14 ENCLOSURE

14.1 Introduction

As telescopes grow in size with correspondingly more demanding performance specifications, the task of providing an enclosure becomes more challenging: The structure must adequately protect the telescope from the elements while simultaneously minimizing the effects of thermal and wind flow conditions that impact seeing. Numerous considerations factor into the choice of the design. The structure will necessarily be large and yet will rotate at rates comparable to less massive enclosures for smaller telescopes. There are functional requirements associated with servicing the telescope and instruments that have to be satisfied for increasingly complex systems. Ease of erection and the availability of materials and skilled labor in the host country are also considerations. The enclosure and associated facilities will have to fit the local topography of the site. Not least, the enclosure represents a significant fraction of the total cost of the project that must be minimized.

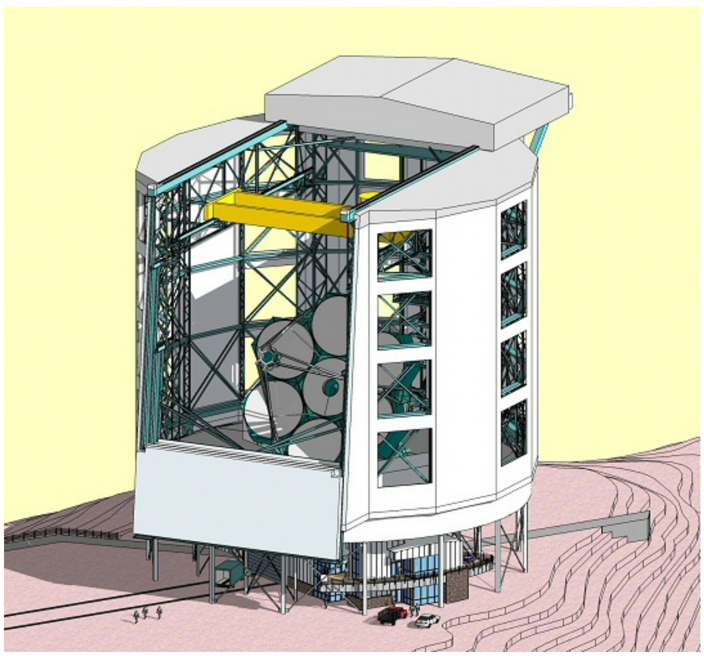

Figure 14-1. GMT Enclosure Concept.

Various enclosure concepts were considered during the initial phase of the project. The Carousel design shown in Figure 14-1 was selected for the GMT baseline. The shape of the structure is roughly cylindrical with vertical walls. Also considered were spherical domes (e.g. Keck), co-rotating cube enclosures (e.g. MMT, LBT), roll-off structures, and the calotte concept. The Carousel was chosen based on its (a) efficient use of structural material and insulated panels, (b) use of standard and universal construction techniques, (c) ease of implementing shutter and ventilation door concepts, and (d) the ability to accommodate an overhead crane which is necessary for servicing the off-axis primary mirror segments.

The principal trade-offs between a co-rotating and independently-rotating enclosure are the ability to mount instruments and equipment on a structure that moves with the telescope such as with the MMT versus greater flexibility in servicing mirrors and the telescope using handling equipment built into the enclosure. The azimuth utility transfer system ("cable wrap") is part of the enclosure in the co-rotating case and part of the telescope for the independent case. The weight of an independent enclosure with its stationary observing floor and bogeys distributed around the perimeter is expected to be significantly less than a scaled up MMT or LBT concept. Given the compact design of the GMT and small swing radius, the difference in size between the two enclosure types is relatively modest (Figure 14-2).

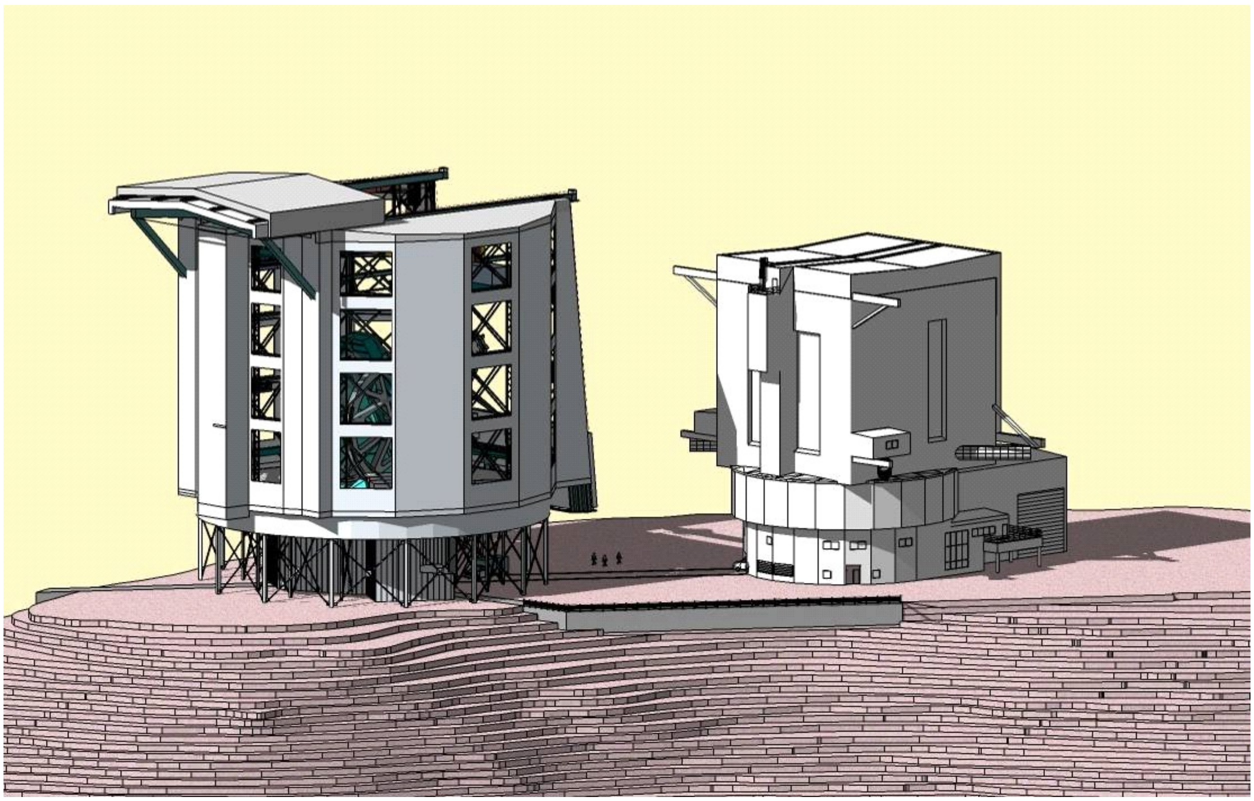

Figure 14-2. Comparison of GMT and LBT Enclosures.

The Carousel concept has been selected for further study after weighing these considerations. The baseline concept consists of:

- The stationary Enclosure Base structure that supports the Carousel rotation rails and the Observing Floor at a level even with the top of the telescope azimuth platform. Elevators and lifts in the base will provide equipment and personnel access to the Observing Floor and Mezzanine level below. Open structure at ground level allows air to flow below the Observing Floor and around the Pier to encourage the boundary layer to remain below the height of the shutters and vent opening.

- The Pier in the center of the base that supports the GMT but is mechanically decoupled from the enclosure. The center mirror assembly and Gregorian instruments will be serviced with a lift in the center of the Pier.

- The upper Carousel structure that rotates independently of the telescope. The telescoping main shutter doors open up to provide an unobstructed view down to a minimum specified telescope elevation angle of 25°. The doors will be partially deployed and tracked to shield the telescope from wind and stray moonlight during observing. Windows in the walls of the upper structure will provide roughly 25% open area for ventilation of the telescope chamber. A bridge crane mounted at the top of the Carousel will be used for telescope assembly and to remove the outer six primary mirror assemblies for mirror recoating.

- A Control Building located below the Observing Floor that communicates with the upper levels via an elevator and stairway but is otherwise thermally isolated from the Enclosure structure.

- A cart and rail system for transporting instruments between the Enclosure and Auxiliary Building for service (see site plan in section 14.3). This will also be used for moving the primary mirrors during recoating.

Modeling of the thermal properties and wind flow through the enclosure will be key to reducing the effects of dome seeing and wind shake on the telescope. These studies will be conducted during the design development phase of the project.

Many of the current generation of large telescopes have been built in multiples of more than one. Magellan has two telescopes, as do Keck and Gemini; ESO built four Very Large Telescopes (VLTs). While the current project is for a single GMT, the Board has requested that consideration be given to a second GMT on the summit of Campanas Peak, as shown on the baseline site plan presented in Figure 14-3. The site plan will change if a different site is eventually selected.

Details of the enclosure requirements and design are discussed in this chapter. The Control Building, Auxiliary Building and other facilities are discussed in the Chapter 15.

14.2 Requirements

The functional requirements for the GMT enclosure are summarized as follows.

- The enclosure will be designed to sustain specified seismic and weather conditions without damage.

- The enclosure will protect the GMT from weather under all conditions up through specified survival conditions with the main shutters and ventilation windows closed and sealed. The shutter and window seals will provide protection against stray light during the day, and dust infiltration.

- The Carousel will rotate independently of the telescope. Inside clearance will be provided for all azimuth and elevation angles of the telescope down to a minimum elevation angle of 25° with floor hatches, cranes and service platforms retracted.

- The Carousel will track the telescope rotation during observing, to provide an unobstructed view over the entire sky for all telescope elevations angles above the minimum angle.

Minimum clearance around the beam will be maintained in the process. The maximum rotation rate for slewing and tracking is 1.5 degrees/second.

- Shielding will be provided for the telescope from wind and stray light during observing. In the current design this function is performed by the main shutters and vent opening.

- The Carousel will incorporate vent openings in the side walls to provide wind forced ventilation of the telescope chamber. The open area of the vents will be adjustable to control the amount of flow and for minimal wind induced vibration of the telescope.

- The enclosure design will minimize nighttime heat release into the interior and around the telescope due to passive cooling of the enclosure structure and active sources. Air in the telescope chamber will be actively cooled during the day to match the predicted evening air temperature at opening.

- The structure will be designed to minimize enclosure induced turbulence within the telescope chamber and in the beam of the telescope, and suppress elevation of the boundary layer in the flow around the enclosure.

- The enclosure will incorporate elevators, lifts, cranes, and other handling equipment for moving instruments and telescope parts around the facility including removal of the primary and secondary mirror assemblies from the telescope for service and re-coating. A lift platform in the center of the pier will be provided for transferring instruments and the center primary mirror assembly between ground level and the telescope.

- Stairways and elevators will provide access to all floor levels and the roof. Stairways and platforms will be provided to access all systems (wind vents, shutter mechanisms, etc.) that require routine service.

- The fixed Base will support a floor ("observing floor") below the level of telescope at the approximate height of the telescope azimuth disk. An auxiliary control room for operating the telescope will be provided at this level.

- Unheated floor space will be provided below the observing floor on a mezzanine level between the telescope pier and the outer diameter of the base for electronic equipment and workspace, instrument staging and storage of fixturing, handling equipment, and tools.

- An enclosed staging area will be provided for large Gregorian instruments on the opposite side of the pier from the Auxiliary Building. The rails for transporting instruments from the Auxiliary Building will carry through an opening in the pier into the staging area.

- A ventilation system will be provided for ducting and a fan for extracting waste heat from the volume below the observing floor and from inside the pier and exhausting it away from the enclosure structure at right angles to the prevailing wind directions.

- The enclosure will provide routing for power, data communications, liquid cooling and hydraulic lines throughout the structure. Sub-panels will be provided for the distribution for electrical power and communications.

- A covered passage way and rails through the pier will be provided at grade level to the outside for removing mirror cells and instruments. Space will be provided for instrument staging in this area.

- The pier will be designed to provide a stiff connection between the telescope and the mountain to maximize the telescope modal performance; mechanical isolation between the pier and the rest of the enclosure structure prevents enclosure vibration being transmitted to the telescope.

The full set of functional and performance requirements for the enclosure is contained in the "GMT Enclosure and Facilities Design Requirements Document", GMT document number 293, Appendix 14-1 to this report.

14.3 Site Plan

For the purpose of the conceptual design, the baseline site is Las Campanas Peak located in the northern region of Chile approximately 160 km north of La Serena, Chile. The site is within Las Campanas Observatory owned by The Carnegie Institution of Washington.

The elevation of Las Campanas Peak is 2524 meters. Access to the site is currently provided by a dirt road that begins on the southern face of the mountain and ends at the northeast section of the proposed site.

The top of the mountain is to be excavated to 2516 meters altitude, providing a level platform with adequate space for the GMT enclosure ("GMT 1"), support facilities and a future possible second GMT ("GMT 2").

Las Campanas Peak site characteristics determine the site layout of the enclosure and support facilities. The prevailing winds are generally from the north northeast, with views of the mountains predominately to the north and east and Las Campanas Observatory to the west.

The buildings are aligned along the mountain ridge with access to the buildings along the northern edge minimizing travel between the buildings. The orientation of the buildings is 90° from the prevailing winds and downwind of the observatory. See Figure 14-3 and Figure 14-4.

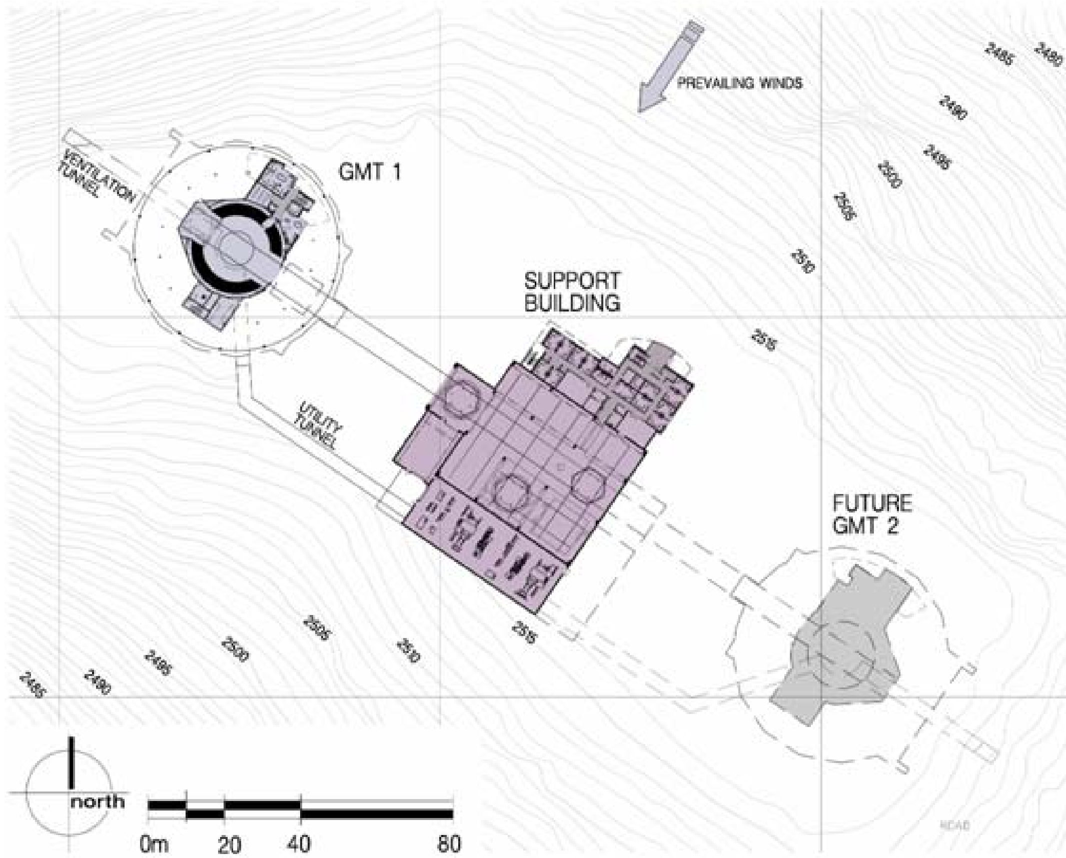

Figure 14-3 Cerro Las Campanas with the GMT enclosure ("GMT1"), support buildings, and a possible future second GMT ("GMT2").

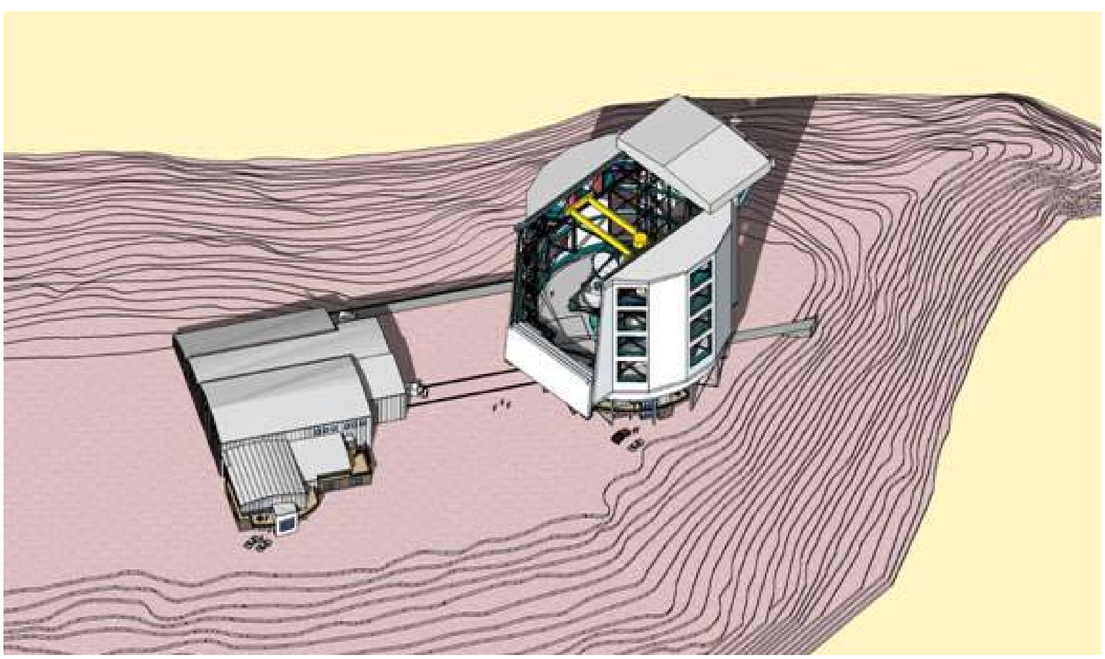

Figure 14-4. Aerial View of the GMT Site.

Fixed tracks connect the observatory and the auxiliary building allowing the primary mirror cell and instruments to be transported between the buildings on wheeled carts. The auxiliary building is centered and on-axis between GMT 1 and GMT 2, connecting the three buildings in the future.

Along the southern edge of the site is a concrete utility tunnel between the equipment building and the enclosure providing an accessible route for the utility lines. This maintains the primary heat-generating equipment away from the enclosure and downwind from the site. A second tunnel between the equipment building and GMT 2 is envisioned.

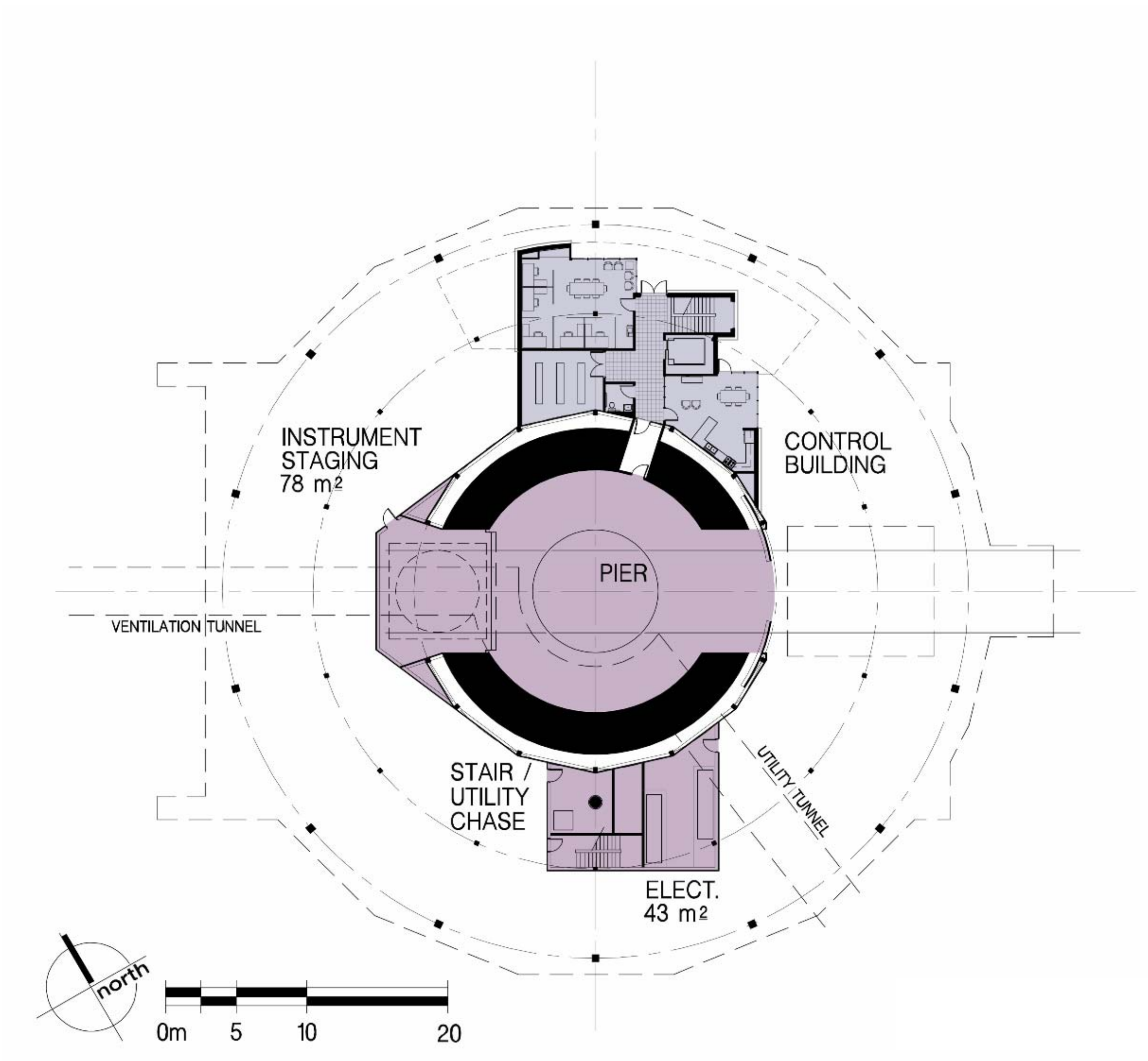

Figure 14-5. Grade Level Plan.

14.4 Layout and Floor Plans

The GMT Enclosure consists of three parts: the pier, the enclosure base and the rotating carousel.

14.4.1 The Pier

The pier is the fixed cylindrical concrete structure in the center of the enclosure that supports the telescope. It is physically detached from the other structures maintaining vibration isolation between the pier and the rest of the enclosure. The pier design and performance is discussed in Section 7.5.

14.4.2 Enclosure Base

The enclosure base supports the rotating carousel and extends to the observing level located 14.72 m above finish grade elevation. A steel structure surrounds the telescope pier providing a thermal barrier and protection against wind buffeting. Adjacent and to the south of the pier is a utility chase, electrical room and emergency exit stairs from the observing level.

North-west of the telescope pier is the instrument staging area accessible from the pier. The fixed tracks extend into the space providing a temporary storage and staging area for the mirror cart and instruments. The staging area's current function does not include instrument servicing, however it may be expanded for that purpose.

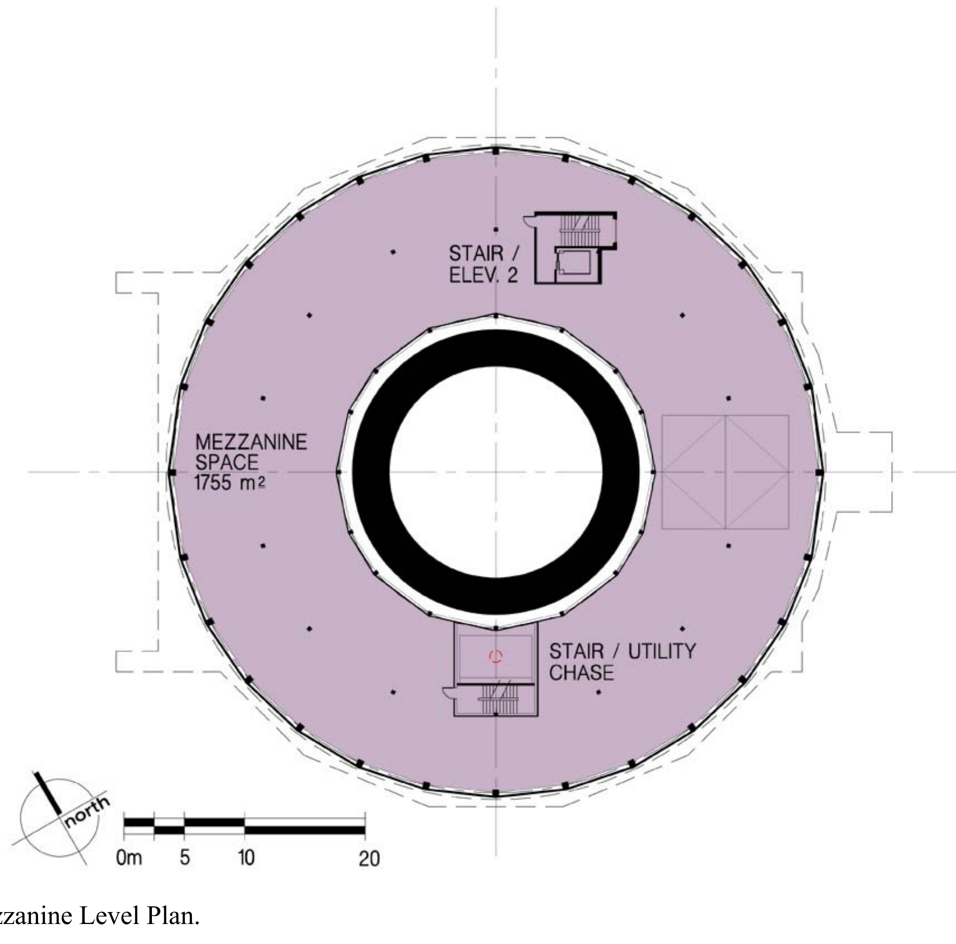

Figure 14-6. Mezzanine Level Plan.

The lower level spaces are designed to minimize wind turbulence underneath the carousel. The instrument staging area that does extend from the pier in the cross-wind direction is kept small for that reason. The width of the utility chase and control building are within the pier diameter and in line with the prevailing wind.

The mezzanine level is at 11.0 meters above finish grade and is directly below the observatory floor. This space evolved during the conceptual design due to the depth of the steel structure required to support the rotating carousel above. The structure is approximately 3.75 meters deep creating a shallow space that can be used for storage or equipment. At night it will be kept at the ambient outside temperature.

The total area of this level is undefined at this time. During the next phase of the design a study is needed to determine whether the added space below the observatory level creates any wind turbulence. The space may decrease in area or be eliminated entirely based on the results of the study.

The observing level floor is at 14.72 meters above grade, with the exterior perimeter wall at 26.76 meter radius. This is the highest level of the lower fixed enclosure and the interface point with the rotating carousel. Located along the perimeter of the floor is a double rail for the rotating carousel and bogies, and a circular seal. Service to the bogies and the seal is from the interior side at the observing level.

The observing level flooring consists of steel plate decking with a floor loading of 1600 kg/m^2. The decking is insulated from below to prevent heat conduction from the lower levels.

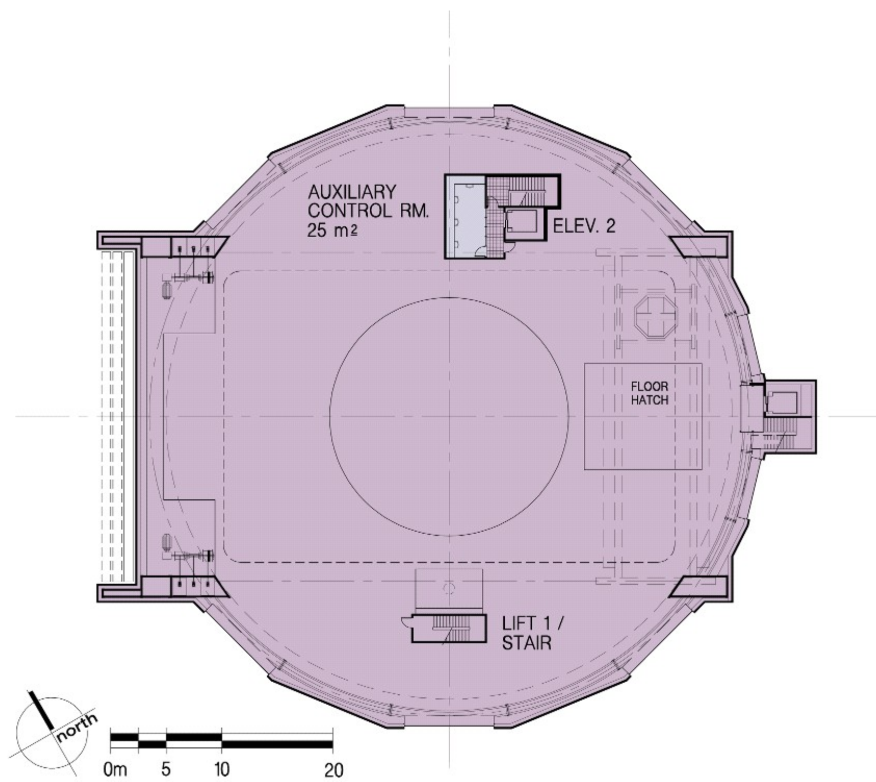

Figure 14-7. Observing Level Plan.

Centered in the space is the telescope mount and rotating platform. The observing level is flush to the telescope platform and has a continuous seal along the perimeter edge. In line with the axis of the ground-level rails and the other buildings is a 9.5 meter by 10.5 meter hinged, bi-parting floor hatch flush with the observing level. All large instruments and equipment in the telescope chamber are hoisted through the floor hatch with a 100-ton capacity overhead bridge crane mounted on the rotating carousel.

Primary access to the observing level is via a stairwell and elevator (Elev. 2) from the control building directly below. The elevator is a 5000 lb. capacity, service-type elevator for personnel and small instruments. A second stairwell is located on the opposite side of the observing level for emergency exit requirements.

Adjacent to the elevator is a 25 meter^2 auxiliary control room. This room is primarily used while servicing the telescope or preparing for the night's observing. It is not the main control room and it is not envisioned to be used during observing. This space is well insulated on all sides maintaining a thermal barrier to the telescope chamber and windows provide visibility to the telescope.

Lift platform 1 (Lift 1) is located adjacent to the south stairwell and is used to lift instruments and equipment onto the telescope. It extends up to the level of the telescope Instrument Platform. The hydraulic lift is a 4-ton capacity with a 4 meter by 5 meter platform. The hydraulic piston extends below the observing level in a shaft adjacent to the stairwell. This lift can also extend down to the mezzanine level if the space remains in the next design phase.

14.4.3 Carousel

The carousel is the upper rotating portion of the GMT enclosure and is centered on the azimuth axis of the telescope. The height of the carousel is approximately 60 meters above finish grade elevation to the upper shutter door rails and 65 meters to the top of the shutter.

The carousel provides the telescope a 26.2 meter wide clear viewing path from 25° to 90° elevation angle. The telescope swing clearances are 2 meters minimum on the sides and 1 meter to the overhead bridge crane hook. The telescope elevation axis is 25.39 meters above grade. Openings through the carousel's exterior walls promote wind-forced ventilation of the inner structure and telescope chamber.

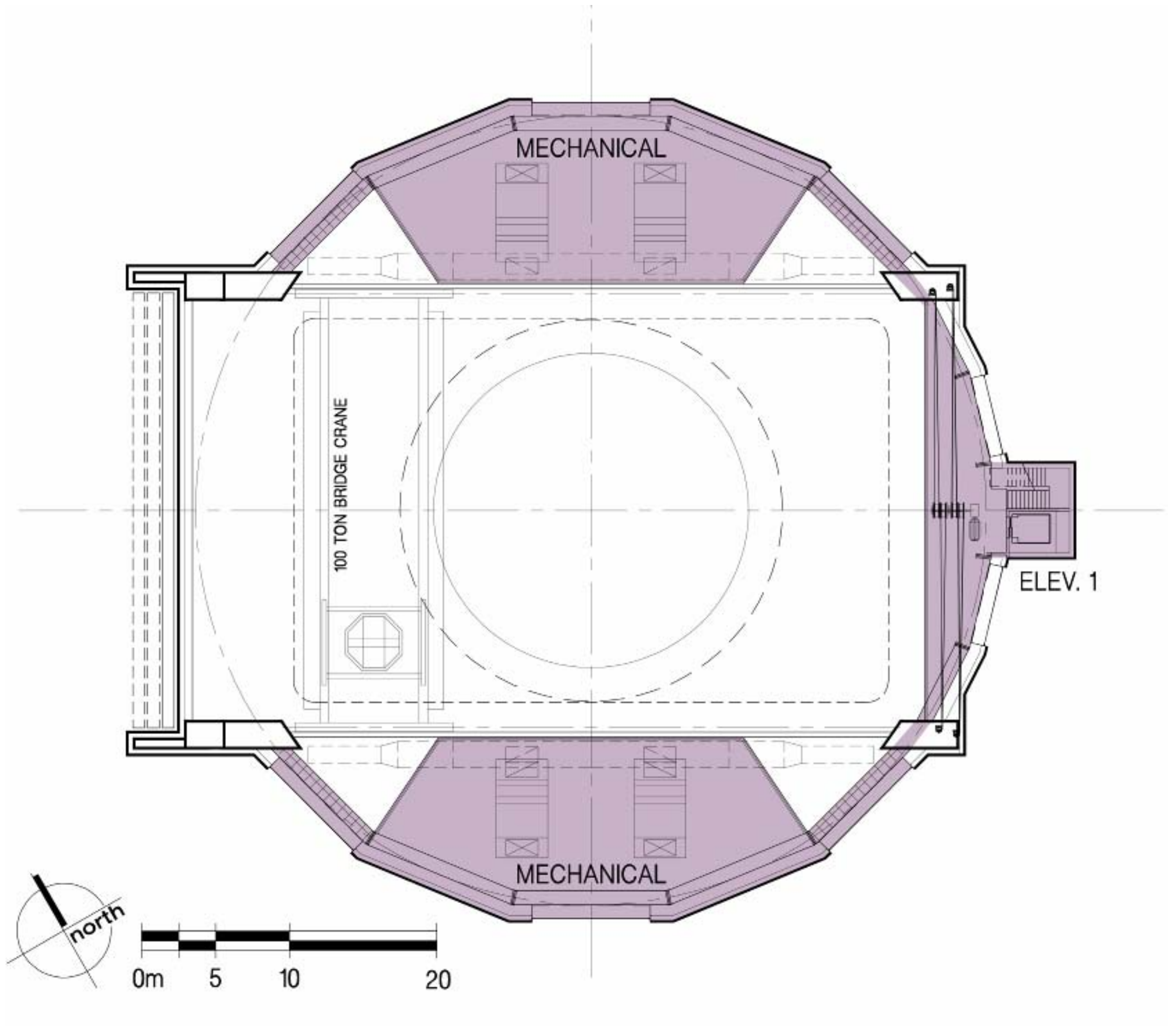

Figure 14-8. Mechanical Level Floor Plan.

The carousel has unlimited range of travel in azimuth and rotates on 12 bogie assemblies and a double rail attached to the observing level. Mounted on the bogies is a circular ring-beam which supports the steel structure. Both the rotation bogies and steel structure are discussed in Section 14.8. At 54 meters above grade are the mechanical levels which house the upper shutter door drives and the HVAC equipment for the dome cooling system. The equipment platforms are on the back and sides of the carousel connected by catwalks.

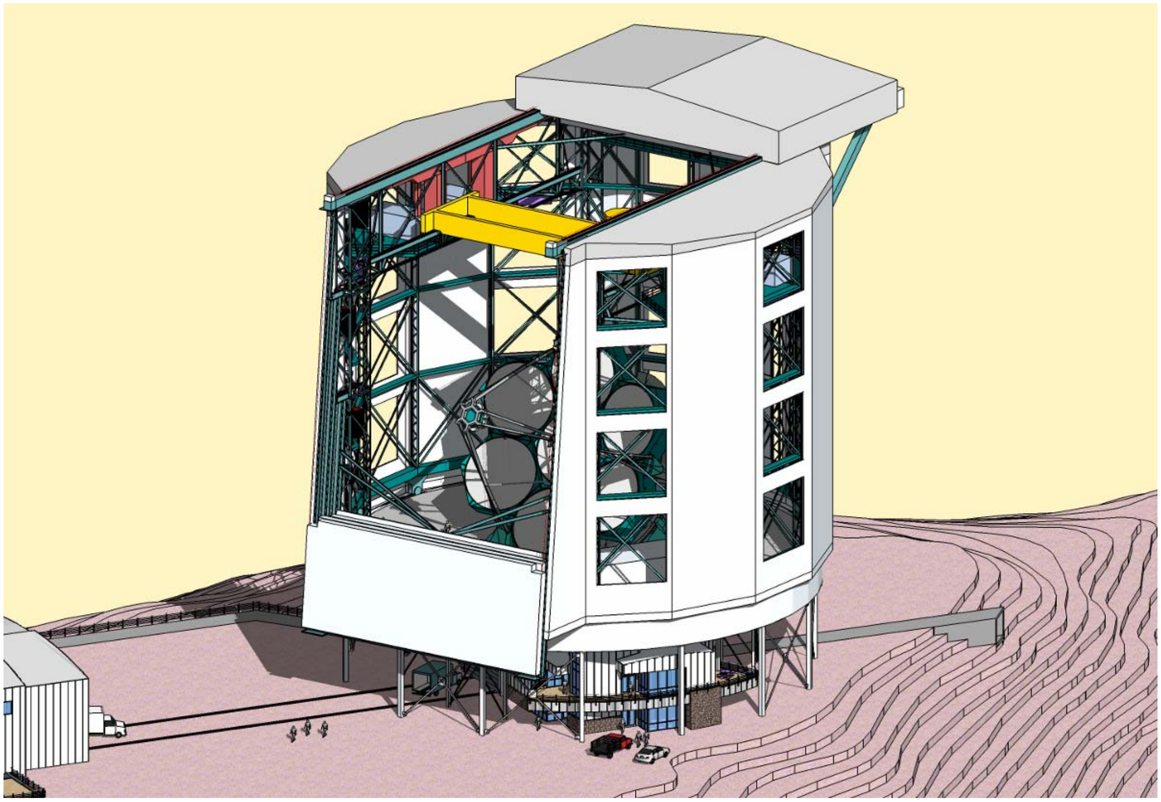

Figure 14-9. View of the Enclosure with Shutter Doors Open and overhead crane deployed.

14.4.3.1 Shutter Doors

The shutters consist of a pair of horizontal roof panels and three vertical front panels. The structure around the shutter openings provide 1.5 m of clearance on either side of the optical path. When the roof panels are fully retracted there is 0.76 m of clearance at the back of the optical path when the telescope is pointed to the zenith.

The nested panels of the upper shutter run on a pair of double rails fixed to the Carousel structure on either side of the top opening. The rails extend beyond the back of the carousel cylinder and are supported at the rear by an exposed steel structure. The lower nested panel rolls on the rails with four bogeys. The two front bogeys of the upper panel also roll on the fixed rails. At the rear, the upper panel is supported by the lower panel and rolls on rails attached to the top of the lower panel.

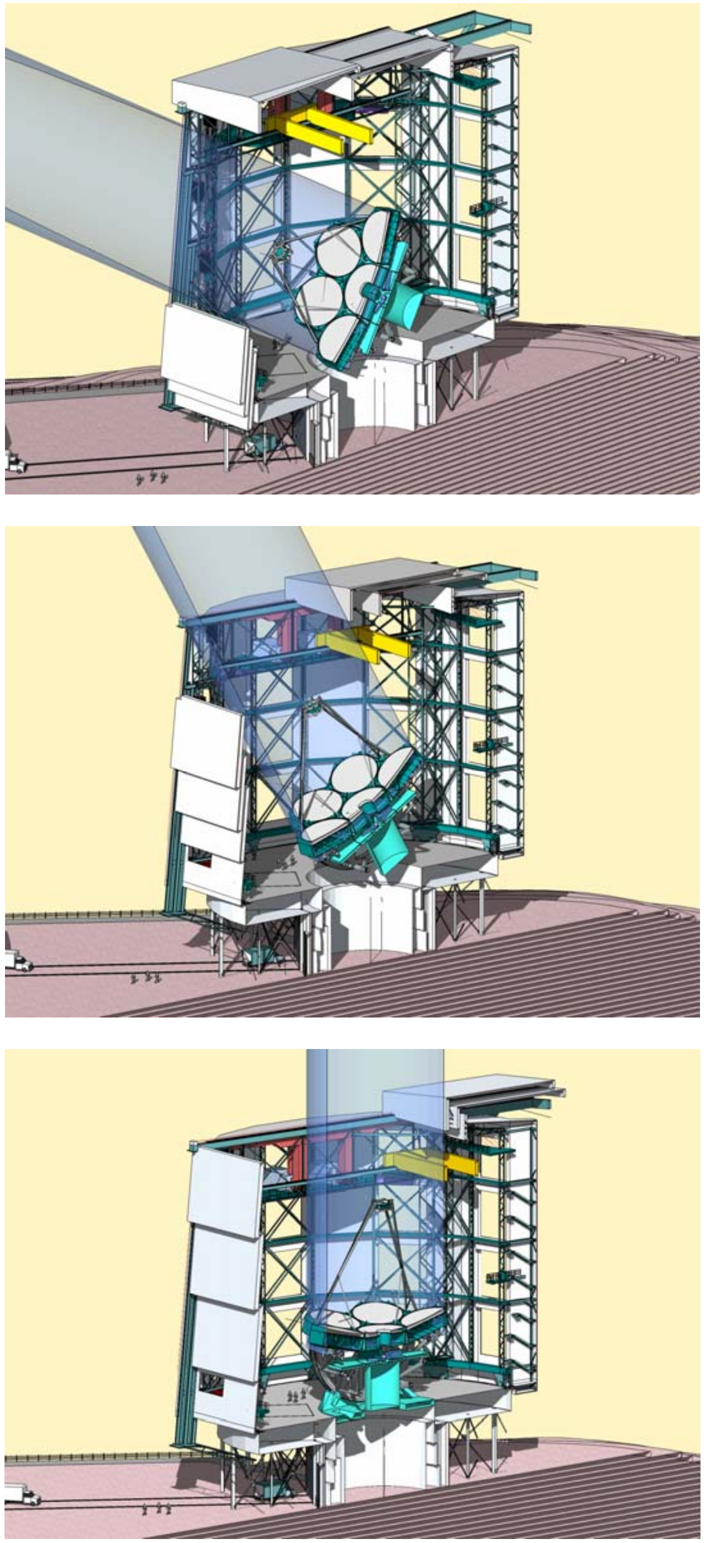

Figure 14-10. Shutter doors deployed at 30°, 60°, and 90° telescope elevation angles as wind and moon screens.

The upper shutter layout is designed to have the doors act as a moon screen by having the front edge of the door follow the telescope aperture in elevation. As a fail-safe system the doors are closed manually with a separate hand crank or drill driven winch and cable that is independent of the shutter door mechanism. This provides a safe, emergency closing procedure in case of both power and/or mechanism failure.

The vertical shutter doors consist of three nested panels that run on sets of vertical rails mounted on the carousel steel structure. The steel panels are approximately 120,000 lbs each and have a 100,000 lb. steel counter balance (approximately 10% less than the panel weight) located in the two front carousel columns. The system promotes a gravity assist downward movement and also provides wind and stray light shielding by creating a square observing aperture by coordinating deployment with the upper shutter doors.

The drive mechanism for the vertical shutter doors is located on a platform that is approximately 3 meters above the observing level and at the front of the carousel. Access to the platform is via a ships ladder from the observing level. The drive mechanism for the upper shutter doors is on the mechanism level located 40 meters above the observing level. Access to this level is via a stairwell and a 5000 lb service elevator (Elev. 1) located at the back of the carousel structure.

Further discussion on the shutter door mechanisms is in Section 14.7.1.

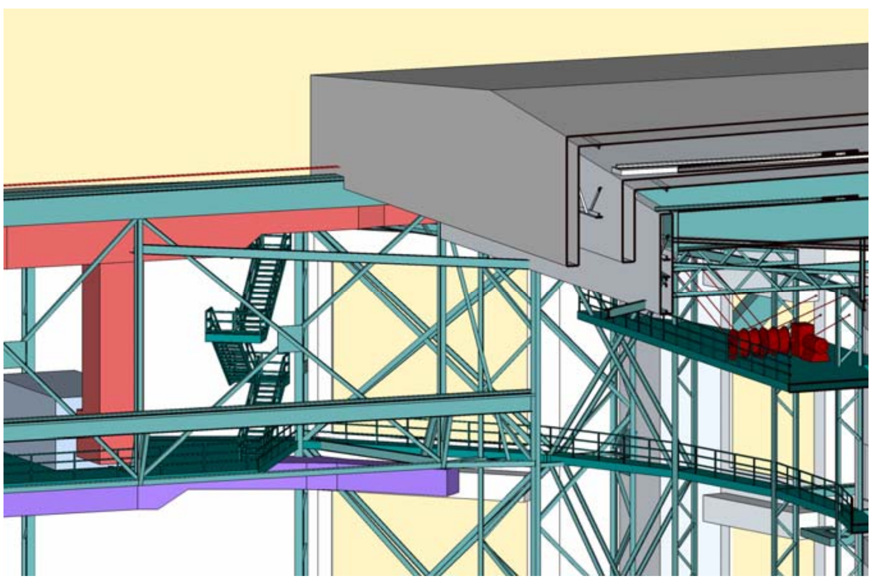

Figure 14-11.. Section view of Mechanical Levels, Catwalks, and Roof Access Stair.

14.4.3.2 Access

Elevator 1 and a stairwell provide vertical access to all levels of the carousel. The elevator is a 5000 lb. service-type elevator used to carry small instruments, equipment and tools to all the levels including the secondary mirror access platform and the 100 ton bridge crane. A network of catwalks fixed to the perimeter wall of the carousel provides access to the ventilation windows, equipment and platforms throughout. All catwalks have a steel plate floor, guard rail and toe-kick plate with a minimum width of 1 meter.

Access to the roof and the upper shutter door rails and bogies is via a ships ladder and floor hatch accessible from the mechanical level on each side of the observing opening. The bridge crane is also accessible from the mechanical level which is approximately 1.5 meter higher in elevation.

14.5 Structure

The enclosure structure consists of a steel carousel rotating on rails supported by a fixed steel base structure. The carousel is 55 meters in diameter and 50 meters high and rotates independently of the telescope.

The fixed base structure consists of perimeter steel columns that support a steel ring girder (55 meter diameter) and carousel rails. Steel bracing is provided around the perimeter except at the portals to allow access to the center of the pier. Two interior rings of steel columns support the observing level floor. Columns are braced in both radial and circumferential directions; Concrete foundations for the fixed base structure are independent of the telescope pier. The structure is designed to carry the static and dynamic loads from the carousel and seismic and wind loads.

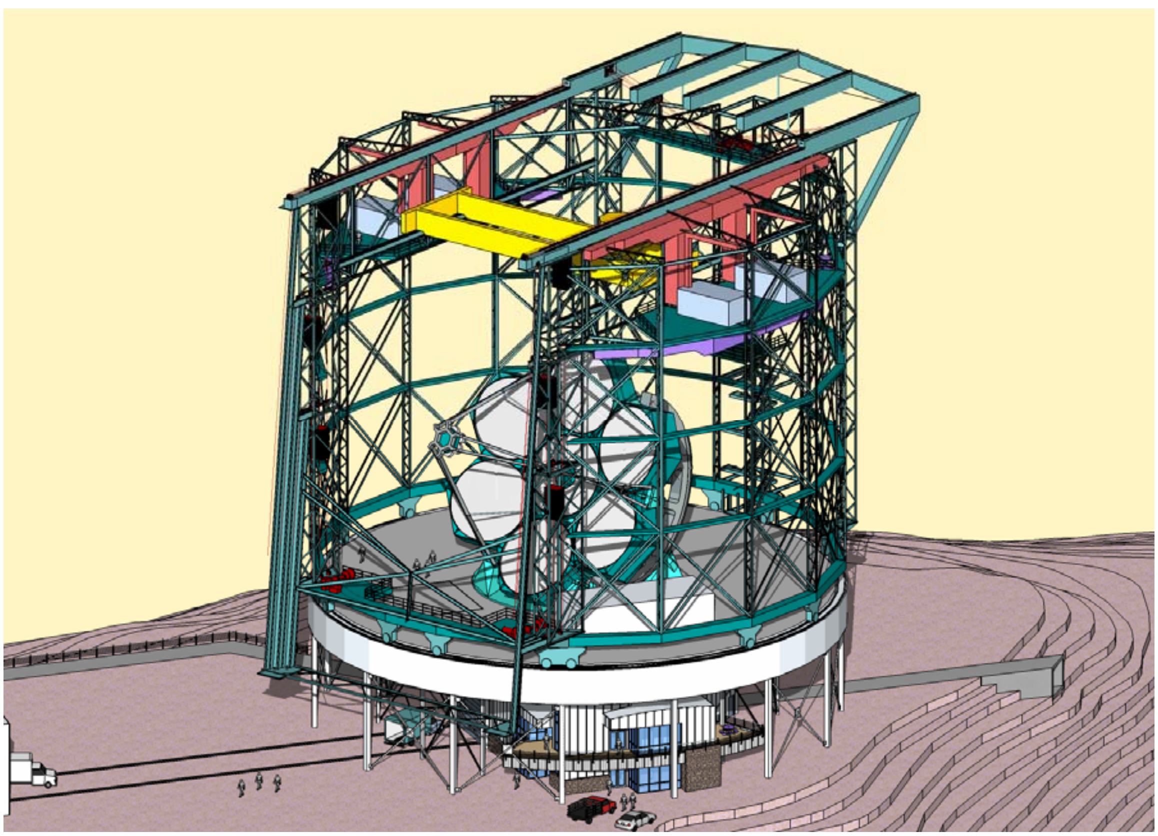

Figure 14-12. Carousel Steel.

The carousel structure consists of two steel arch girders that support the rails for the roof shutter panels, the front shutter panels and overhead crane. Steel framing forms the multi-faceted carousel walls that contain the ventilation openings. The carousel walls are braced for lateral wind and seismic loads. The bracing system incorporates access catwalks into the design.

The typical cross section of the arch girder consists of a 2 m x 4 m column at each end and a 10 meter deep truss along the roof. The columns are 200 mm steel angles or wide flange sections at each corner braced with steel angles. The thickness of the steel is 19 mm, minimizing the thermal properties.

The roof shutters consist of two movable steel framed panels that nest over the elevator shaft at the rear of the structure during observing. The panels are 30 m wide by 23 m long and retract over five rails with the upper panel supported by the lower panel. The drive system coordinates the movement of the two panels so that they arrive at the open or closed position simultaneously.

The front shutters consist of three movable steel framed panels, 30 m wide by 12.5 m high, that nest at the lower end of the shutter opening. The nested panels clear the aperture of the telescope. The drive system coordinates the movement of the three counterweighted panels so that they arrive at the open or closed positions simultaneously. Aluminum could be used for the front shutters to reduce counterweight requirements if necessary. The front shutters can also be used for a wind screen in a partially closed position. Independent control of each shutter leaf is an option which would allow screening of the secondary mirror from wind while allowing ventilation at the lower part of the telescope.

Table 14-1. Material Takeoff.

Material Takeoff

	Material	Size	Pieces	Length[m]	Weight[Kg]
1	Hot Rolled Steel				
2	A36	LL6X6X6X6	284	3631.9	160375.6
3	A36	LL4X4X6X6	30	175.8	5090.7
4	A36	LL8X8X8X6	24	453.4	35589.1
5	A500_46	HSS20X20X8	18	206.1	39579.3
6	A500_46	HSS8X8X6	3	11.6	608
7	A500_46	HSS12X12X6	2	35.8	2886.5
8	A572Grade50	1m BOX	33	289.3	221396.8
9	A572Grade50	1x2mBOX	12	142.1	132068.2
10	A572Grade50	2X4m BOX	30	193.9	452820.9
11	A992	1x.3mWF	177	1540.7	153216.8
12	A992	HSS12X12X6	27	397.4	32081.3
13	A992	W12X26	52	264.8	10258.6
14	A992	W14X43	16	76.6	4890
15	A992	W14X90	36	212.7	28548.2
16	A992	W18X35	61	348.2	18162.3
17	A992	W24X68	35	313.1	31873.4
18	A992	W27X84	10	91.7	11512.3
19	A992	W30X99	10	91.6	13498.1
20	A992	W33X118	36	335.5	58947.2
21	A992	W36X135	24	131.6	26451
22	A992	W40X149	29	304	67426.7
23	Total HR Steel		949	9247.9	1.50728e+6

The conceptual material takeoff for the basic steel structure is 1507 metric tons, not including sub-framing for roofing and siding. 1141 metric tons of that is in the rotating Carousel and 366 metric tons in the fixed base. Sub-framing adds an additional estimated 10% to the weight. The material quantity is shown in Table 14-1.

14.6 Wall Systems

The proposed exterior wall system of the enclosure is an insulated metal panel that is screwed in place to the secondary steel structure. The panel is a 36 inch modular width panel with an off-set double tongue and groove joint. The panels are sealed at the joints with a factory installed continuous seal in the groove and field applied sealant on the opposite side of the joint.

The total area and weight of the metal panels is as follows:

	Area	Weight
• Enclosure base:	1755 m^2	21,000 kg
• Carousel:	6910 m^2	82,920 kg
• Shutter doors:	3470 m^2	41,640 kg

The panel has a smooth 22-gauge steel exterior face and a slightly fluted, 24-gauge interior surface for rigidity. The core is 3 inch thick foam-in-place polyurethane with R-24 insulation value and the following structural properties:

- 92% closed cell structure
- Density: 2.0 lbs/cu.ft. minimum
- Compressive strength: 22 psi
- Tensile strength: 33 psi
- Shear strength: 21 psi

The metal panel has a factory applied G-90 galvanized finish with a 20 year warranty. It is the most reflective finish on a steel metal panel commercially available. Aluminum foil tape can be applied directly to the panel if needed to control radiation to the night sky and over-cooling of the skin.

The roof panels are similar to the wall panels in material and thickness but have rolled formed overlapping rib exterior for water tightness. The interior joint is the same as the wall panels.

The metal panels are precut in the factory and trimmed onsite. All panel edges are trimmed with either sheet metal flashing or a two part extruded aluminum trim piece that snaps in place. The trim finish matches the metal panel finish.

There are several companies that manufacture the panel and are readily available in the U.S. and Chile. Since they are standard, off-the-shelf panels, lead time should not be an issue.

Along the base of the observatory a stone wainscot similar to the walls commonly found at Las Campanas Observatory is envisioned. This provides a durable base material along the perimeter of the buildings and ties into the surrounding materials common at this site.

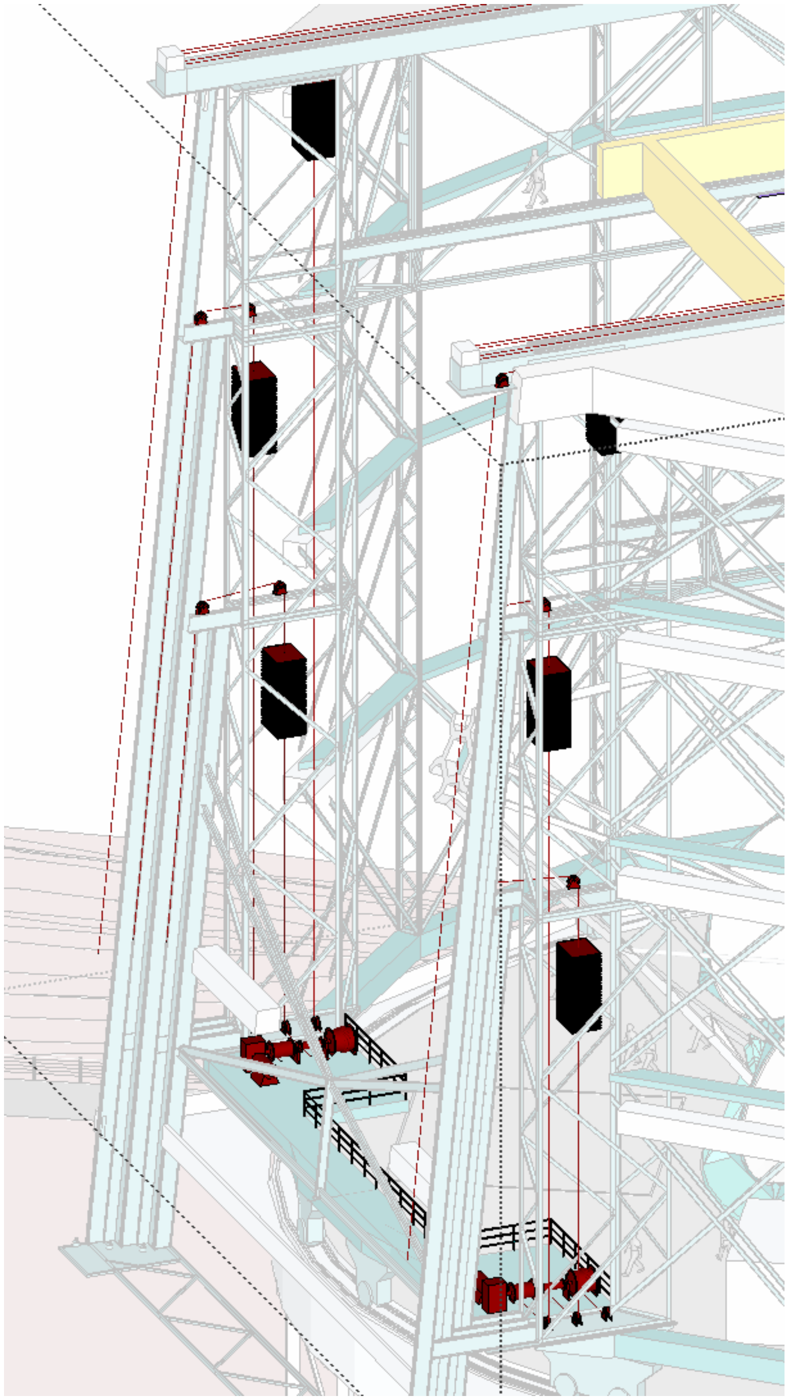

Figure 14-13. Front Shutter Door Mechanism.

14.7 Mechanical Systems

14.7.1 Main Doors

The concept for the vertical shutter is three individual steel framed panels that can be raised or lowered so that each panel arrives at the open or closed position simultaneously. As an option, the panels could be controlled independently to allow partial wind shielding. The panels could also be constructed of aluminum thereby reducing the weight and drive requirements.

Each of the three panels is 30 m wide by 12.5 m high. The estimated weight is 54.5 metric tons if constructed with steel and 18.1 metric tons if constructed of aluminum.

The drive system concept consists of a pair of 7/8 inch wire rope winches and a 24 inch diameter pulley system. The project requirements specify that the shutters open within three minutes and close within six minutes. Counterweights (1.8 m x 1.2 m x 20 mm thick with 12 mm space in between) are provided to reduce the power requirements of the winches and to facilitate manual closing of the panels in case of a power failure. Total winch power is estimated to be 80 horsepower. Lead could be substituted for steel in the counterweight to reduce the thermal load from cooling by 70% if that is shown to be significant.

The winches are controlled by encoder feedback with appropriate safety mechanisms to keep the panels from racking. Differential gearing of the winch drums controls the speed of the shutter panels as the outer panel must travel three times the distance of the inner panel and 1.5 times the distance of the intermediate panel.

Elevator drive and safety technologies such as failsafe braking in case of cable failure are provided. The drive winches are mounted on the observing floor to facilitate maintenance access.

If independent control of the three panels is required, six winches instead of two are necessary. However, louvers could be incorporated into the lowest panel if ventilation is required while shielding the secondary mirror from wind.

The concept for the upper shutter is two individual steel framed panels that open to nest over the top of the enclosure elevator. The roof panels are controlled by wire rope winches so that the two panels arrive at the open or closed position simultaneously. Each of the two panels is 30 m wide by 23 m long.

The drive system concept consists of a pair of 19 mm wire rope winches and a 521 mm diameter pulley system to pull the shutters open and closed. The roof shutters can be partially opened to double as a moon roof.

The winch is a single unit with differential gearing that controls the shutter panel speeds. The upper panel must travel twice as far as the lower panel.

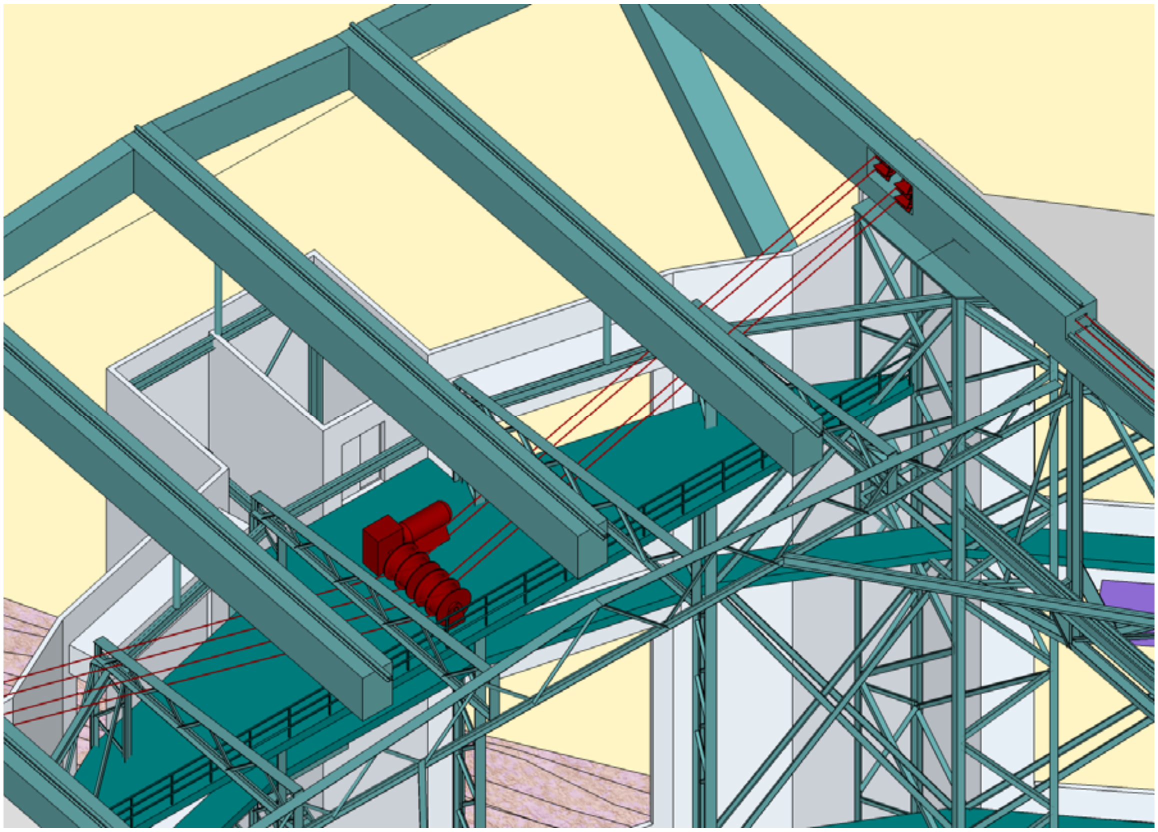

Figure 14-14. Roof Shutter Drive.

The winch drive system is accessible from the top of the service elevator or stair. The technology is modeled after movable roof systems used for new sports stadiums. The estimated power requirement for the winch is 50 horsepower.

14.7.2 Rotation Drives and Bogies

The enclosure is rotated by four bogie drives. The total rotating weight of the Carousel including steel structure, sub-framing, wall panels, overhead crane, shutters and counterweights is 1,689 metric tons. The requirement of the specification is to accelerate the enclosure at a maximum $0.2°/sec^2$ with a maximum speed of 1.5°/sec. At the maximum rate the bogies are traveling at 0.72 meters/sec.

The bogie drives are located at the four main bogies that support the enclosure arch girders. Each bogie assembly consists of a weldment that contains four 1 m diameter canted wheels and a lateral restraint wheel between each pair of bogie rails. The four wheels ride on two rails (171 pound/yard crane rail).

Each four wheel bogie will be driven by two 75 horsepower (estimated) variable speed drive motors (600 horsepower total estimated). The drive motors will be connected to the wheels by a gear drive or chain and sprocket. The drives will be sized to move the enclosure with four out of the eight motors.

The bogies will be mounted to the enclosure structure with roller and/or flexible connections to allow for alignment tolerances and thermal expansion of the structure.

14.7.3 Ventilation Windows

The carousel has four rows of ventilation windows along the front, side and back walls. The total window opening area is approximately 31% of the carousel wall surface. The window sizes are as follows:

- Side wall, top row: 7.0 m x 8.0 m
- Side lower rows: 8.0 m x 8.0 m
- Front: 6.5 m x 3.0 m
- Top back: 5.5 m x 7.0 m
- Lower back: 5.5 m x 8.0 m

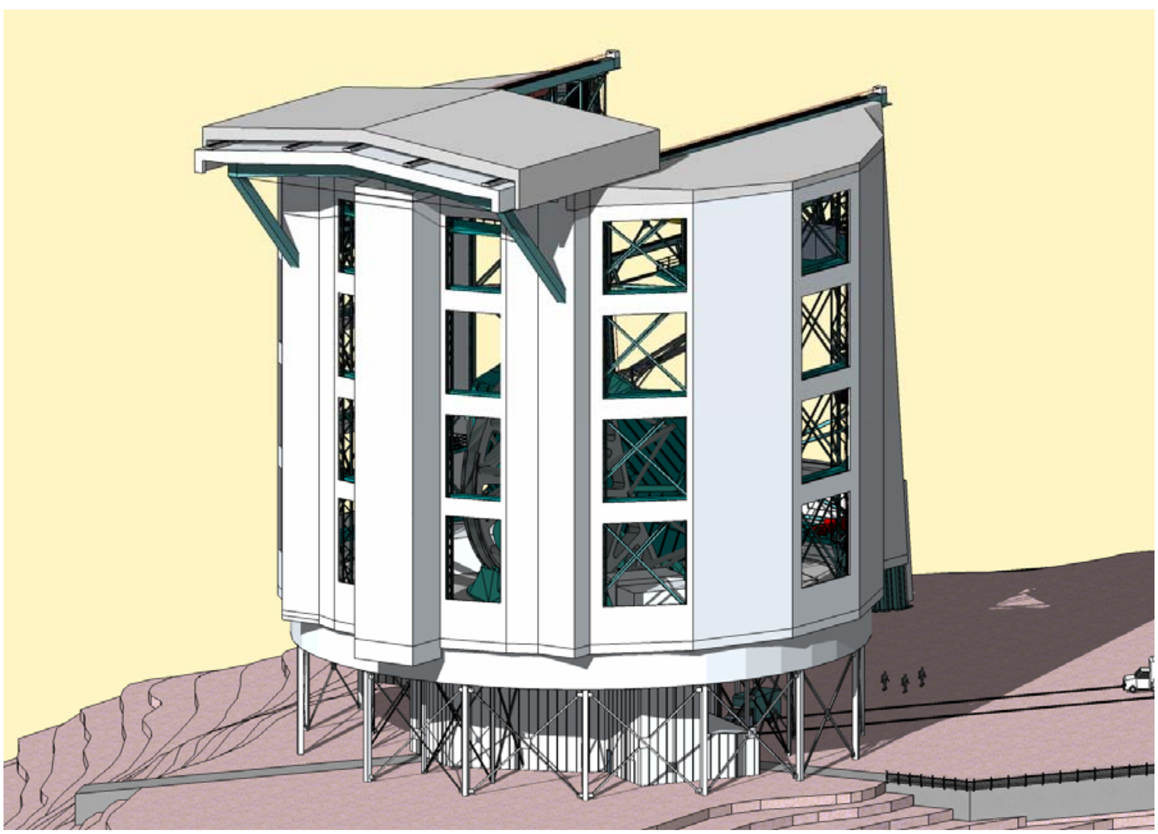

Figure 14-15. Enclosure with the Vent Doors Open.

The ventilation windows are individually actuated with electric motors which are only energized during the time the vents are in motion. The windows operate through a PLC system and absolute proximity sensors control the exact location of the window and opening size.

The ventilation windows are insulated roll-up doors rated for 150 mph wind at the site elevation and have a 6.25 R-value. The door slats are 18-guage steel exterior surface and a 20-guage steel skin on the interior with a polyurethane core. Rubber seals along the jambs and a compressible bulb seal at the sill provide the required weather stripping. Replaceable seals will be specified for long-service life at the site elevation.

14.7.4 Overhead Crane

The overhead bridge crane is used to install and remove the off-axis primary mirrors in their cells in and out of the telescope and move them between the grade level and the telescope through the floor hatch on the observing level. It is also be used to assemble the telescope on-site.

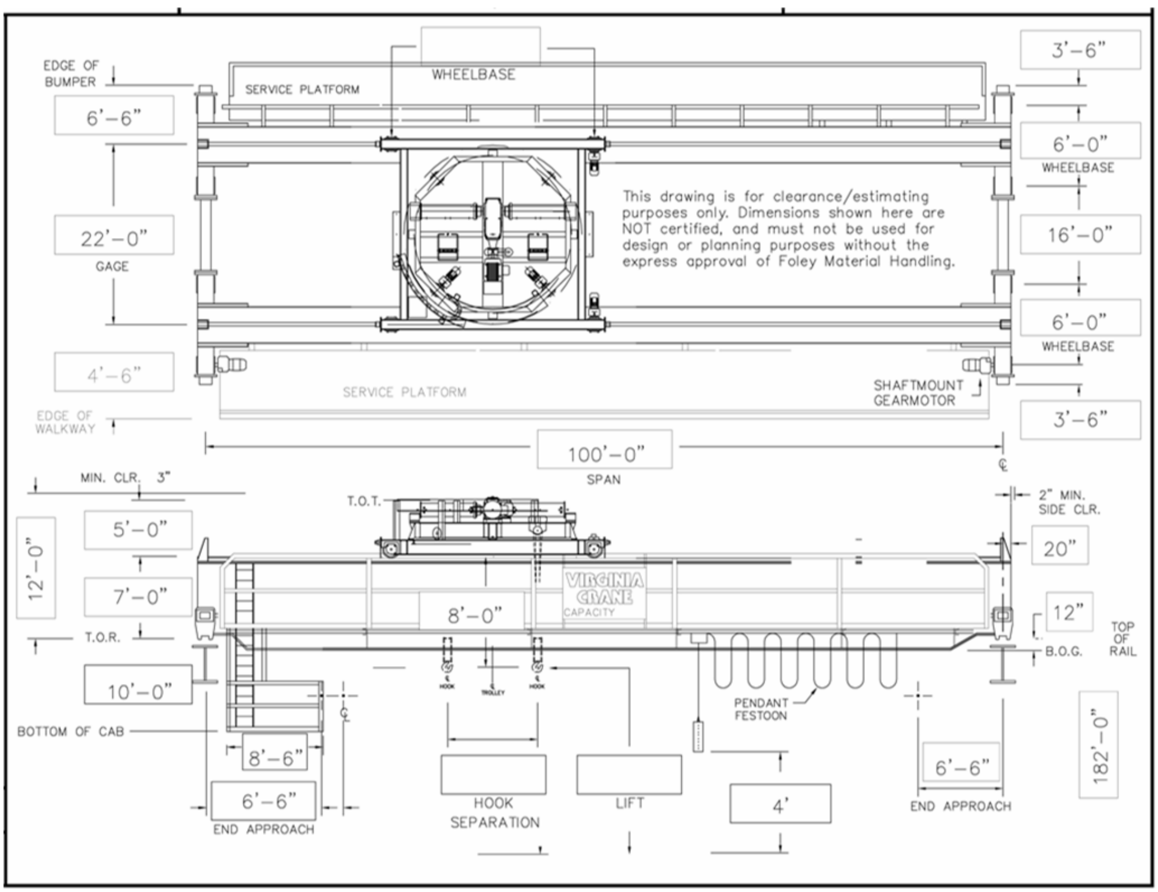

Figure 14-16. 100-ton Bridge Crane.

The crane rides on the steel arch girders at the top of the enclosure and has the following specifications:

- Capacity: 100 tons (91 metric tons)
- Weight: 160 tons (145 metric tons)
- Bridge span: 29.4 meters
- Number of trolleys: 2
- Number of hooks: 2
- Maximum hook height: 51.39 meters
- Bridge travel distance: 40.28 meters
- Trolley travel distance: 26.06 meters

The bridge travel extends beyond the center of the observing level floor hatch and clears the viewing path of the telescope at 90° elevation in the stowed position. Both the bridge and trolley travel distance is centered on the telescope.

The crane has two hoists on a rotating stage and provides the following motions for handling equipment:

- Bridge travel (front-to-back in the enclosure, along the length of the enclosure slit).
- Trolley travel (side-to-side in the enclosure, across the width of the enclosure slit).
- Vertical travel (synchronous extension or retraction of the two hoists).
- Tilt (differential extension or retraction of the two hoists).
- Rotation (rotation of the hoist assembly within the trolley).

Located on each side of the bridge is a service platform with an operator's cab below. The platform is accessible from the mechanical level on the carousel.

14.7.5 Instrument Service Lift

The instrument service lift (Lift 1) is stowed at the observing floor and is used to raise instruments and equipment to the telescope instrument platform (IP). The lift is not rated for personnel and has the following specifications:

- Rated capacity: 4 tons
- Deck dimension: 4.0 m x 5.0 m
- Travel distance: 7.50 m above the azimuth turntable
- Lift speed: 0.50 ft. per second
- Platform deflection: 6 mm
- Safety factor: 5 to 1

The lift deck edge closest to the telescope has a 50 mm radius greater than the circular contour of the telescope instrument platform and locks in place when it reaches the programmed elevation. Interlocks prevent the telescope from moving when the lift is not in the stowed position and guardrails on the lift and the observing level provide the safety requirements. The lift steel deck also has a toe guard preventing the lift from lowering in its stowed position when something interferes with its path of travel.

The lift is hydraulic with a steel casing and 900 mm single acting cylinder. A 460 mm long key in the cylinder prevents the platform from rotating when traveling. The hydraulic drive is located at grade level in the lift shaft and adjacent to the exit stair or can be placed on the mezzanine level as well.

The lift is anchored at the observing level where a 1.2 meter pit provides the platform enough space so it is stowed flush with the observing level. Since the lift only extends from the observing level to the telescope instrument platform, the casing extends down below to the mezzanine level and is anchored to the steel frame at this elevation.

14.7.6 Power Requirements

Electrical power to the enclosure from the main electrical service entrance in the equipment building is routed through the utility tunnel. At the enclosure building main electrical room, the main distribution panel shall be rated at 277/480V, 3-phase, 4-wire, estimated to be 800 ampere bus. From multiple feeders fed by the main distribution panel, electrical power shall be provided and distributed throughout the enclosure using distribution and sub-distribution panels to be located at each level. A second voltage transformation to 120/208V, 3-phase, 4-wire, shall be provided using large, single dry type transformers located at the main electrical room on grade level, and associated distribution and sub-distribution panels located at each level. A large, central static UPS shall be provided and sized as determined by the electrical UPS type loads being served. UPS type electrical power is to be provided to mission critical type loads such as rack mounted electronic equipment, communication computer servers, etc. and is distributed throughout the enclosure using sub-distribution panels. Slip rings will transfer power across the rotating interface between the base and carousel.

The enclosure has an electrical safety grounding system as required by the National Electrical Code (NEC). The building grounding system consists of a continuous grounding mat/mesh made using 1#1/0 bare stranded copper (SDBC) conductor arranged in 1 meter squares and located directly under the building concrete floor and spread foundations. A continuous 1#4/0 SDBC ground ring is provided around the entire building foundation perimeter with ground rods exothermically connected to ground ring at 15 meter intervals and minimum of one ground test well. In addition, the building structural steel columns and concrete reinforcing rebar is bonded to grounding ring and grid using exothermic type welds. The entire building grounding system is buried at a minimum depth of 1 meter below finished grade. Both the equipment building and enclosure grounding systems is connected/tied together to form an overall facility/site grounding system. The site standby generators are also connected to this grounding system.

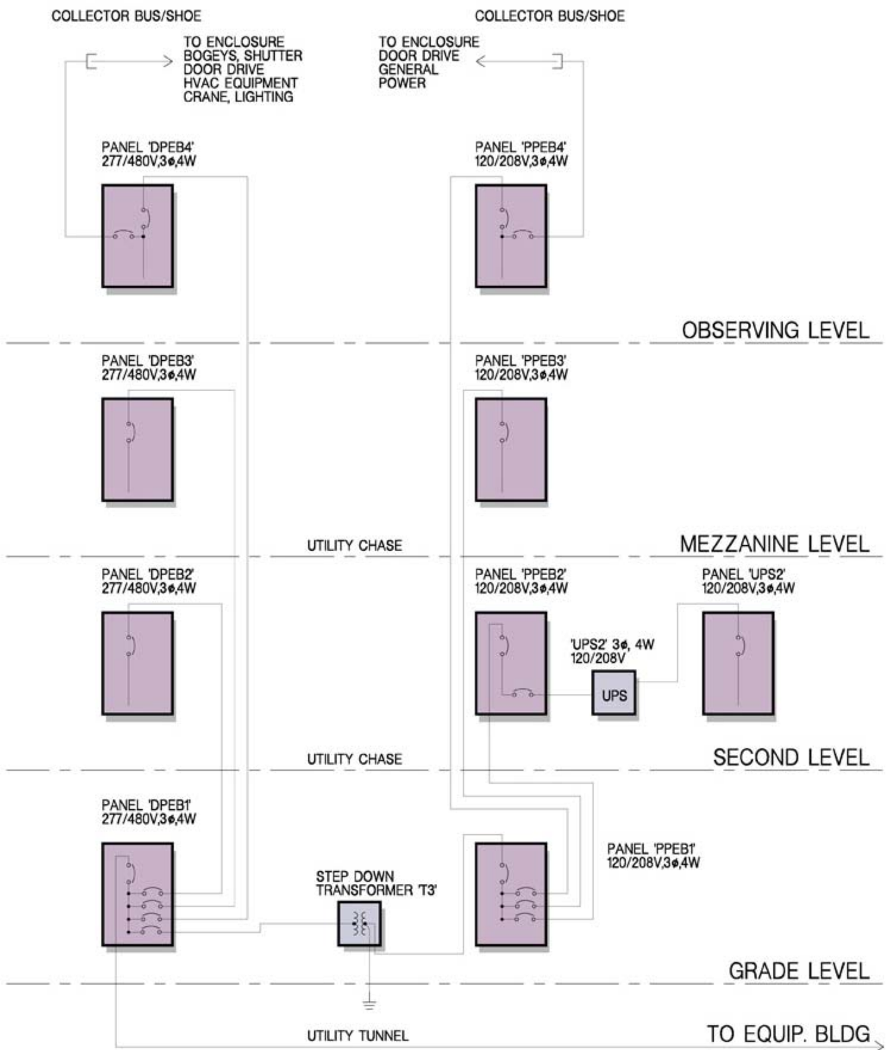

Figure 14-17. Electrical One-Line Diagram.

The enclosure lightning protection system is provided and consists of an array of copper air terminals located at the top of the enclosure. The air terminal array are bonded together using NFPA 780 defined Class II main conductor of 28 strand #14 copper type conductor with direct connections to the building buried grounding system made at a minimum of four to six locations around the building's perimeter.

14.8 Mirror and Instrument Handling

14.8.1 Central lift

The central lift is located in the center of the bottom of the pier and is shown in Figure 14-18 and Figure 14-19. It is used for removing and installing the azimuth disk removable platform, Gregorian instruments that mount on the underside of the instrument rotator as well as the instrument rotator and the S7 mirror cell assembly. The system consists of the following components:

1. **Central lift cylinder** - A telescoping single-acting hydraulic cylinder mounted in a tubular cavity in the center of the pier.

2. **Central lift platform** - A circular structure 8.9 meters in diameter which serves as the floor that is flush with the pier slab when the lift is down and stored and as a structure for supporting removal carts that are used to move the assemblies listed above out from under the pier. The underside of the central lift platform is reinforced with a bracing system as shown in Figure 14-19. This transfers horizontal forces and moments to the lift platform guides described below. The bracing system resides in the recess, or pit in the center of the pier when the lift platform is down. Portable handrails, although not shown, block inadvertent access to the pit opening when the lift is raised. The platform surface includes rails which mate with rails in the pier slab as shown.

3. **Removal carts** - various wheeled structures used for lowering and removing Gregorian instruments, the instrument rotator, and the S7 cell assembly. Shown in Figure 14-19, the S7 cell removal cart also acts as a 2.8 meter tall spacer, eliminating the need for guides above the instrument platform and reducing the travel required of the lift. The cell can be lifted off the spacer cart and lowered to a thinner cart by the enclosure crane working through the observing floor main hatch. The azimuth disk removable platform will have integral wheels and thus not require a separate cart. All carts will be securely bolted or pinned to the lift platform when not in the down or stowed position.

4. **Central lift guides** - stationary structures that interface with the two edges of the central lift platform that react horizontal seismic loads and assure that the platform remains level. The latter feature strengthens the system by reducing the effective column length of the hydraulic cylinder. The guides have three segments: a fixed assembly connecting from the pier slab to the pier top membrane, a short removable section between the top of the pier membrane and the underside of the azimuth disk, and another permanent section mounted on the c-rings to just below the instrument platform. Two options being considered for the guide mechanisms mounted on the platform that interface with the stationary guides are rollers or lubricated bronze sliding bearings.

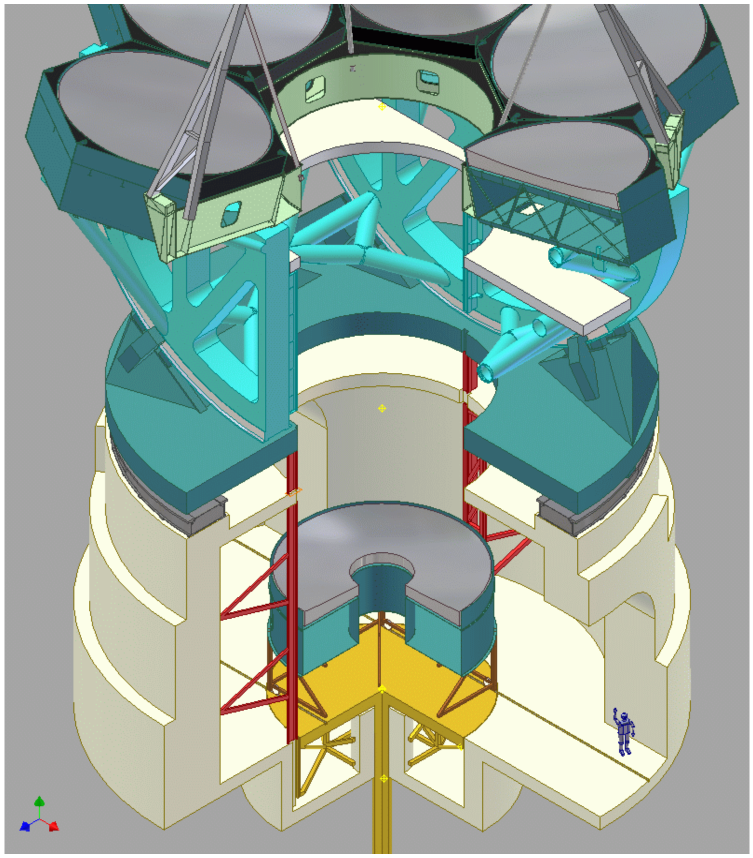

Figure 14-18. Section view of Central Lift in down position with S7 cell and S7 cell cart/spacer.

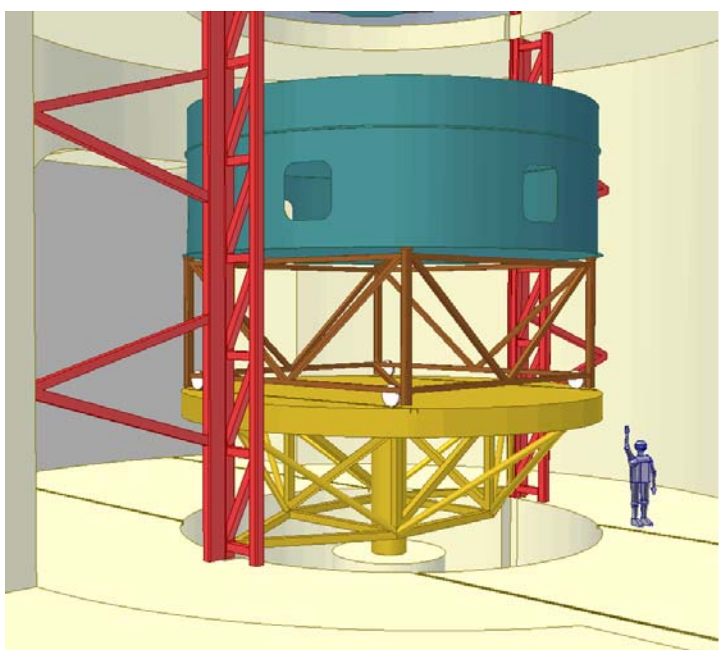

Figure 14-19. View with lift partially raised.

Specifications for the Central Lift are as follows:

Table 14-2. Central Lift Specifications

Feature	Specification	Comments
Lift platform diameter	8.9 meters	
Vertical travel	21.8 meters	
Lift capacity	90 metric tons	Cell assy 48 metric tons S7 spacer/cart 7 metric tons Lift platform 10 metric tons Lift cylinder, misc. 3 metric tons
Lift cylinder:		
Last stage rod diameter	~ 380 mm	
No. stages	4 maximum	
System pressure	~ 6.2E6 Pa	
Extension speed	~ 70 mm/sec maximum ~4 mm/sec minimum	
System power	~ 30 horsepower	

14.8.2 Primary mirror exchange

GMT uses a system of eight mirror cell assemblies for the primary mirror. These include six active outer segment assemblies (S1 through S6), one spare outer segment assembly, and the center segment assembly (S7). The seven outer assemblies are interchangeable in any of the six outer telescope positions. Each segment is recoated in its cell in a large coating chamber in the support building approximately 40 meters from the enclosure. The spare outer cell assembly minimizes lost observing time for six of the seven recoating operations. Details of exchanging the assemblies at the telescope are discussed below.

14.8.2.1 Outer segment exchange

The outer cell exchange at the telescope will be done with the enclosure overhead crane, Section 14.8.4. Immediately after an outer segment cell is removed the spare cell assembly (with its recently recoated mirror) is installed in its place. Assuming recoating of each mirror is necessary every year or two, on average an outer cell must be exchanged every two to four months.

Each cell assembly is brought to, or removed from, the enclosure on a wheeled cart on crane rails at ground level. The cells are raised or lowered through a 9.5-meter by 10.5-meter hatch in the observing floor. A cell in its position on the telescope, including the radial tilt rigging, is shown in Figure 14-20. A typical travel path from below the hatch to the telescope is shown by the wide white line in Figure 14-21.

The cell will be brought through the hatch in a level attitude with its hexagonal geometry nominally aligned with the observing floor hatch. At some point (indicated here by the short yellow intersecting lines) the cell will be rotated 30 degrees around a vertical axis ("rotation" above), and tilted 13.5 degrees from level ("tilt" above). The 13.5 degree tilt becomes a "radial tilt" to match the global shape of the primary mirror in the outer segment areas. This puts the cell in the proper attitude for mating with the telescope. The rest of the installation travel path, shown here with single horizontal and vertical facets, may require two or more facets to maximize clearance from adjacent telescope structure. Energy-absorbing guides will line the structure to preclude damage due to minor contact during installation. The definition and bolting of the outer cells is as described in Section 7.4.5.2, "Outer segment mirror cells".

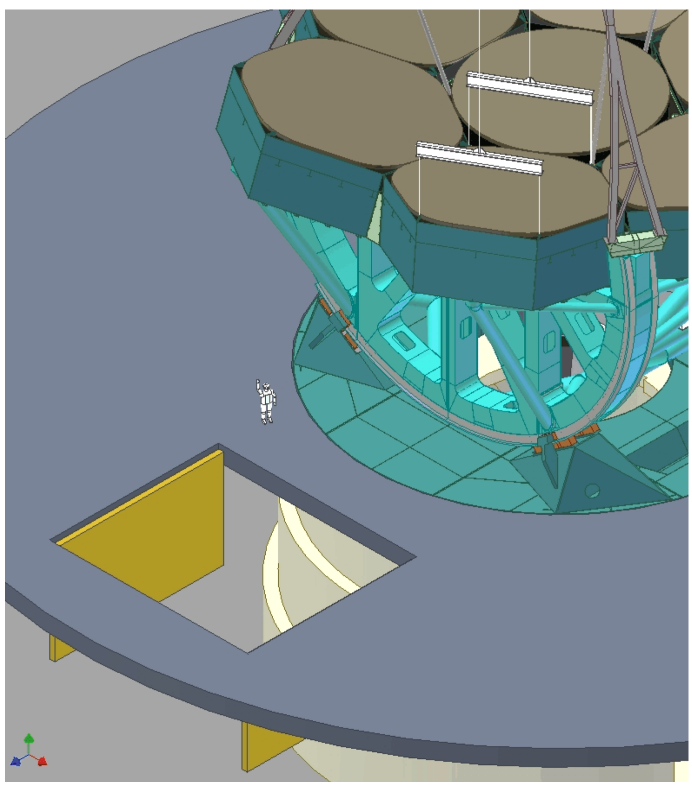

Figure 14-20. Rigging used for outer segment cell removal and installation.

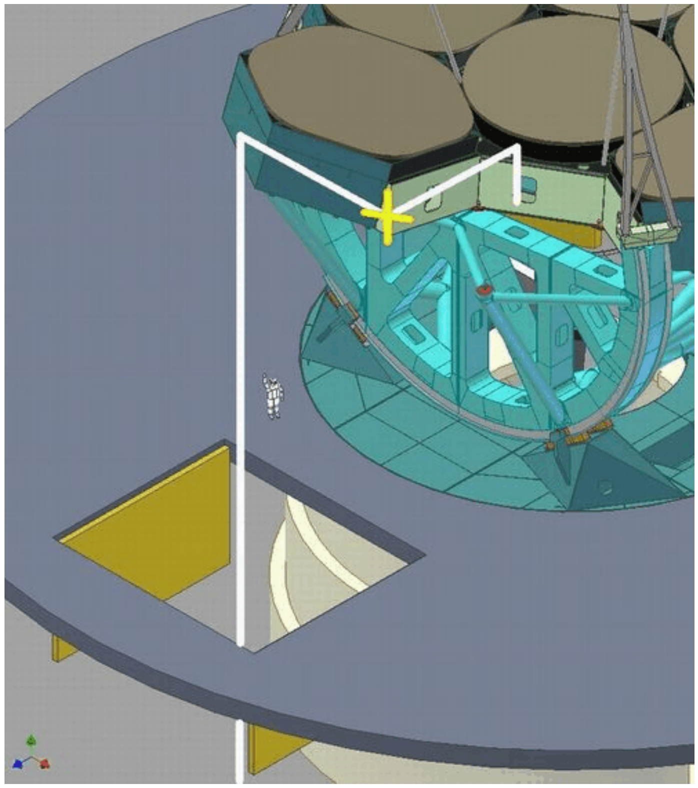

Figure 14-21. Removal and installation path of outer segment cells.

14.8.2.2 Center segment exchange

The S7, or center segment cell exchange is accomplished with the central lift, which is described and shown in Section 14.8.1. Done much less frequently than the outer cell exchange, this operation first requires removal of Gregorian instrument(s) from the underside of the instrument rotator then the instrument rotator itself (with or without folded instruments on the top side). After removal of these assemblies, the S7 cart/spacer is rolled onto and secured to the central lift platform, Figure 14-18 and Figure 14-19. Then the lift is raised to engage the bottom of the S7 cell. Using a pressure transducer at the lift cylinder, the lift is loaded against the bottom of the cell with approximately 71 metric tons, or 5% above the weight of the cell assembly plus S7 cart/spacer plus lift platform and lift cylinder.

The S7 cell is then unbolted from the CCF. This requires removing approximately (36) 20 mm socket head cap screws at each of the top and bottom flanges of the cell. Access to the top flange screws is via access holes through the inner wall of the CCF with personnel inside the CCF. Access to the bottom flange screws is from the instrument platform. After securing the cell to the top of the S7 cart/spacer, the assembly is then lowered to the pier floor, the spacer/cart unfastened from the lift platform, and the assembly rolled out from under the pier.

The installation procedure is the reverse of that just described. Registration of the cell top flange to the CCF is by round pin/diamond pin. The bottom flange is flexured so as to carry only in-plane loads and does not define the part.

14.8.3 Instrument exchange

GMT instruments use two mounting configurations on the top side of the Instrument Platform (IP) and a third mounting for Gregorian instruments on the underside of the instrument rotator. The rationale for this instrument arrangement as well as details of the mounting configurations and payloads are described in section 7.7.3. The system chosen requires that there are two areas accessed for instrument exchange: the underside of the instrument rotator for Gregorian instruments, and the top side of the rotator and IP for folded instruments. Details of instrument exchange are discussed below.

14.8.3.1 Gregorian instrument exchange

A notional Gregorian instrument is shown in Figure 7-35. This could be one large instrument, or an instrument module with two or more smaller instruments mounted inside which could be changed into the light path during the night. For example, if the instrument had a folded beam and were larger in diameter (it could be as large as the 8.9 meter diameter instrument rotator) focal plane optics could be moved to the outer area remotely. A smaller-diameter, perhaps long instrument could be advanced axially to the focal plane using an axial-travel mechanism.

Gregorian instruments are exchanged using the central lift, which is also used to remove the instrument rotator and center mirror cell (see section 14.8.1). Views of the lift with the S7 cell and its cart/spacer are shown as Figure 14-18 and Figure 14-19. A similar cart would be used for Gregorian instruments. In the example described above the center instrument would be removed using a cart designed for its unique interface and a second one for the outer instrument. Although not shown, personnel platforms and stairs will be built in the C-ring structure to access areas as necessary for exchanging and servicing the instruments. Instruments of sufficient size and internal space will also include personnel access within the instrument volume.

14.8.3.2 Folded instrument exchange

Instruments on the top side of the IP are exchanged using the instrument service lift shown in Figure 14-22 and described in detail in section 14.7.5. The upper instrument space, including areas for rotating and non-rotating instruments, is 10 meters wide, 16.4 meters long and 1.9 meters tall. Another less obstructed view of this area is seen in Figure 7-36. Instruments will have separable or integral wheeled carts. They will be secured to the service lift at the observing floor, and then raised to the IP level at the back side of the telescope. Personnel at the IP will then move the instrument to its intended position on the instrument rotator or stationary platform and secure it to the structure. As shown and described in Figure 14-23, the space between the lift and main platform area is somewhat limited by the structure. Larger individual instruments may require a modular construction requiring reassembly in the upper platform area.

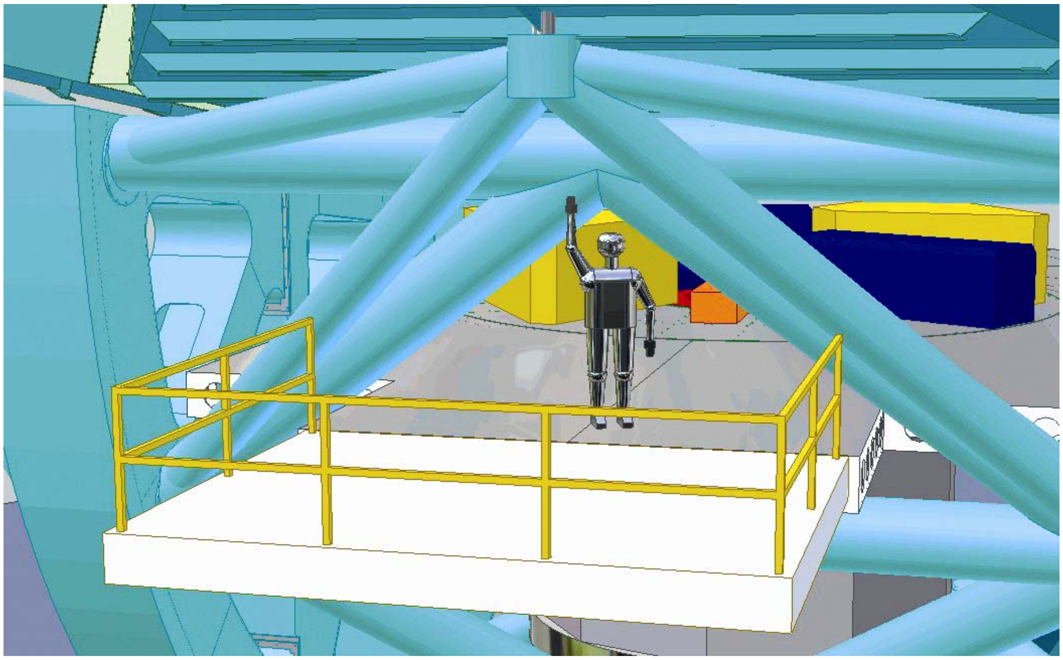

Figure 14-22. View of top side of instrument platform and instrument service lift. Partially visible is the instrument rotator, with notional folded instruments.

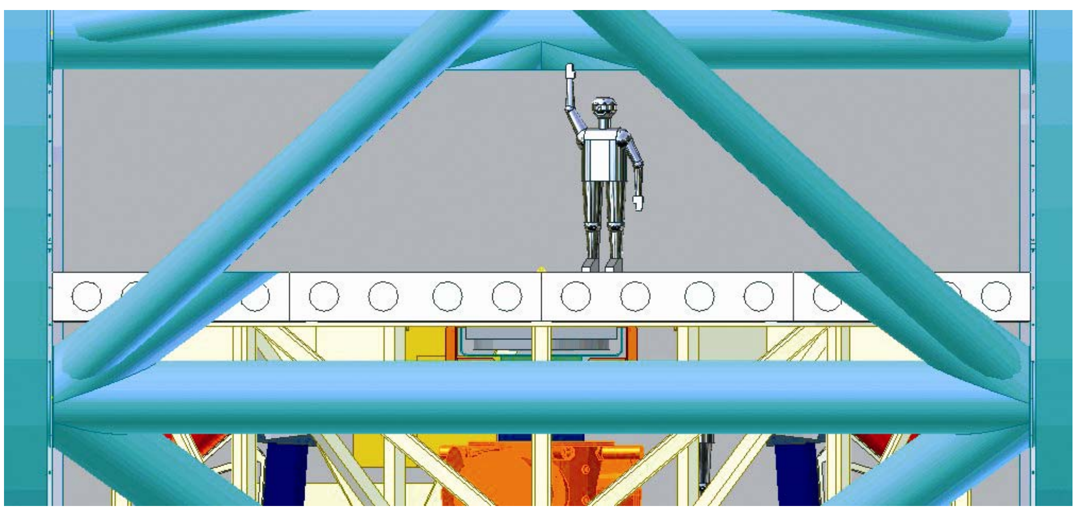

Figure 14-23. Access to upper instrument area is currently limited by the large pipes which brace the C-ring structure. A goal of the next design phase is to revise the bracing so that access is only limited by the smaller quadrupod pipes as shown.

14.8.4 Secondary Mirror Service

GMT will have two secondary mirror assemblies - the Fast Steering Mirror (FSM) and the Adaptive Secondary Mirror (ASM). Generically referred to as "M2", either assembly can be serviced on the telescope from a system of platforms that mount to the back area of the enclosure. Alternatively, an M2 assembly can be removed from the end of the truss and serviced from a fixture which resides on the main M2 service platform or the observing floor below. The M2 on-telescope service and removal operations are done at the minimum elevation angle. The removal or exchange can be done using the enclosure overhead crane. However, the addition of a smaller special-purpose crane, which might be more convenient for this operation, is being considered.

One possible service platform configuration is shown with the ASM in service position in Figure 14-24 through Figure 14-26. The two-level platform system consists of a large stationary platform (the tan “main platform”) 18 meters above the observing floor and two smaller (blue) platforms. The front smaller platform is powered horizontally into place after the telescope is lowered into position. Also, the rear smaller platform can be pivoted up (hinge line at interface with enclosure) to provide clearance for M2 removal, which first requires horizontal motion away from the truss. In this concept the main platform is notched to clear the truss members, and the telescope and enclosure would be interlocked to preclude motions that would allow physical contact between the two structures.

An alternative platform system in which the main platform also has moving elements, will be investigated in the next design phase, with the goal of eliminating the telescope/enclosure interlocks mentioned above.

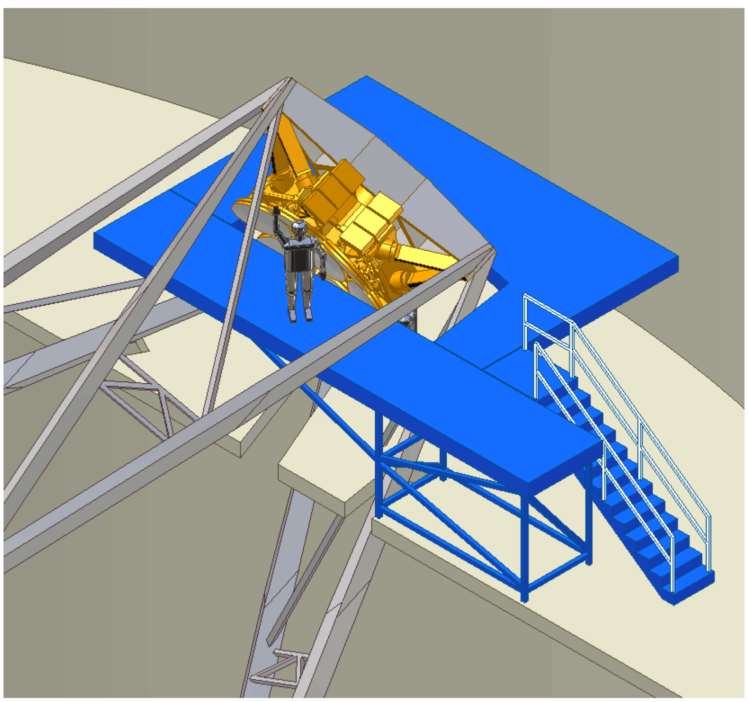

Figure 14-24. M2 service platforms. Main platform (stationary - tan), front platform (translating - blue), and rear platform (pivoting - blue). Handrails are not shown.

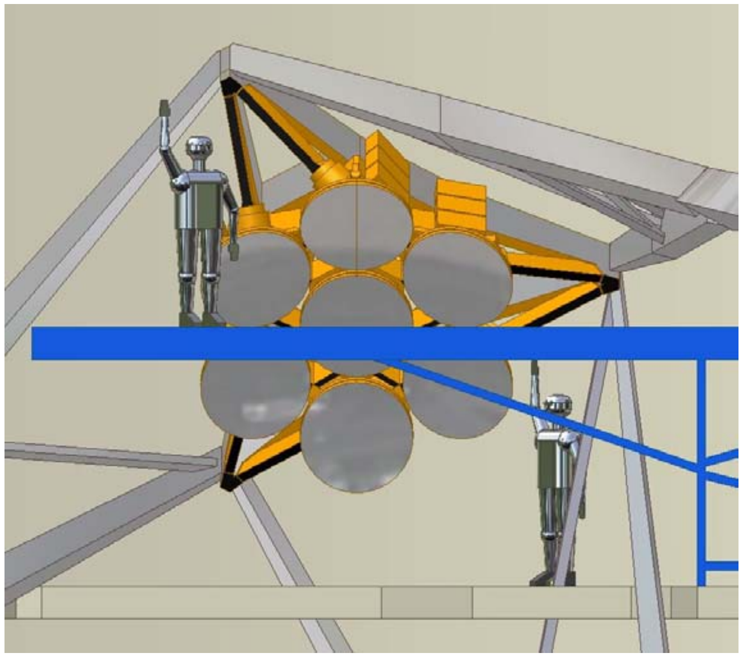

Figure 14-25. Front access.

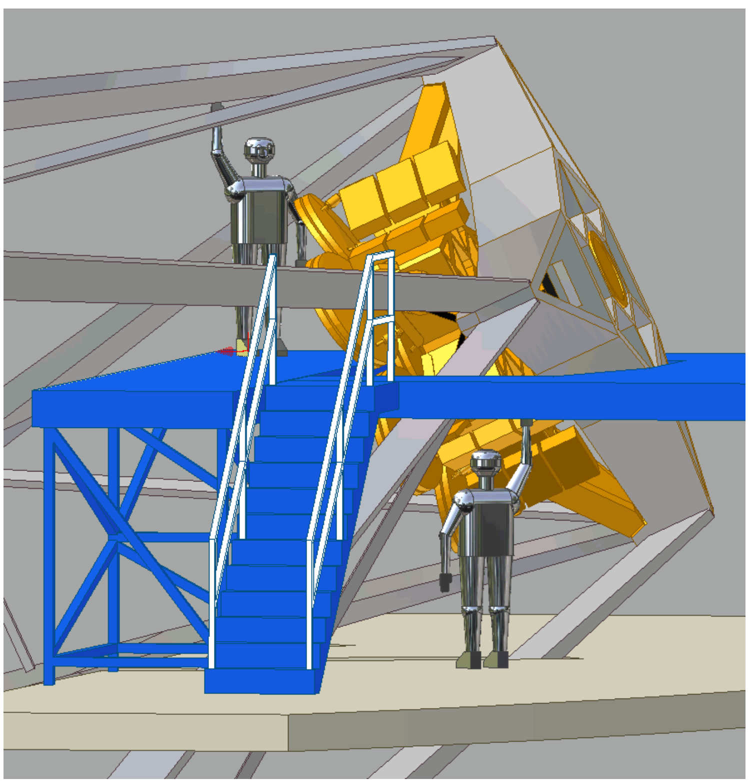

Figure 14-26. Rear and side access.

14.9 Thermal Design

14.9.1 Dome seeing

The thermal environment inside the telescope chamber can degrade the imaging performance of the telescope if not carefully controlled. The effect is called “dome seeing” and is caused by turbulent mixing of air at different temperatures in the telescope beam. In the most detailed empirical study of dome seeing to date, Racine, et. al. (1991) derives a relationship between image quality and dome air temperature relative to outside air temperature, of the form $(0.1'' \pm 0.05'')/K^{6/5}$ FWHM, based on temperature and seeing measurements at the Canada, France, Hawaii Telescope (CFHT). This implies that the air inside the enclosure during observing should never be warmer than the outside air by more than 0.22 K in order to satisfy the 80% encircled energy image budget of 0.025″ (0.017″ FWHM) for this source of error. Colder temperatures were found to be less damaging in that study.

The thermal management system will operate 24 hours a day. During the day the enclosure will be sealed up and the inside air will be actively cooled to maintain the interior air temperature at the predicted ambient values at the start of the night. The air at different levels within the chamber will be mixed with fans to reduce stratification. The stratification will be monitored by a network of thermometers and used to control fans and louvers. In the late afternoon the air conditioning will be turned off and the enclosure will be opened up to the early evening sky. The thermal control system for the primary mirror will be turned on if not already operating and set to follow the ambient temperature. Wind driven ventilation through the shutters and ventilation windows will then be relied on to bring the rest of the enclosure and telescope structure to equilibrium with the ambient air and to track changes through the night. Cooling systems for active sources such as electronic racks will operate continuously day and night.

Potential nighttime heat sources include (a) cooling of the telescope and enclosure structure, (b) waste heat from electrical/electronic equipment, (c) waste heat from electric motors, (d) heated oil for the hydrostatic bearings, and (e) entrainment of air from the outside boundary layer. The cooling mechanisms at night include (a) active cooling of heat producing motors and electronic equipment and the primary mirror assemblies, (b) wind-forced ventilation of the telescope chamber and (c) radiation to the cold night sky.

Another potential source of dome seeing comes from air in thermal contact with the sides and top of the enclosure that is carried by the wind in front of the shutter opening. Depending on the exterior skin temperature, the air could be either warmer or colder than ambient. The wall and roof panels are made of insulated panels with a thin steel face sheet. In the absence of radiation cooling, the panel surfaces will rapidly equilibrate with the surrounding air. Radiation to the night sky however can drive surface temperatures up to 3.6 K below the ambient temperature (Good 2004) depending on factors including cloud cover, wind speed, conduction to the panel, and emissivity of the surface. The strategy adopted by Magellan and other telescopes to address this problem has been to apply low emissivity tape to the areas around the shutter. In the case of Magellan the whole dome was covered with tape. The much greater surface area of GMT makes this approach, while possible, not as practical as on smaller domes but local application around the shutters is still possible. Other low-emissivity surface treatments will be investigated in the design development phase and the effect of a cold outside surface will be modeled.

The GMT plan for dealing with dome seeing involves a number of measures:

- Raising the telescope above the boundary layer and providing for flow below the observing floor to prevent the heated boundary layer from entering the telescope chamber.
- Reducing the thermal mass and time constant of the steel structures within the telescope structure by the efficient use of steel truss members in the enclosure structure and thin cross section steel plates in the telescope,
- Maintaining the inside air during the day at the expected early evening temperature and mixing the air to prevent stratification,
- Insulating the observing floor to prevent conduction from below,
- Providing maximum wind-driven ventilation through the structure at night to expel pockets of warm air and promote rapid thermalization,
- Actively cooling heat producing motors and equipment with a chilled liquid system to capture and extract waste heat,
- Insulating and sealing the wall structure, shutters, and ventilation windows to reduce infiltration of heated outside air during the day,
- Cooling the hydrostatic oil,
- Actively cooling the primary mirror segments and cell assemblies,
- Applying low-emissivity surface treatments to the upper portion of the telescope to prevent overcooling from radiation to the cold night sky.

14.9.2 LCO temperature conditions

Temperature conditions are relatively benign at Las Campanas Observatory. Table 14-3 lists the 10^{th}, 25^{th}, 50^{th}, 75^{th}, and 90^{th} percentile conditions for (A) the rate of temperature change during the night and (B) the change in temperature from close-down in the morning to opening-up at night. The data were obtained in the 1987-1988 Magellan site testing campaign (Persson et al, 1988).

Table 14-3. Temperature variation at LCO.

		Percentile Temperature Conditions				
	Parameter	10%	25%	50%	75%	90%
A	$\Delta T/\Delta t$ (night, °K/hr)	-0.80	-0.44	-0.12	0.22	0.67
B	$T_{open} - T_{close}$ (°K)	2.6	1.8	0.8	-0.3	-1.4

14.9.3 Heat balance

A preliminary estimate of nighttime thermal conditions in the enclosure has been obtained by looking at the balance of heat loads and cooling mechanisms within the telescope chamber.

The thermal equilibrium in the enclosure is dominated by the heat released by the steel mass of the telescope and enclosure cooling at the nighttime rate. This is balanced by radiation cooling through the shutters and wind-forced ventilation. Not all of the 960 metric ton telescope structure will contribute to the heat load. The primary mirrors and cells are actively cooled to the ambient temperature and do not contribute to dome seeing. Subtracting their mass from the total telescope weight leaves 680 tons. The inside exposed steel of the enclosure including the observing floor is estimated at 1,888 tons. Additionally, we assume that 10 kW of heat escapes from active cooled sources such as electronics, motors, drives, and the laser system.

Table 14-4. Heat sources.

Heat Sources	Effective Mass metric tons	Power per K/hr kW/K/hr	ΔT/Δt (°K/hr) 10% -0.80	25% -0.44	50% -0.12	75% 0.22	90% 0.67
Telescope Structure	680	92	73	40	11	-20	-62
Enclosure Structure	1888	255	204	112	31	-56	-171
Active Sources	na	10	10	10	10	10	10
Total (kW)			**287**	**163**	**52**	**-66**	**-222**

Table 14-4 shows the expected heat load for the 10th, 25th, 50th, 75th, and 90th percentile range of hourly temperature variation. The heat must be removed with a combination of radiative cooling to the night sky and by ventilation with nighttime air.

Fully retracted, the upper shutter provides an opening of 1,380 m^2 looking out at the sky. The vertical shutter provides an additional 1,500 m^2 and the ventilation windows add 1,828 m^2. Assuming the vertical openings radiate 50% as effectively as the roof opening due to their reduced view factor of the sky, the cooling rate is 213 kW for a radiative coefficient of 70 W/m^2. This assumes clear conditions and ignores any reduction of the loss due to the reflective mirror surface. Ventilation efficiency and radiation loss can be traded by closing down the shutters around the telescope aperture and closing or baffling the ventilation windows to baffle exposure to the sky.

The GMT design relies heavily on wind-forced ventilation to drive inside temperatures to the ambient temperature. Fully open, the ventilation windows present 700 m^2 of open area to wind approaching the enclosure from the side. The experience at Magellan is that the wind enters the up-wind vent windows at roughly undiminished speed. Assuming the same for GMT, the volume of air inside the dome will be exchanged with the nighttime air every 26 seconds in a median 6.5 m/s wind. The exchange time increases to 105 seconds for the 10th percentile 1.6 m/s wind. CFD modeling of the enclosure and vents will be used to verify these assumptions during design development.

Table 14-5. Air temperature rise with wind forced ventilation.

Air Temperature Rise (°K)							
			Ambient Air Heating/cooling Rate				
			10%	**25%**	**50%**	**75%**	**90%**
					K/hr		
			-0.80	**-0.44**	**-0.12**	**0.22**	**0.67**
	Wind speed		**Heat Production (kW) from Table 14-4**				
Frequency	speed	P/K	**287**	**163**	**52**	**-66**	**-222**
	(m/s)	(kW/°K)	(°K)	(°K)	(°K)	(°K)	(°K)
10%	1.6	1,133	0.25	0.14	0.05	-0.06	-0.20
25%	4.0	2,833	0.10	0.06	0.02	-0.02	-0.08
50%	6.5	4,564	0.06	0.04	0.01	-0.01	-0.05
75%	9.4	6,610	0.04	0.02	0.01	-0.01	-0.03
90%	12.4	8,719	0.03	0.02	0.01	-0.01	-0.03

Table 14-5 gives the mean temperature rise of the air exiting the enclosure over a range of temperature cooling/heating rates and wind speeds that cover the 10^{th} to 90^{th} percentile conditions assuming that the ventilating air carries off all of the heat produced by a steady rate of temperature change. For all but the slowest wind speed and most rapid cooling the temperature rise is within the 0.22 °K specification. No allowance has been made in the table for radiative cooling that would otherwise reduce the heat load and air temperature.

14.9.4 Summary

The results of this section do not represent a full analysis of the thermal performance of the GMT enclosure but do show that, at this stage of the development, thermal management of the structure using a combination of active cooling during the day and wind-forced ventilation at night is a viable strategy. A significant increase in the cross-wind ventilation could be achieved by installing windows on the four vertical wall panels that are currently solid. The trade-off is cost, more seals to contend with and a small reduction in the insulating value of the wall.

The major issues that must be confronted during the design development phase include

- Non-uniform heating and cooling of the interior structures of the enclosure and telescope including the effects of radiation to the night sky,
- Elimination of vertical temperature stratification of the inside air during the day,
- Treatment of the enclosure outside surface to prevent over-cooling of air around the shutter caused by radiation to the night sky,
- Behavior of the boundary layer at the selected site and its interaction with the enclosure structure,
- Prevention of heat infiltration from below the observing floor,

- Cooling of active sources, and
- Trapping the heat from equipment and structures with long thermal time constants (e.g. the bridge crane, arch girder structure, counterweights, etc.).

These will be investigated with a combination of analytical modeling and measurements at the site to better characterize wind and thermal conditions.

14.10 HVAC Requirements

During daylight hours the enclosure will maintain the interior at the expected sunset temperature by actively cooling the air in the telescope chamber. The thermal environment on LCO is relatively benign. The median difference between the daytime high temperature and the temperature at sunset is 1.9 °C with a range of 0.9 °C to 2.8 °C between the first and third quartiles. The median difference between the closing temperature in the morning and the ambient temperature late in the afternoon at opening is 0.8 °C with first and third quartile values of -0.3 °C and 1.8 °C respectively. Weather predictions will be used each day to obtain the late-afternoon target opening air temperature in the dome.

The inside air temperature will be controlled by a set of four air handling/heat exchanger units (AHU) in the top of the enclosure supplied with a solution of chilled glycol. Coolant will be piped to the heat exchangers from a remote chiller unit.

The enclosure cooling load is calculated at 204 kW (58 tons). This load can be broken down into four basic components, 13% to environmental, 14% to infiltration, 11% to internal loads and 62% to waste heat produced by the fans themselves. Environmental loads are governed by the wall and roof R-value and the maximum temperature difference between the interior and exterior spaces. In this case the interior space is set at 19.5 °C while the exterior daytime high is 24 °C. Infiltration loads are influenced by the air tightness of building construction and average wind velocity. The internal loads are from electrical equipment such as lights and equipment. Fan heat is the brake horse power required to move 75.5 m^3/s (160,000 CFM) at a pressure differential of 0.87 kpa (3.5 in. wg).

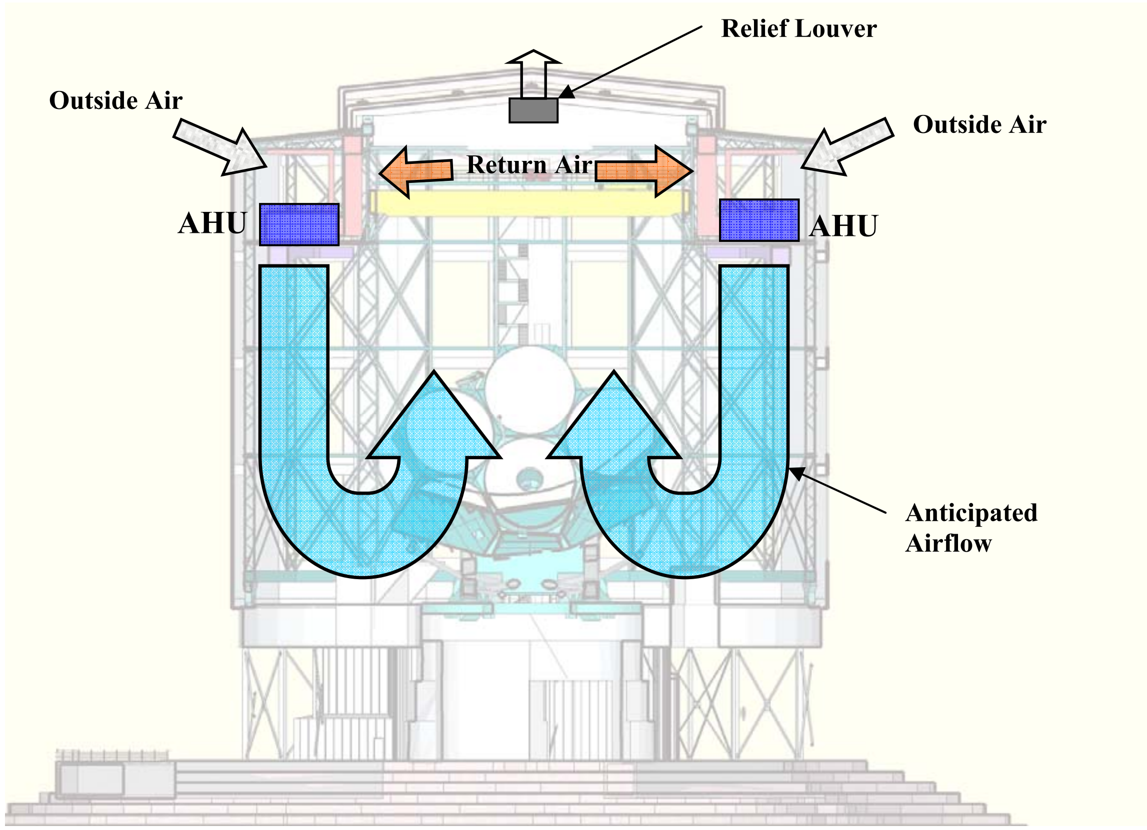

Figure 14-27. Carousel Air Flow Diagram.

Four 18.9 m^3/s (40,000 CFM) air handling units (AHUs) are located at the mechanical level. Two air handling units without heaters and humidifiers are placed on each side of the enclosure. The air handling units consist of a filter mixing box, cooling coil and fan section plus several smaller access sections. The air is filtered to an ASHRAE dust spot efficiency of 25-30%. The air discharges from the two units into a common supply duct located below the platform level. The supply air is discharged down the building interior walls creating an air swirl where the cold air falls down the interior walls while the hot air will rise in the enclosure center. The return air duct is located centrally as high as possible in the enclosure to capture this rising hot air. A relief air vent is located high in the enclosure to vent warm air above the return air ducts. Sufficient air is brought in from the outside by each air handling unit to make-up for the air that is expelled through the vents.

Temperature stratification is a concern with this enclosure. With a height of approximately 50 meters it is difficult to achieve a uniform vertical temperature distribution in the enclosed volume. The air handlers move 75.5 m^3/s (160,000 CFM) of air but that only represents 2.5 air changes per hour and air circulation at that rate will be relatively slow. To help reduce the potential for stratification the mixing of air may have to be increased with additional fans. Further analysis will address this issue.

A nominal 246 kW (70 ton) screw chiller is remotely located near the equipment building, with 100 mm (4 inch) diameter distribution piping routed in the utility tunnel to the telescope enclosure. For the distribution piping to cross over from the fixed to the rotating portion a flexible hose with a quick disconnect coupling is required. Safety interlocks are provided to prevent enclosure rotation while the chilled water piping is connected. 30% ethylene glycol is used as the brine to prevent freezing of the pipes during cold weather operation. The expected maximum operating temperature of the brine in the summer will be 10 °C and a minimum of -6.5 °C in the winter. With this range of brine temperatures the enclosure can be maintained at 18 °C in the summer down to 1.5 °C in the winter.

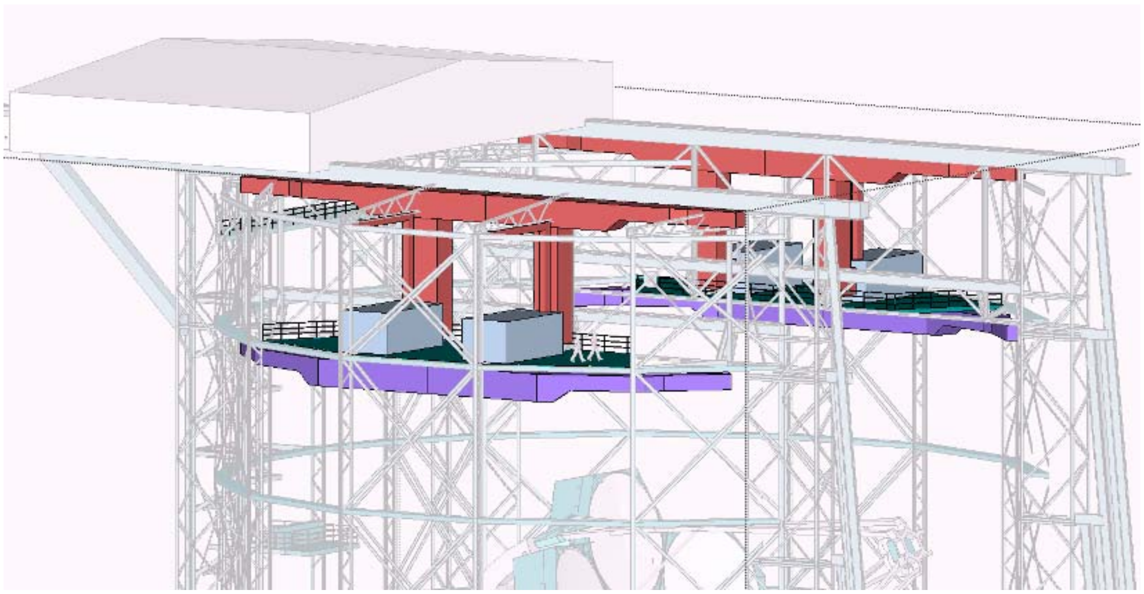

Figure 14-28. HVAC System at Mechanical Level.

14.11 Future Studies

During the GMT Design Development Phase the following enclosure studies will be performed.

- Wind flow around and through the structure will be investigated with computational fluid dynamics modeling to optimize flow characteristics of the structure, determine wind turbulence within the telescope chamber that will affect wind shake of the telescope, and investigate thermal performance for different wind cases.
- The enclosure structure will be developed in greater detail and incorporate changes identified in the CFD studies. Spaces within the building will be detailed.
- Light weight panels for the vertical shutter will be investigated with the goal of reducing the moving weight and thermal mass of the panels and counterweights.
- Preliminary designs will be completed for the various dome mechanisms including the rotation bogies and drives, shutter mechanisms, ventilation systems, and service and lift platforms.
- Foundation plans will be developed based on measured soils properties for the selected site.

The cost study will be refined and a construction plan will be developed.

14.12 References

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