Telescopio San Pedro Mártir Observatory preliminary design and project approach

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ABSTRACT

The Instituto de Astronomia of the Universidad Nacional Autónoma de México (UNAM) along with Instituto Nacional de Astrofisica, Optica y Electronica, the University of Arizona and the Smithsonian Astrophysical Observatory are developing the *Telescopio* San Pedro Mártir (TSPM) project, a 6.5m diameter optical telescope. M3 Engineering & Technology Corp. (M3) is the design and construction management firm responsible for all site infrastructure, enclosure and support facilities.

The *Telescopio* San Pedro Mártir project (TSPM) will be located within the San Pedro Mártir National Park in Baja California, Mexico at 2,830 m. above sea level, approximately 65 km. east of the Pacific Ocean, 55km west of the Sea of Cortes (Gulf of California) and 180km south of the United States and México border.

The aim of the paper is to present the preliminary design of the site infrastructure, enclosure and support facilities to date and share the design and construction approach.

Keywords: TSPM, San Pedro Martir, Mexico, observatory, enclosure, support, mechanisms, pier, BIM

1. INTRODUCTION

The Institute of Astronomy of the National Autonomous University of Mexico (UNAM) and the Instituto Nacional de Astrofisica, Optica y Electronica will be constructing a 6.5m diameter telescope to be located at the National Astronomical Observatory of San Pedro Mártir, Baja California within the Sierra de San Pedro Mártir National Park. Based on the Magellan Telescopes located on Las Campanas, Chile, the TSPM enclosure and support facilities design utilizes the successfully proven functional and space organization layout and adapts the design to project's unique requirements and site challenges. M3 Engineering and Technology Corporation (M3) has provided a Preliminary Design study for the *Telescopio* San Pedro Mártir Observatory (TSPM). This new telescope will join a group of three existing telescopes of smaller diameters (0.84 meters, 1.5 meters and 2.1 meters). The telescope facilities include an enclosure building and a support building connected by an access corridor and bridge on the observation level for telescope related activities.

"The telescope's mechanical design is inspired by the Magellan telescopes in Las Campanas, Chile. However, the primary mirror cell will be completely compatible with the Multiple Mirror Telescope's (MMT) Cassegrain focus. The TSPM will also include Nasmyth focal stations slightly farther from the primary than at the Magellan telescopes to allow a wider field of view. This design is being lead by the Centro de Ingeniería y Desarrollo Industrial (CIDESI) in

Figure 1.1 Basis of design: Magellan Observatories, Las Campanas, Chile.

Ground-based and Airborne Telescopes VI, edited by Helen J. Hall, Roberto Gilmozzi, Heather K. Marshall, Proc. of SPIE Vol. 9906, 99062D · © 2016 SPIE · CCC code: 0277-786X/16/$18 · doi: 10.1117/12.2230767

Querétaro, México. Initially, the telescope is to operate in a f/5 Cassegrain configuration. The specific configurations for the future expansion to other focal stations, including Nasmyth and folded Casssegrain stations, are currently under study.” [3]

This paper also shares M3's design approach, tools and BIM software capabilities to create the construction documents and the construction method utilizing an engineering, procurement and construction management (EPCM) contract to cost effectively build an observatory on a remote mountain with limited nearby construction resources for a project of this scale and complexity.

2. SITE

2.1 Location

The site has an average elevation on site of 2,830m above sea level. The National park is located roughly 65km West of the Pacific Ocean and 55km East of the Sea of Cortes (Gulf of California). The existing terrain increases in elevation from North, West, and South, with a peak that rises more than 2,000m from the desert to the East. The highest point in the area of Baja California, is Picacho del Diablo (3,095m), located approximately at 6km south-west of such observatory. The area is located within the interior of a pine tree forest. Most of the area comes with a strong number of rainfall events with clear intervals between. The nearest city is Ensenada (300,000 inhabitants) at 140km to the North. The closest commercial airports are located in Tijuana (at 220 km) and San Diego (250km). There is a 20km paved road leading to the observatory from the National Park’s entrance.

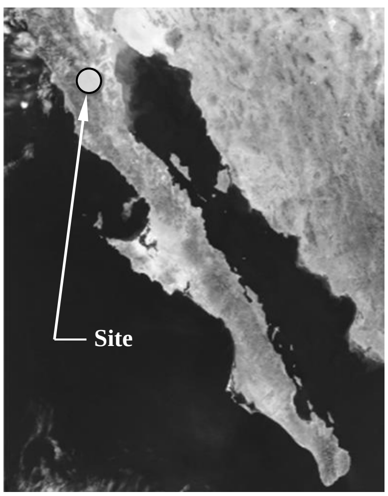


Figure 2.1 Telescopio San Pedro Mártir Location in the Baja California Península

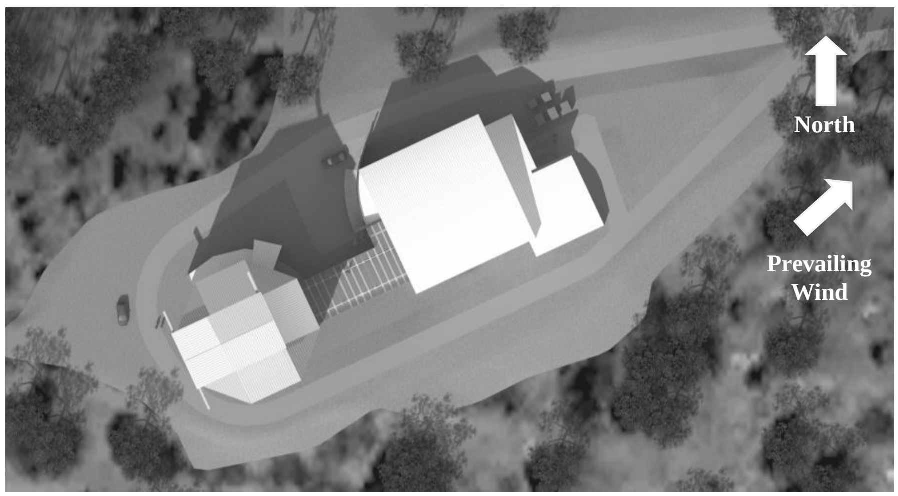


Figure 2.2 Telescopio San Pedro Mártir Site Plan

3. BUILDING CODES

The San Pedro Mártir Telescope (Baja California, México) shall consider on its design, the applicable guidelines of the following national and international references:

- International Building Code, Edition 2006
- Occupational Safety and Health Administration (OSHA)
- International Plumbing Code
- International Mechanical Code
- National Fire Protection Association Codes and standards
- International Energy Conservation Code
- National Electrical Code
- Ley de Edificaciones del Estado de Baja California
- Instituto Mexicano del Seguro Social (IMSS)
- Secretaría del Trabajo y Previsión Social (STPS)
- Comisión Federal de Electricidad

4. BUILDING LAYOUT

The *Telescopio* San Pedro Mártir Observatory is integrated by two distinguishable building volumes: Enclosure Building and Support Building. The Enclosure Building houses the telescope, telescope pier and Spectrograph room, while the Support building caters to telescope related activities, utilities infrastructure and personnel related functions. The two buildings are connected by a bridge that allows for mirror handling, and by an enclosed corridor for both personnel access and utilities.

4.1 Overall Floor Plans

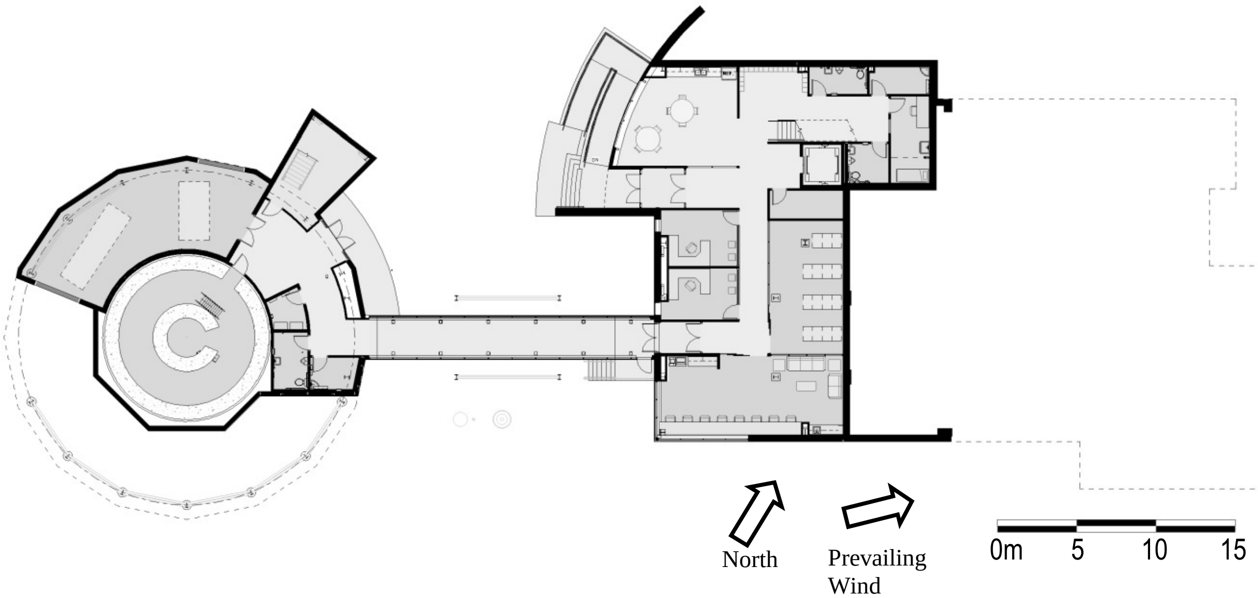


Figure 4.1.1 Overall Floor Plan – Lower Level

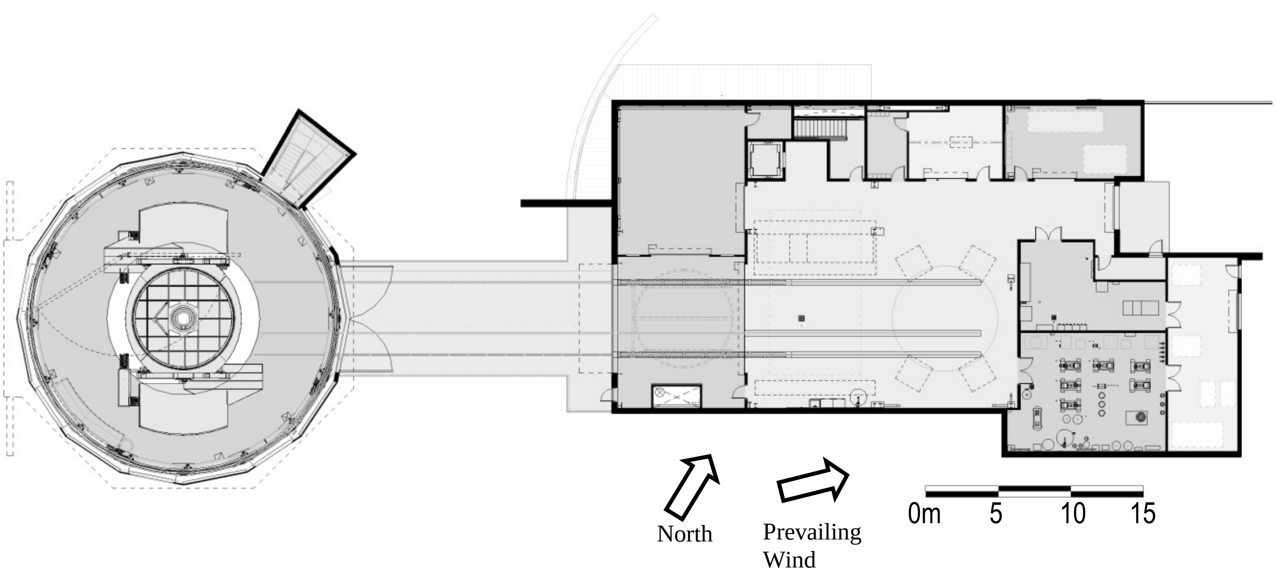


Figure 4.1.2 Overall Floor Plan – Upper Level

4.2 Overall Building Section

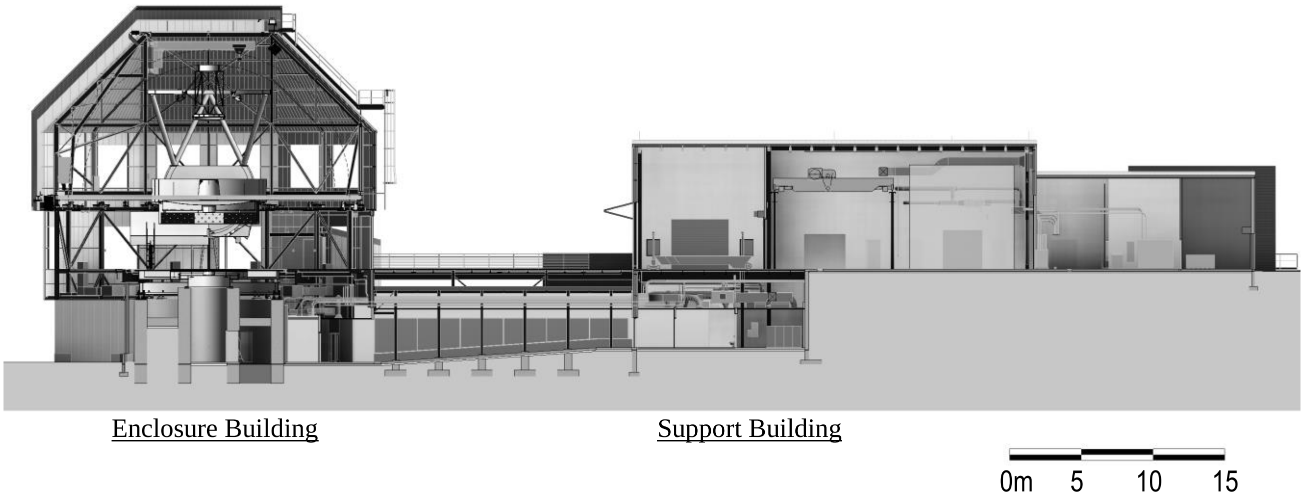


Figure 4.2.1 Overall Building Section

5. ENCLOSURE BUILDING

5.1 Enclosure and Enclosure Base

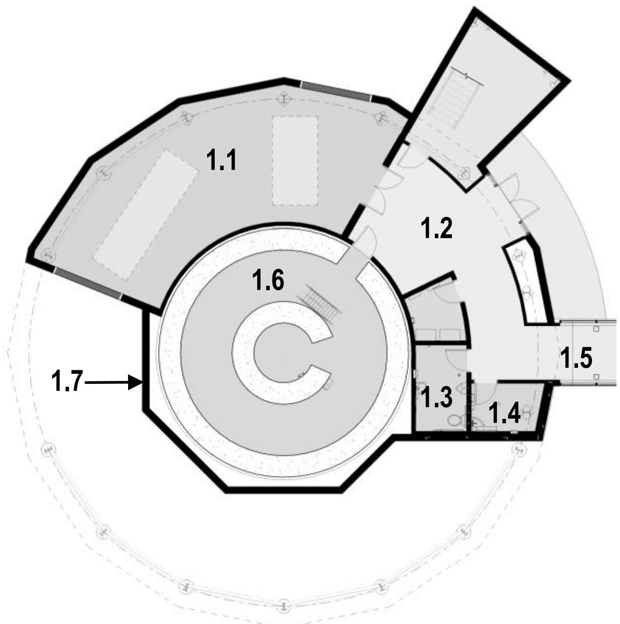
The Enclosure houses the 6.5 meter TSPM telescope. In the closed position, the Enclosure protects the telescope and its instruments against adverse weather conditions. In the open position, the Enclosure allows the telescope a free field view by means of a large slit in the Enclosure. Also in this position, the Enclosure provides wind protection, ventilation, and air circulation to create optimum observing conditions for nighttime astronomical observations. The Enclosure is connected to the Support Building through the use of a bridge with embedded floor rails on the observing floor. The rails allow the mirror to be transported to the Support Building for washing and aluminizing.

Equipment at the Enclosure includes a jib crane and a secondary mirror access platform. The 5-ton jib crane is located near the top of the Enclosure and is utilized to lift heavy equipment on the observing floor or telescope maintenance. The secondary mirror access platform is provided to access the secondary mirror for maintenance and is also equipped with a mechanism to remove the secondary mirror if necessary.

The Enclosure Base serves as a foundation and stationary floor for the rotating Enclosure. Along with providing a stationary floor at the observing level, multiple functions are provided at grade level. These functions include a Spectrograph Room, Entrance Lobby, Toilet, Janitor’s Closet, and vertical circulation. The Spectrograph Room is capable of housing two optical benches for instruments, and requires a dedicated HVAC system to maintain a constant temperature.

Materials used for the construction of the TSPM have been chosen for their performance as well as their availability in Mexico. The Enclosure and Enclosure Base are clad with insulated metal wall panels which provide thermal performance and moisture control. The panels consist of a galvanized steel face with polyisocyanurate foam-insulated core. The rotating portion of the Enclosure is faced with adhesive aluminum foil tape, which allows for the optimization of the thermal characteristics of the Enclosure, and minimizes emissivity.

Architectural seals are provided between stationary and moving building components. The main function of seals is to protect the interior environment from a wide range of environmental conditions such as water, air, light, and dust. Seals are positioned for ease of adjustment, maintenance, and replacement. Two layers of seals will be provided. The first seal stops high wind, light and most precipitation from entering the building. The second seal keeps out moisture.



1.1 Spectrograph Room

1.2 Entrance Lobby

1.3 Toilet Room

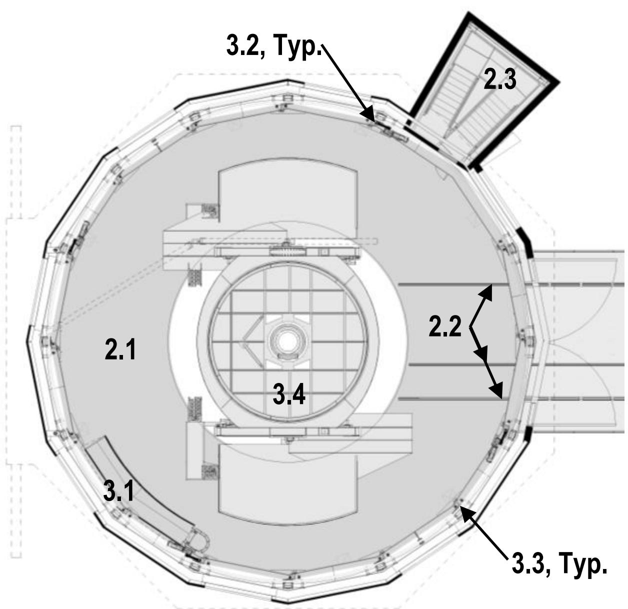
1.4 Janitor's Closet

1.5 Enclosed Access to Support Building

1.6 Telescope Pier

1.7 Telescope Pier Skirt

Figure 5.1.1 Enclosure Floor Plan – Ground Level



2.1 Stationary Observing Level Floor

2.2 Floor Rails to Support Building

2.3 Stairs

3.1 Secondary Mirror Access Platform

3.2 Azimuth Drive Bogie, Typical of 4

3.3 Azimuth Idler Bogie, Typical of 12

3.4 Telescope

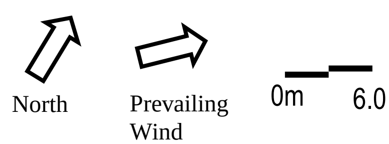


Figure 5.1.2 Enclosure Floor Plan – Observing Level

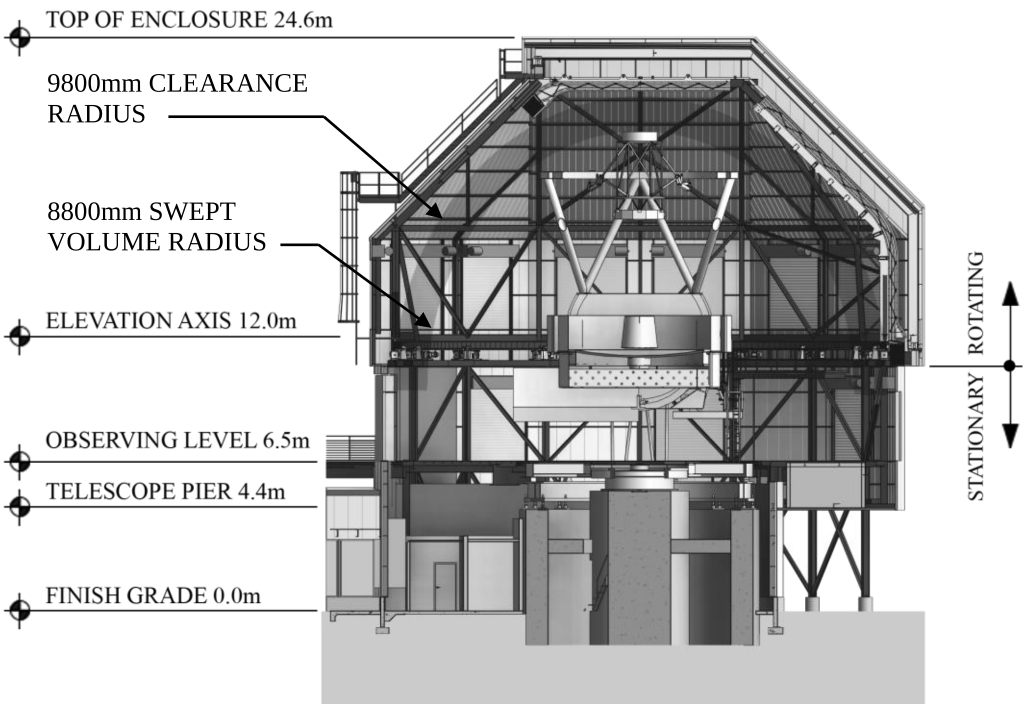


Figure 5.1.3 Enclosure Section Perspective

6. SUPPORT BUILDING

6.1 Support Building Overview

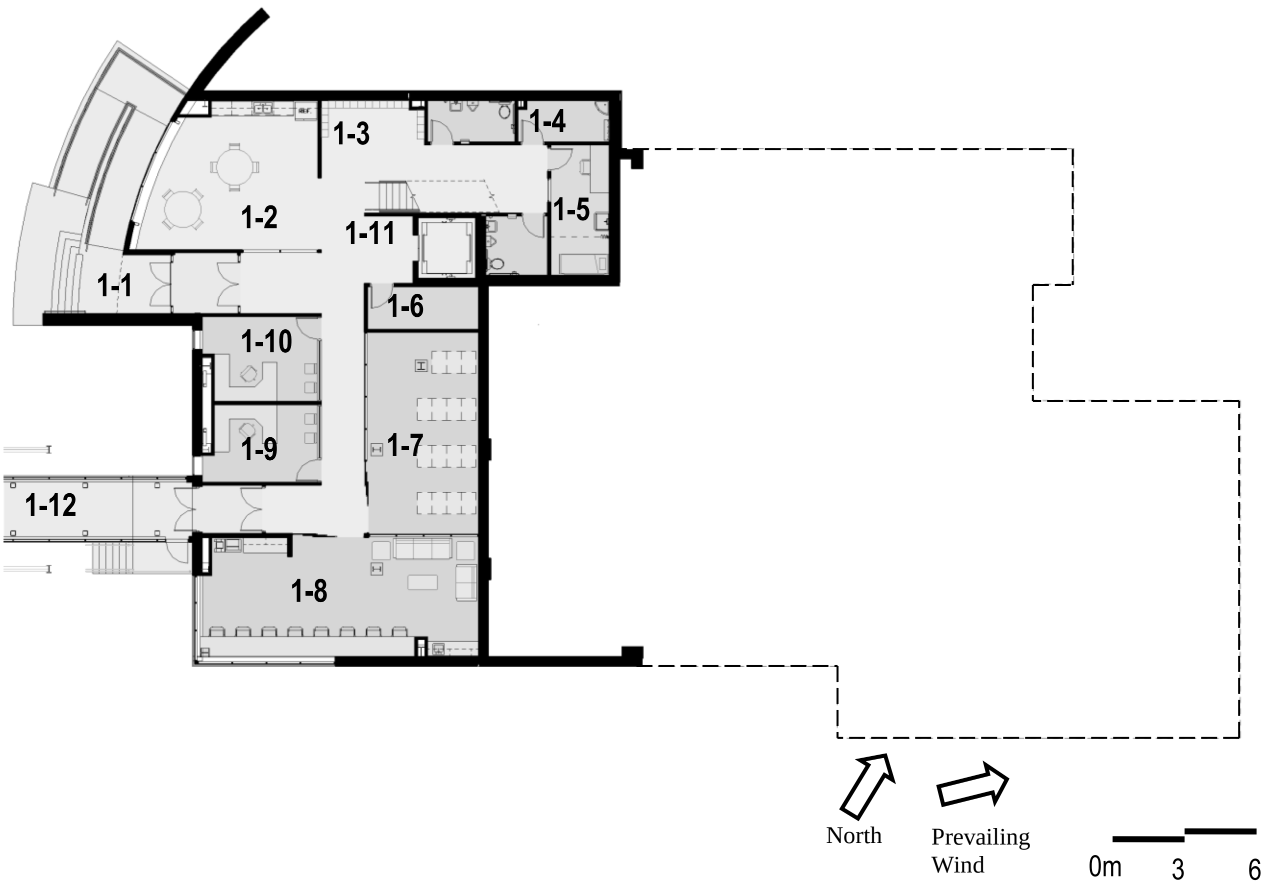
The support building houses telescope related activities, utilities infrastructure, and personnel related functions and is located adjacent to, and downwind from, the enclosure building. Telescope related activities and the utilities infrastructure are located on the upper level, while personnel spaces are located on the lower level. The support building is connected to the enclosure via the utilization of a bridge with embedded floor rails for the transportation of mirror cells at the upper level. An enclosed walkway, below the bridge, is also provided for the movement of personnel on the lower level. The support building can be divided into three categories to better understand the functional and space requirements. The three categories are Telescope Related Activities, Utilities and Personnel Related Functions.

Telescope related activities are housed on the upper level of the support building. This level shares the same elevation as the enclosure observing level. This facilitates the movement of mirror cells between the two buildings via a pair of embedded floor rails. Three large bays are provided for mirror washing, mirror coating, and an instrument lab. The first bay is for mirror washing, and will provide space for a traveling wash platform above. The second bay is for mirror coating, and provides for the permanent placement of a high vacuum sputtering system. This system is used to deposit high-reflectance aluminum films on the primary and secondary mirrors. The third bay provides an open space for instrument assembly and maintenance. A clean room, with vestibule, is also provided adjacent to this bay. To support the washing and coating activities, a dedicated room is provided to house equipment and controls for these activities.

The utilities infrastructure for the entire site is located on the upper level of the support building. Dedicated rooms are provided for telescope and Owner furnished equipment, mechanical equipment, and electrical equipment. These spaces are located as far as possible from the Enclosure to reduce heat and vibration that would be detrimental to telescope operations. Ancillary space is also provided for tool storage, a janitor’s closet, and miscellaneous storage. Exterior to the utility spaces, and further downwind, is the exterior mechanical and electrical equipment. This includes the electrical service entrance, transformer, switchgear, and fluid coolers.

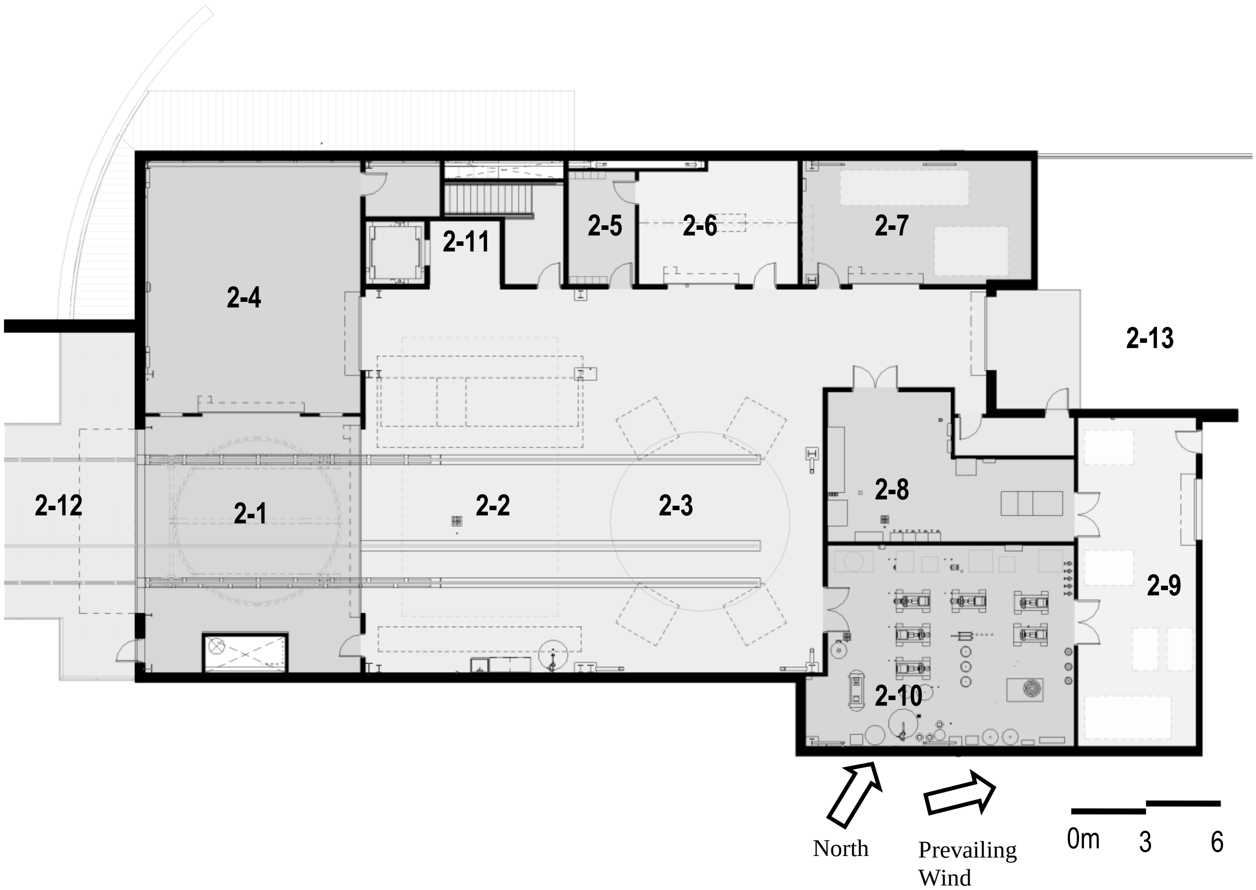
Personnel related functions are housed on the lower level of the support building. These spaces are those frequently occupied by TSPM staff and astronomers. An open control room with countertop space is provided near the access corridor to the enclosure, and provides windows for views directly to the enclosure. Supporting the control room is the computer room. The computer room will store the astronomers' data, and is supported by an independent cooling system specifically designed to promote air movement around the computer racks. The space will be designed with maximum flexibility to allow ease of expansion and future modifications. Observers will also have a dedicated lounge space with a small kitchenette and tables for eating and/or conference functions. Two private offices will be provided along with other ancillary spaces such as a health room, toilets, IT room, and a storage room. Vertical circulation to the upper level of the support building is provided via stairs. Access to the enclosure is provided through an enclosed walkway that provides personnel with a protected space to move between the two buildings in the event of a storm or detrimental weather conditions.

6.2 Enlarged Floor Plans



1-1	Support Building Main Entrance	**1-7**	Computer Room
1-2	Break Room	**1-8**	Control Room
1-3	Lockers	**1-9**	Office No. 1
1-4	Janitor's Closet	**1-10**	Office No. 2
1-5	First Aid Room	**1-11**	Vertical Circulation
1-6	I.T. Room	**1-12**	Enclosed Access to Enclosure

Figure 6.2.1 Support Building Enlarged Floor Plan – Lower Level



2-1	Mirror Vestibule	**2-8**	Electrical Room
2-2	Mirror Washing	**2-9**	Telescope Equipment Room
2-3	Mirror Coating	**2-10**	Mechanical Room
2-4	Instrument Storage	**2-11**	Vertical Circulation
2-5	Clean Room Vestibule	**2-12**	Bridge to Enclosure
2-6	Clean Room	**2-13**	Upper Level Entrance and Ext. Equipment
2-7	TSPM Equipment Room		

Figure 6.2.2 Support Building Enlarged Floor Plan – Upper Level

7. ENCLOSURE STEEL DESIGN

The Enclosure and Enclosure Base are designed using a steel structure, following the same principles used for the Magellan Observatories with variations to accommodate a revised elevation, Telescope plan dimensions according to the requirements of TSPM and, the local steel shapes available for the project. See Figure 7.1 for a rendered representation of the structural analysis model of the Enclosure and Enclosure Base. In addition, the structure has been updated to incorporate the design requirements from the TSPM site as well as the current building code requirements, which are more stringent for this structure than those placed upon the Magellan design.

The Enclosure and Enclosure Base model have been analyzed using a tridimensional structural model that incorporates all gravity as well as the lateral loads determined by site conditions. Using this model, deformations as well as maximum stresses have been compared to those allowed by the building codes that govern this project. See Figures 7.1 and 7.2

The Enclosure Base incorporates the use of Ordinary Concentric Braced Frames, with a seismic response modification factor R of 3.25 per ASCE 7-05. The Enclosure follows a similar detailing philosophy to resist the lateral loads imposed by wind and seismic conditions. This lateral force resisting system is considered appropriate for this project, however if lower level of seismic risk is required, then a lower R value will be required while maintaining a ductile design as required for high seismic resistance.

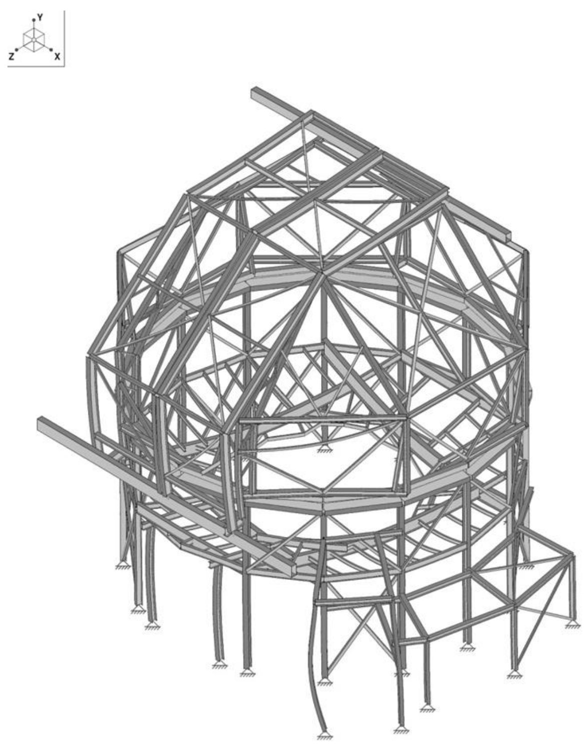


Figure 7.1 – Enclosure Model Deformation under "Dead+.75Wind+.75Live+.75Snow" Load Combination. (Magnified a factor of 20)

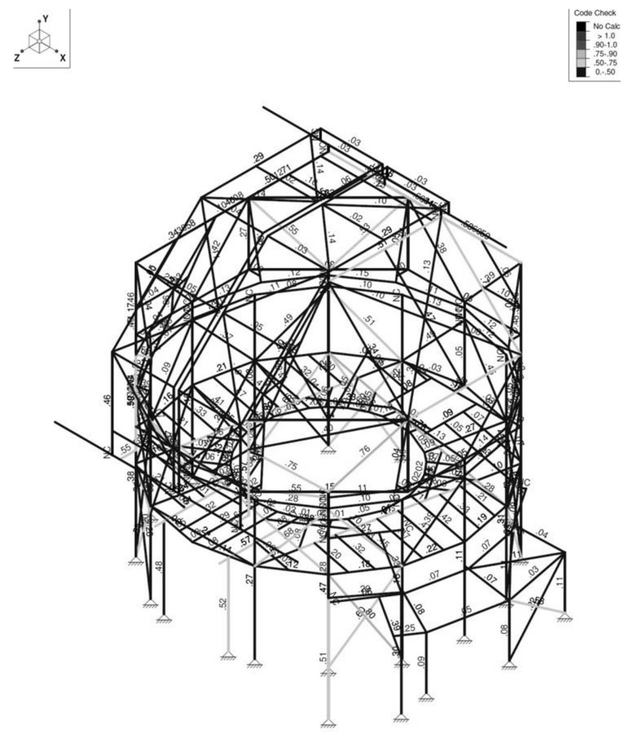


Figure 7.2 – Enclosure Model Envelope of the Bending Stress Ratios on members.

8. TELESCOPE PIER

The Telescope Pier is a cylindrical concrete structure that supports the Telescope vertically and laterally. The Telescope Pier is composed of two concentric walls and a horizontal slab. The exterior wall provides support for the vertical reactions from the Telescope through the Azimuth Track and, the interior wall provides lateral support of the Telescope against Seismic forces. In addition, the Telescope Pier provides access to the Telescope bearings as well as instrumentation and is a vital part in the maintenance operations' access.

The current model of the Telescope Pier has been derived using the model used for the Magellan Observatories as a genesis of design, with variations to accommodate a revised elevation and Telescope plan dimensions according to the requirements of TSPM. See Figure 8.1 for a rendered representation of the Telescope Pier.

The Telescope Pier model has been analyzed on a volumetric finite element model to determine the frequencies and dynamic modes, including a set of springs to represent the soil-structure boundary condition and a set of eight highly-rigid and mass-less bars to represent the link between Telescope and Pier. These bars have the releases to transfer the forces to the concrete walls as described lines above. See Figure 8.2 for a pictorial of the Finite Element Model used.

Given that the project geotechnical report depicts a transition zone around the 3 meters, at a Preliminary level of design has been determined prudent to model the soil structure interaction for two moduli of subgrade reaction values as a lower and upper boundary cases. The frequencies obtained from the dynamic analysis are presented on Tables 8.1 and 8.2. These values fall within the expected frequencies for similar structures and as can be seen the modulus of subgrade reaction has an important influence in the frequencies. Furthermore, the stiffness and mass moment of inertia of the Telescope will have influence in the dynamic behavior of the Pier. These values are expected to be incorporated as the Telescope design is advanced in the following stages.

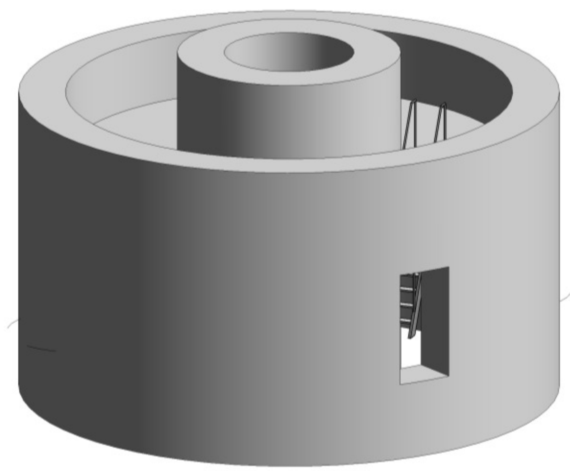


Figure 8.1 – Telescope Pier Model Isometric.

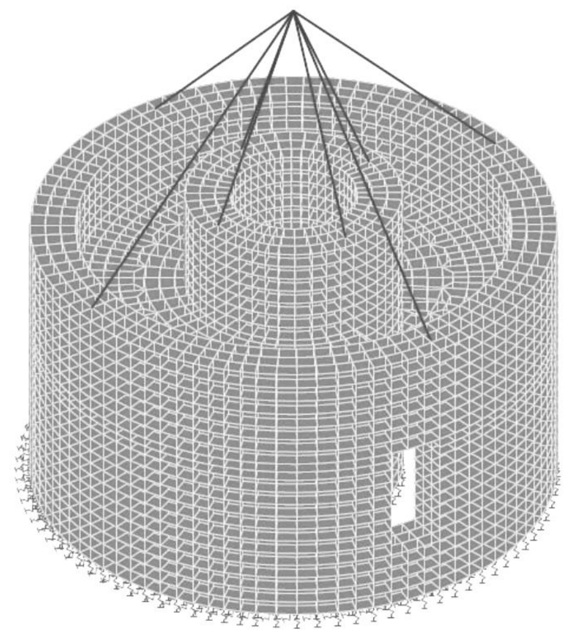


Figure 8.2 – Telescope Pier Model Finite Element Model Isometric.

Table 8.1 Frequencies for case with Modulus of Subgrade Reaction of 1000 MPa

Mode	Frequency (Hz)	Period (Sec)	Mass Participation			Mode Description
			SX	SY	SZ	
1	5.76	0.174	44.926		28.416	Rocking about Z
2	5.78	0.173	28.45		45.129	Rocking about X
3	11.403	0.088				
4	15.75	0.063	6.948		16.185	Rocking about X
5	15.953	0.063	16.65		6.909	Rocking about Z
6	16.408	0.061	0.012		0.205	
7	28.964	0.035	0.013		0.02	
8	29.621	0.034	1.292		1.293	
Totals:			98.3		98.157	

Notes:

Based on 1000 MPa modulus of elasticity (E) and considering outer pier supports axial (vertical) forces, while inner pier supports radial (horizontal) forces. Bottom of Pier is considered to be 3m below grade.

Table 8.2 Frequencies for case with Modulus of Subgrade Reaction of 6000 MPa

Mode	Frequency (Hz)	Period (Sec)	Mass Participation			Mode Description
			SX	SY	SZ	
1	10.954	0.091	37.152		22.507	Rocking about Z
2	11.104	0.09	23.263		37.456	Rocking about X
3	23.552	0.042	7.995		17.659	
4	23.917	0.042	5.776		0.408	
5	24.163	0.041	14.985		11.209	
6	26.255	0.038	0.017		0.011	
7	46.065	0.022			0.025	
8	49.277	0.02	4.95		2.403	
Totals:			94.139		91.677	

Notes:

Based on 6000 MPa modulus of elasticity (E) and considering outer pier supports axial (vertical) forces, while inner pier supports radial (horizontal) forces. Bottom of Pier is considered to be 3m below grade.

Currently, the ratio of the Telescope Pier mass to the Telescope mass is 4.9 to 1 which tells us that the Pier is robust in mass. As the design progresses into the following stages, a refinement of the material quantities will be carried, including the stiffnesses of the other components as well as the target frequency and dynamic modes considered of importance.

9. MECHANISMS

9.1 Mechanisms Design Philosophy

The basis-of-design for the *Telescopio* San Pedro Mártir (TSPM) utilized the Magellan 6.5 Meter Telescope Project (Magellan). The Magellan design is a proven design, with simple reliable construction incorporating standard industry practices.

Assemblies have been designed to facilitate ease of maintenance and accessibility through the following methods:

- Limiting extraneous weights
- Sizing the components to assemble into manageable pieces
- Identifying component lifecycles
- Identifying maintenance requirements
- Allocating adjacent floor space to allow maintenance and accessibility

Repeatability in weldment design and component selection is incorporated. The use of off-the-shelf components is maximized as much as practical.

9.2 Azimuth Rotation Mechanisms

9.2.1 Design Requirements

The rotation mechanism shall comply with the following specifications:

- Maximum rotation speed of 3 degree per second (3°/sec)
- Minimum rotation speed of 0.03 degree per second (0.03°/sec)
- Rotation stop in less than 5 seconds in case of emergency
- Acceleration rate of 0.4 degrees per second per second (0.4°/sec2)
- Wind Speeds
  - Maximum operational wind speed of 60 kilometer per hour (37 mph)
  - Maximum operational gust wind speed of 80 kilometer per hour (50 mph)
  - Survival wind speed of 175 kilometer per hour (110 mph)

The rotation mechanism shall comply with the following requirements:

- Sustain all imposed vertical loads
  - Dome structure, equipment, and shutter weight for normal operations.
  - Dome structure, equipment, shutter, snow and ice weight for survival conditions.
- Sustain all imposed horizontal loads
  - Zero, normal and maximum wind speeds for normal operations.
  - Survival wind gust speed for survival conditions.
- Unlimited rotation in any rotation direction
- Provide easy alignment and adjustment of mechanism during erection
- Provide for maintenance access
- All parts shall be protected against corrosion

9.2.2 Rotation Mechanism Design

The rotation mechanisms shall consist of 16 equidistantly spaced fixed bogie assemblies mounted to the fixed structure of the dome enclosure.

9.2.3 Bogie Weldments

Bogie weldments shall be of all welded construction. Bogie weldments shall be provided with flexure plates and Fabreeka spring blocks for vertical load fluctuation support. Horizontal load fluctuation support is provided through shoulder bolts mounted in slotted holes. Permanent and removable adjustment blocks and jack screws are provided on bogie weldments for alignment and positioning of truck wheels, drive units and restraints to required tolerances. A drive force reaction constraint is provided on drive bogie assemblies.

9.2.4 Idler Bogies

Each idler bogie assembly consists of a single fabricated truck wheel, truck shaft, shaft thrust washers and piloted flange bearings mounted onto the bogie weldment designed to withstand the loads imposed for operating and survival conditions.

9.2.5 Drive Bogies

Four bogie assemblies shall be provided with gearmotor units driving chain and sprocket assemblies for azimuth rotation. Drive bogie assemblies are similar in design to idler bogie assemblies with extended truck shafts to accommodate gear sprockets.

The four drive bogie assemblies shall be provided with 10 horsepower (7.5 kilowatt) gearmotor units. Based upon the current design level of structural steel and mechanical design components, this gearmotor unit is required to be larger than the 7.5 horsepower (5.6 kilowatt) gearmotor used for Magellan.

Based upon a potential over-heating of gearmotor components, each unit will require an auxiliary, non-shaft driven fan unit. The temperature of exposed surfaces of gearmotors shall not be higher than 4 degrees Celsius above ambient temperature during telescope operation, assuming a constant rotation speed of 0.2 degrees per second and maximum speed rotation speed for 180 degrees rotation every half hour. To accomplish this temperature requirement, additional cooling of motor housing should be provided by insulation or chilled liquid cooling.

Gearmotor units shall be provided with electromagnetic brakes to stop the dome rotation. Brakes will engage automatically in case of power failure. Gearmotor encoders shall be provided to indicate azimuth position and rotation speed. Gearmotor speed shall be controlled by adjustable frequency drives (AFDs).

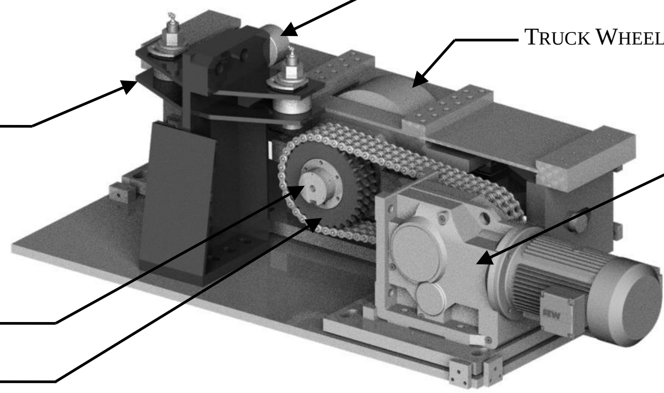


Figure 9.2.5.1 Drive Bogie Model

9.2.6 Rotation Mechanism Uplift and Lateral Restraints

Weldments bolted at each bogie shall provide mounting locations for uplift and lateral restraint blocks and rollers. Uplift restraints shall be cam followers mounted in blocks sized to accommodate survival uplift loads. Lateral restraints shall be cam yoke roller bearings mounted in blocks sized to accommodate survival lateral loads.

9.2.7 Position Encoders

Position encoders shall be provided to ensure synchronization of the azimuth movement with the telescope movement. Gearmotor encoders shall be provided with each drive bogie to indicate azimuth position and rotation speed. Control software will be utilized to ensure synchronization.

9.3 Windscreen

The enclosure shall be provided with a windscreen to protect the telescope from excessive wind during observations. The windscreen shall be located inside the enclosure structure within the observation opening (see figure 9.3.1). When not in use, the windscreen shall be folded and stored in a dedicated recess at the bottom of the observation opening. The windscreen operation shall be limited to operating wind speed conditions.

The windscreen maximum elevation shall be below the horizontal roof of the enclosure. The windscreen shall consist of rigid, hinged, aluminum, honeycomb panels. The windscreen shall be able to be raised or lowered, fully or partially. The operating mechanism for the windscreen shall consist of a chain and sprocket drive with guide rollers located within a U-shaped channel to maintain necessary windscreen orientation.

Limit switches and gearmotor encoders shall be used to indicate position of the windscreen. Limit switches will be located as a minimum at the extreme operation limits (full open, full closed). The windscreen shall be electrically bonded to the structure of the dome.

9.4 Moonroof

The enclosure shall be provided with a moonroof to protect the telescope for stray light during observations. The moonroof shall be located in the roof of the enclosure structure within the observation opening (see figure 9.4.1). When not in use, the moonroof shall be folded and stored in a dedicated recess at the back of the observation opening and shall fully clear the observation opening when stored. The moonroof operation shall be limited to operating wind speed conditions.

The moonroof shall cover the entire horizontal opening in the observation opening. The moonroof maximum extension shall be to the end of the horizontal roof of the enclosure.

The moonroof construction shall be similar to the construction of the windscreen.

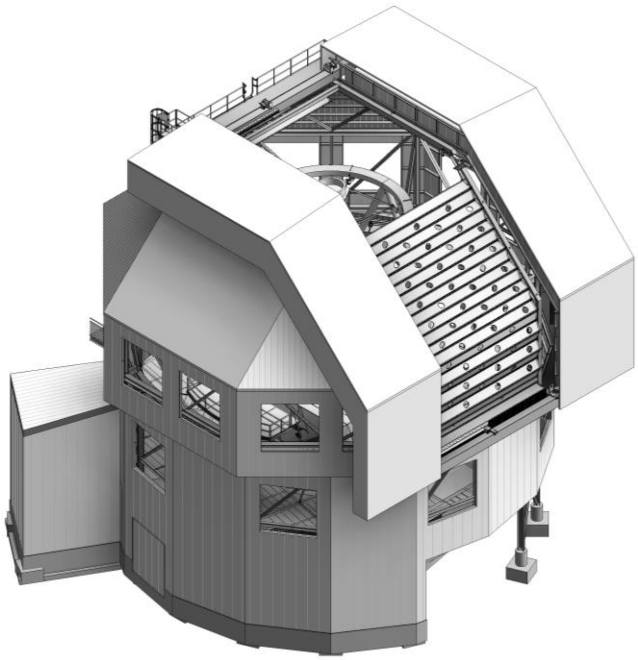


Figure 9.3.1 Enclosure building showing windscreen

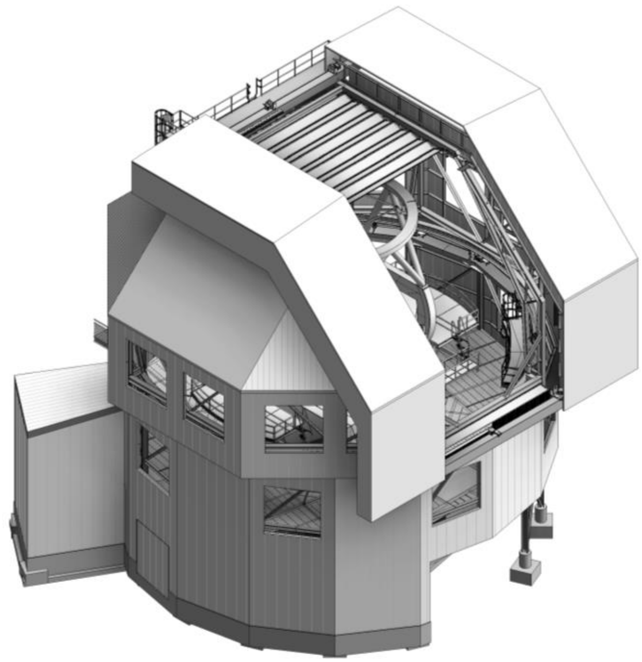


Figure 9.4.1 Enclosure building showing moonroof

9.5 Circular Bearing Ring

A Circular bearing ring shall be provided at the bottom of enclosure dome structural ring beam. The circular bearing ring shall be concentric with the telescope azimuth axis within tolerances defined for operation of the dome drive and idler bogies. The required planarity, circularity, and deformation tolerances of the underside of this ring shall be determined as a function of the selection of the rotation mechanism, the loads experienced and the rotation requirements of the dome. The ring shall be smooth to minimize the wearing away of the bogie wheels.

9.6 Shutter Mechanisms

9.6.1 Design Requirements

The shutter mechanism shall comply with the following specifications:

- Shutter open/close maximum time 2 minutes
- Wind Speeds
  - Maximum operational wind speed 60 kilometer per hour (37 mph)
  - Maximum operational gust wind speed 80 kilometer per hour (50 mph)
  - Survival wind speed 175 kilometer per hour (110 mph)

The shutter mechanism shall comply with the following requirements:

- Independent operation of each shutter.
- Sustain all imposed vertical loads
  - Shutter weight for normal operations.
  - Shutter, snow and ice weight for survival conditions.
- Sustain all imposed horizontal loads
  - Zero, normal and maximum wind speeds for normal operations.
  - Survival wind gust speed for survival conditions.
- Provide for maintenance access
- All parts shall be protected against corrosion

9.6.2 Shutter Mechanism Design

The shutter mechanisms shall consist of bogies, drive assemblies (gearmotor, reduction gearboxes, shafting, and shafting support bearings), rack and pinions, uplift and lateral restraints, and over travel stops.

9.6.3 Bogies

Four shutter bogies shall be provided for each shutter, one at each upper corner and one at each lower corner. Shutter bogie weldments shall be of all welded construction. Each weldment shall support one flat faced, crane type wheel with internal bearings and wheel shaft. Permanent adjustment blocks and jack screws are provided on bogie weldments for alignment and positioning of bogie wheels and restraints to required tolerances. Bogies shall travel along structural steel beams sized to allow full movement of shutter to open position.

9.6.4 Drive Assemblies

Each shutter drive assembly shall be provided with gearmotor units driving shafting to operate drive pinions located at the upper and lower shutter ends. Shafting shall follow the geometry of the enclosure arch girders through a series of bearing supports, couplings and universal joints. A reduction gearbox shall be located at the end of each shaft (upper and lower) driving the pinion to operate the shutter.

Each shutter drive assembly shall be provided with 5 horsepower (3.7 kilowatt) gearmotor units. No auxiliary cooling will be required due to use of reduction gearing. An emergency, manual operator hand wheel shall be provided for each gearmotor for use in case of loss of power.

Gearmotor units shall be provided with electromagnetic brakes to stop the shutter movement. Brakes will disengage automatically in case of power failure. Gearmotor encoders shall be provided to indicate shutter position and speed. Gearmotor and reduction gearbox adjustments position adjustments have been provided.

9.6.5 Rack and Pinion

Rack gear shall be provided along the upper and lower shutter length. Rack gear shall be mounted on a steel structural member to allow shimming and alignment adjustment to ensure proper engagement with pinion gear. Matching pinion gear shall be driven through gearboxes located at upper and lower edges of shutter.

9.6.6 Shutter Uplift and Lateral Restraints

Weldments bolted onto the shutter door structure near both upper and lower bogies shall provide mounting locations for uplift and lateral restraint rollers. Uplift and lateral restraints shall be cam yoke roller bearings mounted on plates sized to accommodate survival uplift loads.

9.6.7 Over Travel Stops

Over travel stop weldments shall be mounted to both the upper and lower shutter beams, at the extreme open travel limits of the shutters. A total of four over travel stop weldments shall be provided, one at the end of each shutter beam. The over travel stop weldments shall include bumpers and stop bolts. A proximity switch shall also be provided for each over travel stop weldment on the lower shutter beam.

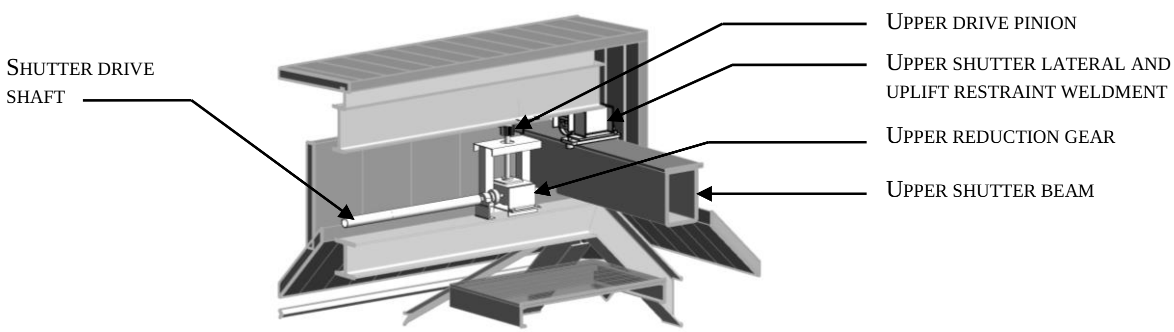


Figure 9.6.1 Upper Shutter Drive

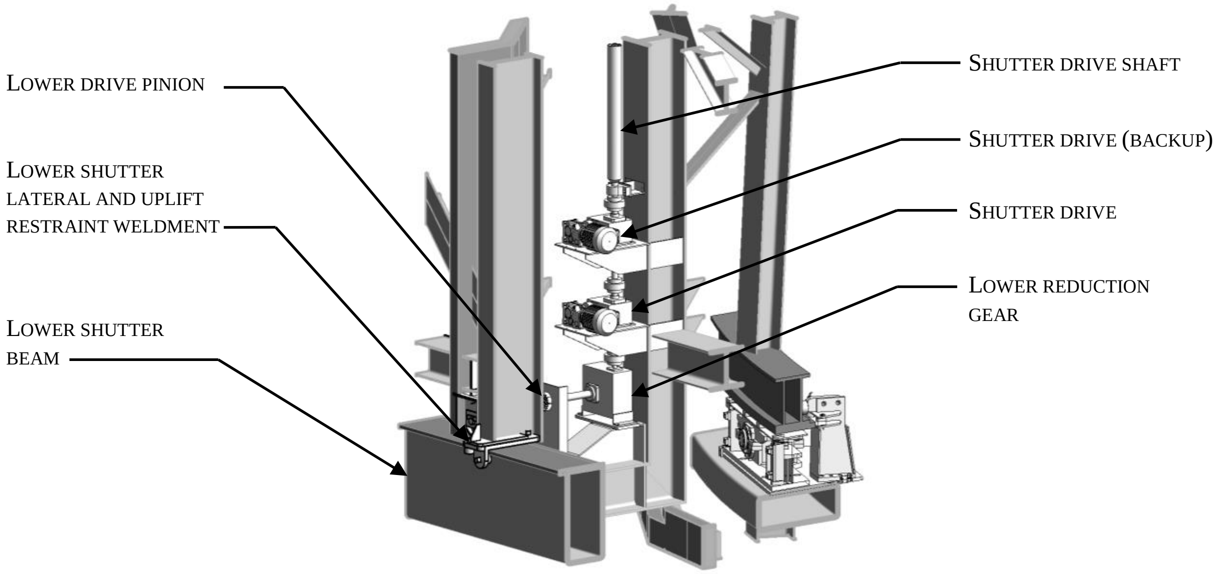


Figure 9.6.2 Lower Shutter Drive

9.7 Enclosure Thermal Control System

The TSPM will utilize both active and passive thermal control systems to ensure optimum observing conditions. These conditions are ensured when the surfaces of the telescope and enclosure have a temperature identical to the predicted ambient nighttime observing temperature. Active thermal control systems include air conditioning the inner volume of the closed Enclosure during the daytime. Passive thermal control systems include reducing the daytime heat input through the utilization of insulated wall panels and architectural seal systems.

The active air conditioning thermal control system will consist of multiple fan-coil units placed on the underside of the Enclosure observing level floor. Conditioned air will be ducted from the fan-coils through the observing level floor into the Enclosure. The ducting will be arranged in a manner to encourage homogenous mixing and minimum temperature stratification within the Enclosure. The fan-coil units will use chilled water supplied from outside the building and no heat from the units will be dissipated into the Enclosure. Based upon the system sizing calculations performed for the TSPM, four units having a nominal capacity of 6 tons (21 kW) each may be provided to achieve proper thermal control.

The fan-coil units will be served with a low-temperature chilled water solution (also known as “brine”) circulated from chillers located at the Support Building. The chillers will be located outside the Support Building and downwind from the Enclosure. The brine is anticipated to be a mixture of propylene glycol and water, with the proportions depending on the coldest anticipated temperature. Propylene glycol is preferred over ethylene glycol for environmental reasons. The chiller will need to provide brine at a temperature low enough to maintain the dome at the anticipated evening temperature. In the winter season, this may be as low as -15°C, so the brine may need to be -20°C. This is lower than standard HVAC systems operate, so a special low-temperature chiller may be needed. In some cases, this low-temperature chiller must be cooled by a separate air-cooled chiller producing brine at a temperature of ~ 7°C.

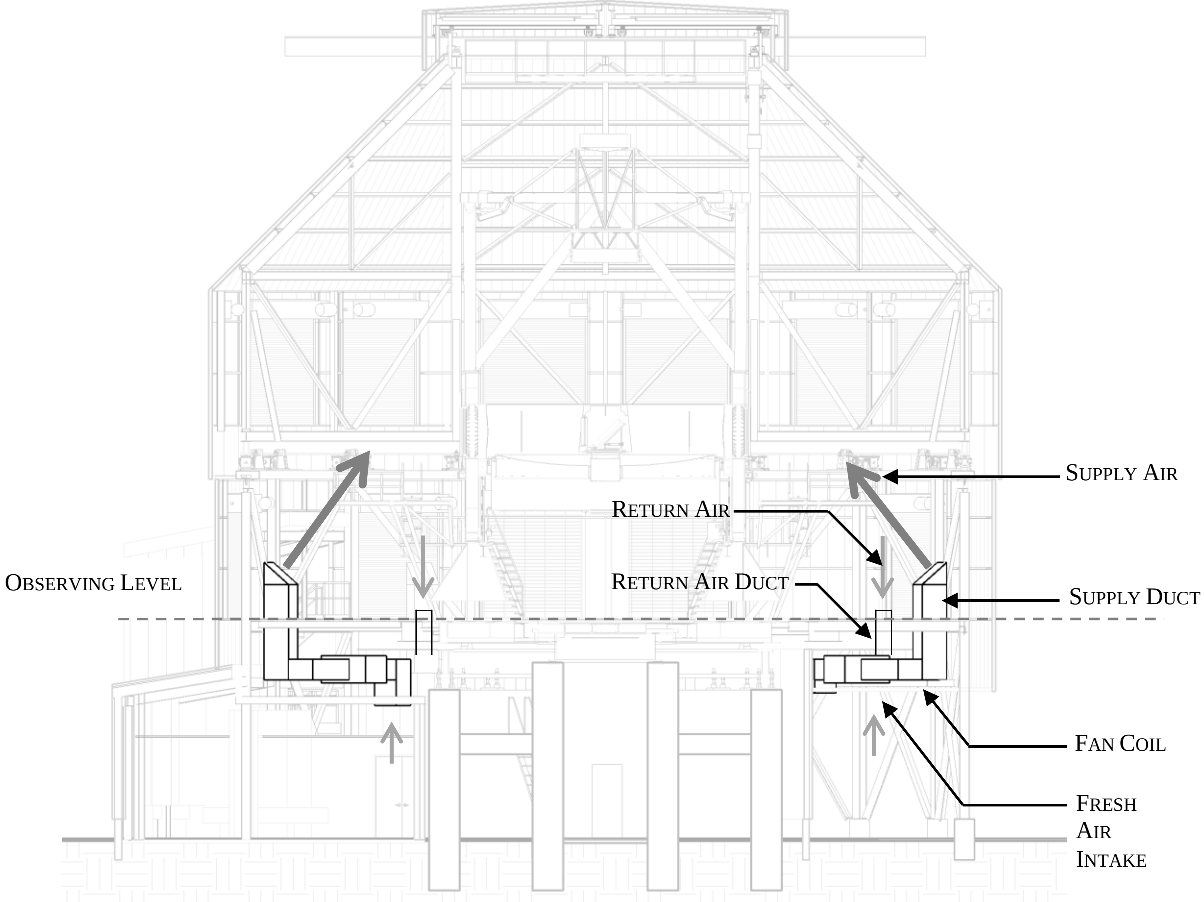


Figure 9.7.1 Fan Coil Profile Section

The passive thermal control systems will consist of insulated metal wall panels and architectural seal systems to reduce daytime heat input. The insulated wall panels consist of galvanized metal skins with foamed-in-place polyisocyanurate insulation. The joints are tongue and groove with interlocking rain screens to provide air tightness, low thermal bridging, and high thermal performance. Architectural seal systems protect the interior environment from a wide range of environmental conditions such as water, air, light, and dust. Two layers of architectural seals will be provided at all locations, reducing outside air infiltration.

A cooling load evaluation was performed for the TSPM. The Enclosure was modeled in Carrier's HAP (Hourly Analysis Program) software to evaluate the cooling load due to environmental effects. No equipment heat loads were included as they are assumed to be minimal and are unknown at this time. The dome was evaluated using two different insulation thicknesses. The first case (Case No. 1) was using wall and roof panels of 100mm thickness. The second case (Case No. 2) was using wall and roof panels of 75mm thickness. In each case, the manufacturer's overall R-value was derated by 17% to account for some thermal bridging at fasteners and joints.

In Case No. 1, the 100mm thick insulated wall panels are listed by the manufacturer as having an Rsi-value of 1.3 / 25mm, or Rsi-5.3 in the case of 100mm panels. This value was derated to Rsi-4.4 for the purposes of calculating the cooling loads. The 100mm thick insulated roof panels are listed by the manufacturer as having an Rsi-value of 5.8. This value was derated to Rsi-4.7 for the purposes of calculating the cooling loads. The dome cooling load was estimated to be 23.0 tons, or 80.9 kW of cooling delivered.

In Case No. 2, the 75mm thick insulated wall panels are listed by the manufacturer as having an Rsi-value of 1.3 / 25mm, or Rsi-3.9 in the case of 75mm panels. This value was derated to Rsi-3.0 for the purposes of calculating the cooling loads. The 75mm thick insulated roof panels are listed by the manufacturer as having an Rsi-value of 4.2. This value was derated to Rsi-3.5 for the purposes of calculating the cooling loads. The dome cooling load was estimated to be 23.9 tons, or 84.0 kW of cooling delivered.

Due to the negligible difference between the cooling requirements of the two siding thicknesses, a 75mm thick panel will be used as the basis-of-design. Note that these values are calculated loads. Nominal equipment capacities will be higher, as the equipment must be derated for service at altitude, to account for motor heat, inefficiencies, and internal heat generated by telescope equipment.

9.8 Enclosure Ventilation

During nighttime viewing, the Enclosure will be ventilated to optimize observing conditions. Ventilation will be accomplished through vertical openings on the Enclosure walls, allowing the Enclosure volume to be continually ventilated and flushed with nighttime temperature air. The doors will be individually activated to allow adjustment between fully open and closed positions depending on wind direction relative to the opening of the observing slit doors, wind speed, and the exterior and interior temperatures.

The ventilation doors will be insulated coiling roll-up steel doors. These doors are available "off-the shelf" and have a proven track record in observatory design. All doors will be a common size, 3.0m x 3.0m, and will be installed on both the fixed and rotating enclosure walls that share in the common Enclosure volume. The current design incorporates 23 ventilation doors, for a total open area of 207m^2. The number of doors can be increased or decreased based upon a further review of the Enclosure ventilation requirements.

The ventilation doors will be designed to withstand survival wind pressures and survival seismic requirements. The doors slats will be filled with expanded polystyrene foam to reduce heat buildup within the Enclosure. Weather stripping will be provided around all perimeters to reduce air and dust infiltration. All doors will be motor operated and designed to meet maximum open and close times as defined by the project requirements.

10. BUILDING INFORMATION MODELING

10.1 What is BIM?

Building Information Modeling is the integration of related building data systems throughout the entire project lifecycle. Contrary to common belief – Building Information Modeling is not limited to the selection of any particular engineering or design software package, nor is it limited to the design, engineering and detailing phases of projects. The intent in its abstract form is to integrate design, construction, operation and maintenance information across the lifespan of the building so that no data is ever duplicated. In addition, each portion is integrated in a manner such that each component acts as a contributing piece of a complete, integrated Building Information Model (redundantly named as "BIM model.")

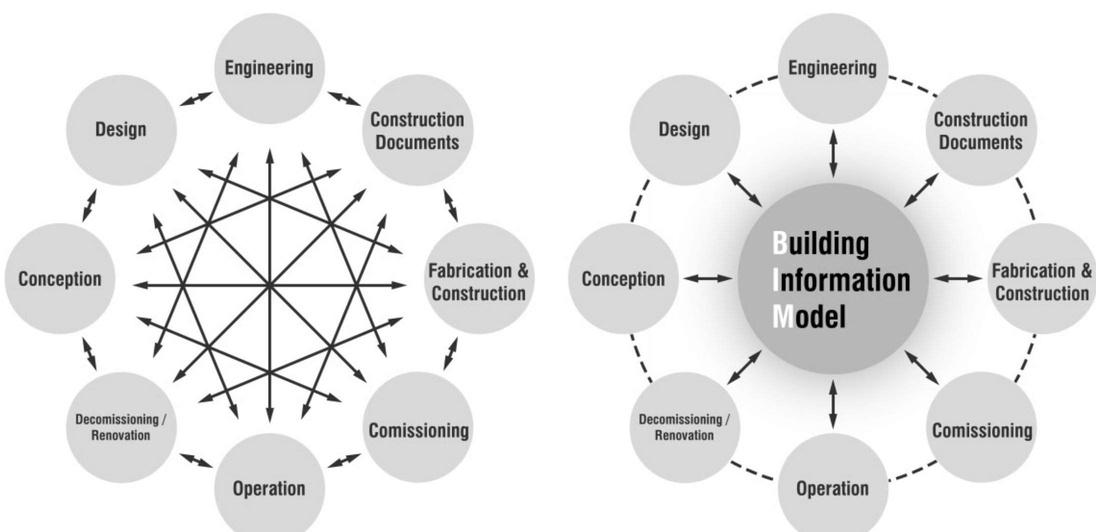


Figure 10.1.1 Topological comparison of traditional v. BIM workflows

10.2 Implementation of BIM on the TSPM Project

By utilizing Autodesk Revit, building models update in real time with the latest information and the chance of drawing misinterpretation is greatly reduced. Not only is 3D information introduced, but the time duration and data behind model elements is embedded into the model as well and is readily available by members of the design team working in separate disciplines and software packages.

In the current (preliminary) phase of design, Revit is predominantly used to author model geometry and metadata while also being used to consolidate design geometry from various programs such as Inventor and Solidworks. Revit is used to generate drawings for documentation and review purposes, material take-offs, perform quantified material analysis used to analyze dome seeing performance and provide rapid feedback of material costs associated with select components. It is important to recognize that Revit at its core is a relational database of model geometry and data – this means that the 3D model, 2D drawings, schedules, views and other model products are viewing the same information in real-time and therefore cannot be out of date from one another so long as they exist within the program. Changing an item on a schedule changes that item everywhere within the model instantly, whether it's 3D information, 2D drawings or other downstream uses of the model.

While Revit plays a major key-role at M3 during the design phase of the project, A BIM model does not necessarily reside in any particular program or set of files; it is a shared modeling and data philosophy that can be linked across many platforms and packages, not just those suitable for solid modeling and content authoring (e.g. Revit, Inventor and Solidworks).

In later phases of the design, the model will continue its flow into Trimble Tekla for macro-driven structural detailing without manual transposition of information required.

One of the most fundamental benefits of adding various models into one location is the ability to run clash detecting analysis between them. Navisworks is used for the automatic and detailed reporting of various collisions between models - it can link together various model formats including but not limited Revit, Inventor, Solidworks, Microstation, Catia, Creo, numerous open file formats pertinent to solid and surface modeling as well as 3D point clouds. Bringing models together from all aspects of the project including telescope and building systems provides detailed coordination capabilities which ensure that no major oversights exist in terms of space allocation. Common examples include ensuring that piping and ductwork stay clear of building structure, doors and openings are kept clear of structural braces, and adequate working clearances are provided around equipment along with various swept volumes pertinent to telescope operation.[4]

Figure 10.2.1 Overall Exterior view of *Telescopio* San Pedro Mártir, computer rendered.

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