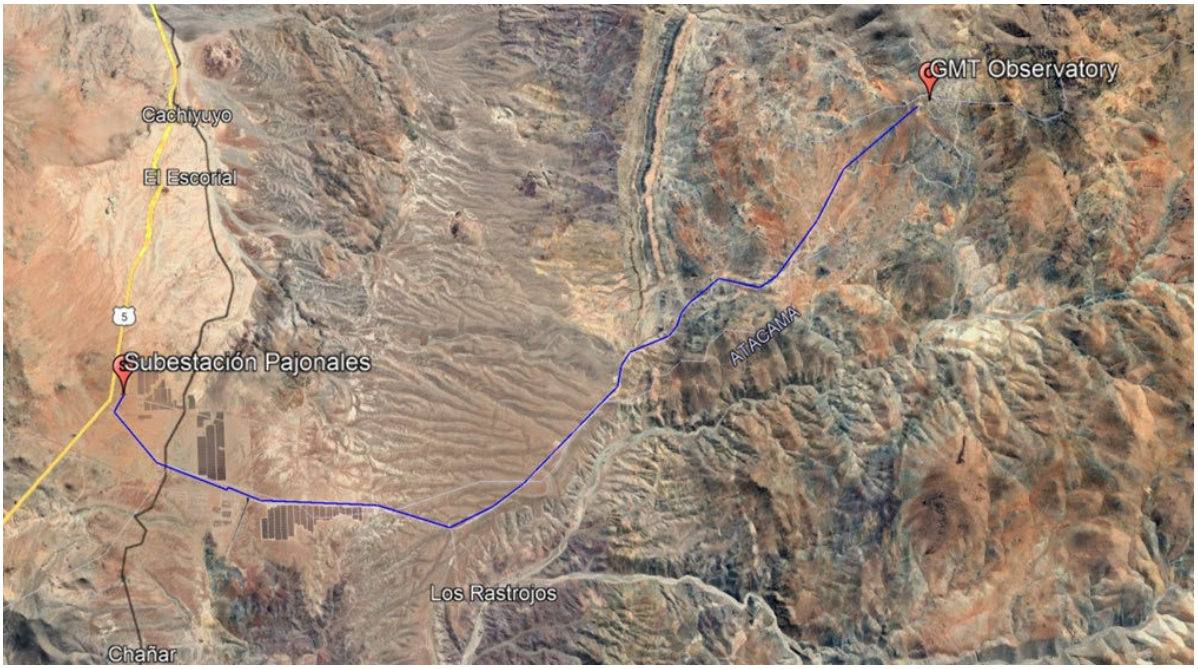

Figure 16 - Concept-phase routing of the new GMT powerline. Image from Google Maps.

6.2 Site Information Technology (IT) Network

IDOM was contracted to conduct a comprehensive conceptual design study for the GMT observatory site IT network in 2023. The conceptual design study was comprised of six key tasks, including reviewing of existing GMTO Site IT Network documentation (initial requirements and operational concepts), conducting site visits, engaging with stakeholders, exploring conceptual architectures, conducting risk analyses, initiating procurement processes with Chilean internet service providers to gather information on cost and schedule, and ultimately delivering a final report documenting the design basis established throughout the study. A conceptual design review of the IT Site Network was convened in January 2024. The results of the review were promising in terms of the studies, conceptual designs, and cost/schedule estimates, but the GMT requirements were still found to be incomplete and missing full traceability. Another round of requirement development will be completed before the design of the Site IT Network resumes.

7. CONSTRUCTION PROGRESS

Construction of the GMT water system, including the Water Equipment Building (WEB) and the GMT water tank were completed in 2021. As part of the same construction package, the underground utility distribution systems for electrical power, network, domestic water, and fire water were also completed in 2021. As of June 2024, plans are underway to relocate the summit office complex to SS2, and to remove one of the metrology towers (the tower closest to the telescope site), prior to the start of construction of the enclosure. Construction during 2019 of the WEB, water tank, trench lines, and pull boxes can be seen in Figure 17. The current state of the entire GMT site is shown in Figure 18.



Figure 17 - Construction of the GMT water system and underground utility distribution systems in 2019.

8. SUMMARY

Since the 2020 SPIE Proceedings, the GMTO-SEF project team has made significant progress in the design of the site, enclosure, and facilities, including a successful final design review for the telescope enclosure. With essentially all of necessary construction facilities and underground site infrastructure complete, the stage is set for the GMT project to move towards the construction phase for the enclosure.

9. ACKNOWLEDGMENTS

Giant Magellan Telescope is being developed by the GMTO Corporation, a 501(c)(3) nonprofit and an international consortium of 14 universities and research institutions from the United States, Australia, Brazil, Israel, South Korea, and Taiwan, in partnership with our host country, Chile. GMTO is a partner in the U.S. Extremely Large Telescope Program (US-ELTP).



Figure 18 - The GMT observatory site as of 2024.

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