PROCEEDINGS OF SPIE

SPIEDigitalLibrary.org/conference-proceedings-of-spie

Mechanical preliminary design of the 6.5-meter Telescopio San Pedro Mártir (TSPM)

Jorge Uribe, Carlos Tovar, Rogelio Manuel, Saúl Rubio, Carlos Ortega, et al.

Jorge Uribe, Carlos Tovar, Rogelio Manuel, Saúl Rubio, Carlos Ortega, German González, Berenice Rodríguez, William Lee, Michael Richer, J. Jesús González, Cesar Martínez, Vicente Bringas, Antonio Estrada, "Mechanical preliminary design of the 6.5-meter Telescopio San Pedro Mártir (TSPM)," Proc. SPIE 10700, Ground-based and Airborne Telescopes VII, 107005U (6 July 2018); doi: 10.1117/12.2313102

Event: SPIE Astronomical Telescopes + Instrumentation, 2018, Austin, Texas, United States

Mechanical preliminary design of 6.5 meter Telescopio San Pedro Mártir (TSPM)

Jorge Uribe* [a], Carlos Tovar [a], Rogelio Manuel[a], Saúl Rubio[a], Carlos Ortega [a], German González[a], Berenice Rodríguez[a], William Lee[b], Michael Richer[b], J. Jesús González[b], Cesar Martínez [a], Vicente Bringas [a], Antonio Estrada[a].

[a] Centro de Ingeniería y Desarrollo Industrial (CIDESI). Playa Pie de la Cuesta 702, Querétaro, México, C.P.76130; [b] Instituto de Astronomía de la Universidad Nacional Autónoma de México (IA-UNAM). Circuito Exterior, área de la Investigación Científica, Ciudad Universitaria, México, Distrito Federal, C.P. 04510.

ABSTRACT

The Telescopio San Pedro Mártir project intends to build a 6.5 meters telescope with alt-azimuth mount and it has currently finished the preliminary design. The project is an association between Instituto de Astronomía de la Universidad Nacional Autónoma de México and the Instituto Nacional de Astrofísica, Óptica Electrónica in partnership with the University of Arizona and the Smithsonian Astrophysical Observatory. The telescope preliminary design this is lead and developed at Querétaro by the Centro de Ingeniería y Desarrollo Industrial. An overview of the preliminary design and the structural design updates are summarized in this paper.

Keywords: Telescope, TSPM, Preliminary Design, Mechanical Design, San Pedro Mártir, 6.5 meters, Visible/Infra-Red, CIDESI

1. INTRODUCTION

The Telescope San Pedro Martir (TSPM) has allocated the design requirements and the design has been updated to fulfill these. It will allow for a similar field of view at the Cassegrain and Nasmyth focal stations of 1 degree; TSPM has a larger distance (3 meter) from the observing floor to the M1 cell in order to accommodate a larger instruments envelope at the Cassegrain focal station.

Initially TSPM will operate with an f/5 Cassegrain station at day one, but the design considers future Nasmyth and folded Cass configurations from a classical f/5 up to a Gregorian f/11. The telescope design includes 7 focal stations: 1 Cassegrain; 2 Nasmyth; and 4 folded-Cassegrain; the design of the telescope has been updated to fulfill the seismic loads for the new code requirements. Also it will include the design to support future configurations where it is necessary to include an M3 cell to feed the Nasmyth and folded Cass ports. Preliminary telescope design consider to have compatible rotators for Nasmyth and Cassegrain focal stations. Preliminary FEM models were performed in order to evaluate structural performance and evaluate it with the error budget. The telescope structure is considered to be mostly manufactured of structural steel, with rotational Eigen frequencies between 9 and 11 Hz depending the optical configuration and the position of the Optical Support System (pointing to horizon or to Zenith). The M1 mirror cell for the 6.5 meter mirror is being developed by the University of Arizona, and it will be integrated at factory to verify the assembly prior to send it to site. The total mass of the TSPM is planned to be below 246000 kg including all instruments mounted on the focal stations and the telescope rotating mass about azimuth axis is 193000 kg. The azimuth and altitude structure are planned to be constructed in modules and transported by road to Ensenada and finally to the OAN-SPM where is going to be finally assembled, verified and tested at these facilities and disassembled to send it to the San Pedro Mártir Observatory for final integration. The azimuth and altitude structure is planned to be constructed in modules and transported by truck and shipped to Ensenada and finally to the OAN where is going to be finally assembled, verified and tested.

TSPM will be constructed as a new 6.5 meter telescope to be installed at the "Observatorio Astronómico Nacional in the Sierra San Pedro Mártir" (OAN-SPM) in Baja California, Mexico.[1] The project is a binational association of Mexican institutions and from United States of America. The TSPM has been designed to allow flexibility an and future upgrades[2],because for first light it will operate with f/5 Cassegrain configuration , but it is planned to have other configuration´s to be used at Nasmyth and folded focal stations.

Ground-based and Airborne Telescopes VII, edited by Heather K. Marshall,
Jason Spyromilio, Proc. of SPIE Vol. 10700, 107005U · © 2018 SPIE
CCC code: 0277-786X/18/$18 · doi: 10.1117/12.2313102

2. TELESCOPE PRELIMINARY MECHANICAL DESIGN

The telescope's structural-mechanical design is mainly inspired by proven concepts from the Magellan telescopes in las Campanas, Chile [3, 4, 5], however the design was also inspired from MMT telescope, the primary mirror cell must be completely compatible with the Multiple Mirror Telescope's (MMT)[6,7] which is a Cassegrain focus telescope and also San Pedro Mártir has its own requirements and capabilities which make the design very different from both of them. The telescope is planned to be manufactured in Mexico as much as possible; it will be preassembled in manufacturer' facilities and disassembled to be shipped to San Pedro Mártir Observatory for final integration. The azimuth and altitude structures are planned to be modular, in order to be constructed and transported by truck and/or ship to the final location on the OAN where is going to be assembled, verified and tested.

TSPM is designed as an Alt-azimuth mount telescope (See Fig 1). The structure is considered to be mostly manufactured of structural steel, with rotational Eigen frequencies between 9 and 11 Hz, depending the optical configuration and the position of the OSS (pointing to horizon or to Zenith). The total mass of the TSPM is below 246000 kg including all instruments mounted on the focal stations and the telescope rotating mass about azimuth axis is about 193000 kg. TSPM should take care of factors such as selection of materials, manufacturing processes and transportation of parts to the site. The design is mainly on welded plates in order to diminish mass and increase the convection heat transfer from structure to keep it near to the ambient temperature.

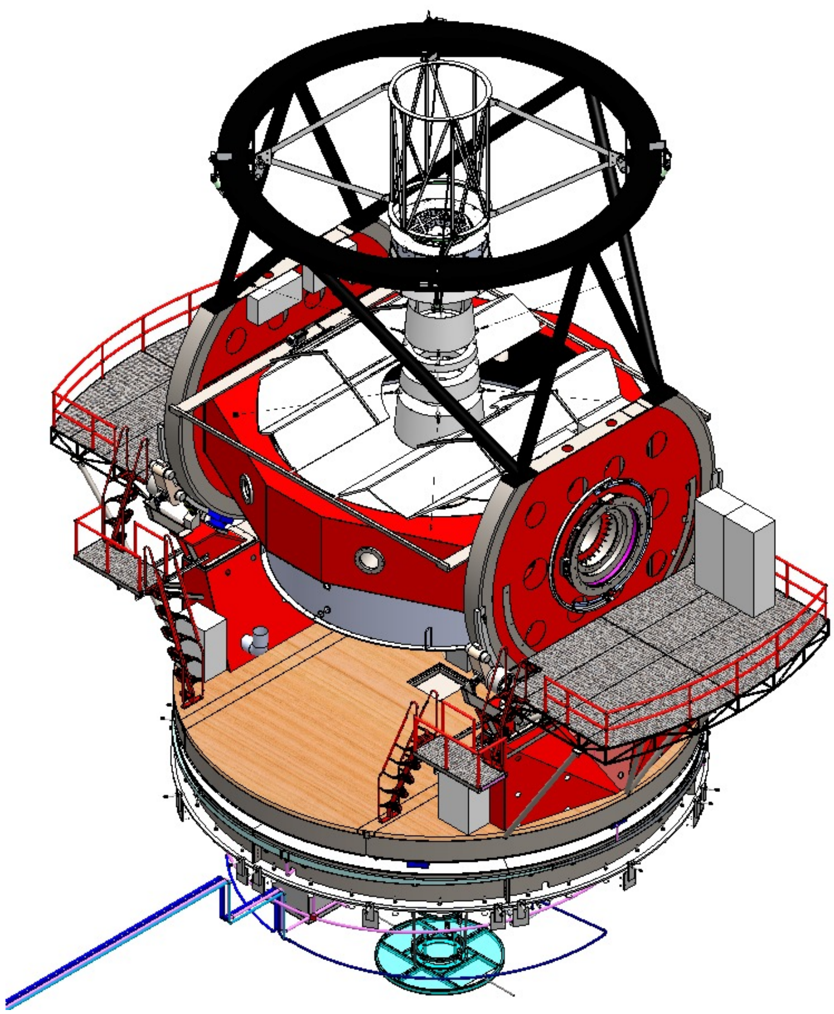

Figure 1. TSPM isometric view

3. MOTION RANGES

In order to define certain important positions for the telescope operation it is necessary to define for origin, observing ranges and limits of the azimuth and altitude axes.

Azimuth motion range

The origin of the Azimuth movement is defined with the telescope pointing to the North[8]. This mean that the side where the telescope moves in elevation to point from horizon to Zenith is facing to the north when the telescope is at 0º azimuth and, therefore, the side where the stairs are located is pointing out to the south. The telescope parking position is defined at the mid-range between B and C, then the parking position of the telescope is located at 180° (pointing to south and the stairs facing to the north), all these positions are shown in the Table 1

Table1 . TSPM Motion Ranges in Azimuth

Position	Azimuth	Use
N	0°	Telescope position pointing to the North
A	+65.08°	Alignment parallel to M1 mirror cart rails of the building (TBC)
A+180°	245.08	M1 removal position
B	-90°	Azimuth counter clockwise operational limit
C	+450°	Azimuth clockwise operational limit

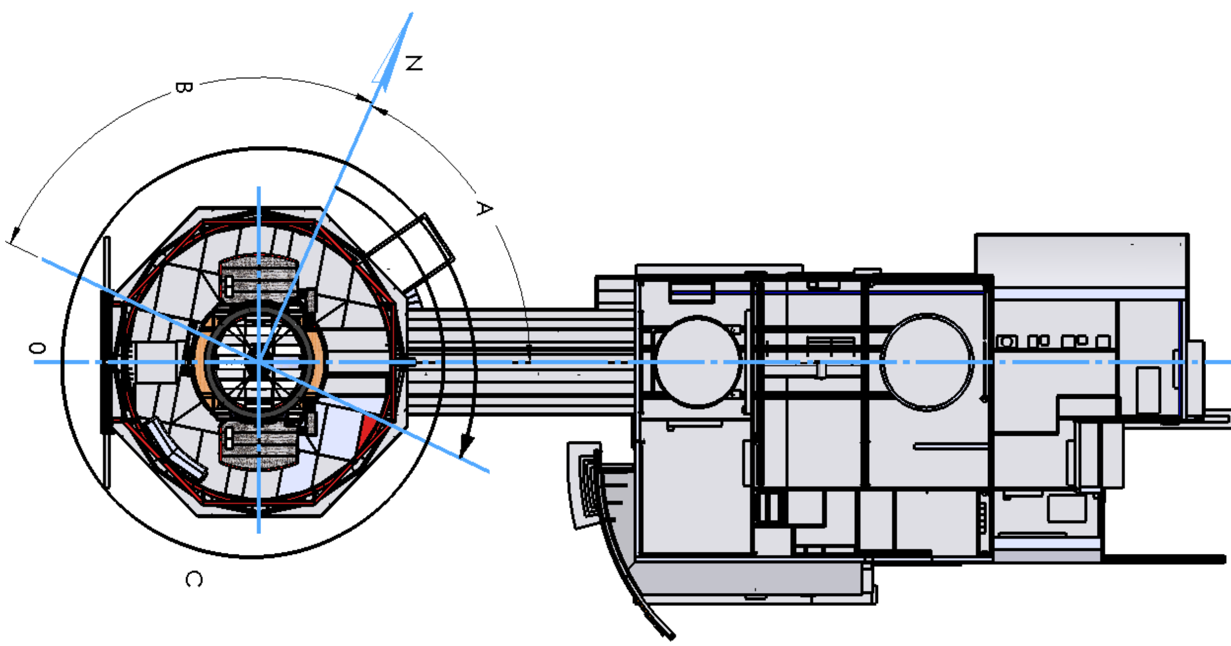

Figure 2. TSPM motion ranges in Azimuth

Elevation motion range

The TSPM will have an operating range in elevation

Table2 . TSPM Motion Ranges in Elevation

Position	Elevation	Use
Horizon	0°	Minimum allowable physical stop
A	5°	M2 mirror change (and limit switch lower position)
B	15°	Limit switch (operational lower limit switch)
C	18°	Observing lower limit
D	89.5°	Observing upper limit
Zenith	90°	Parking position and operational upper limit switch (M1 mirror change)
E	95°	Limit switch upper position
F	100°	Maximum allowable physical stop

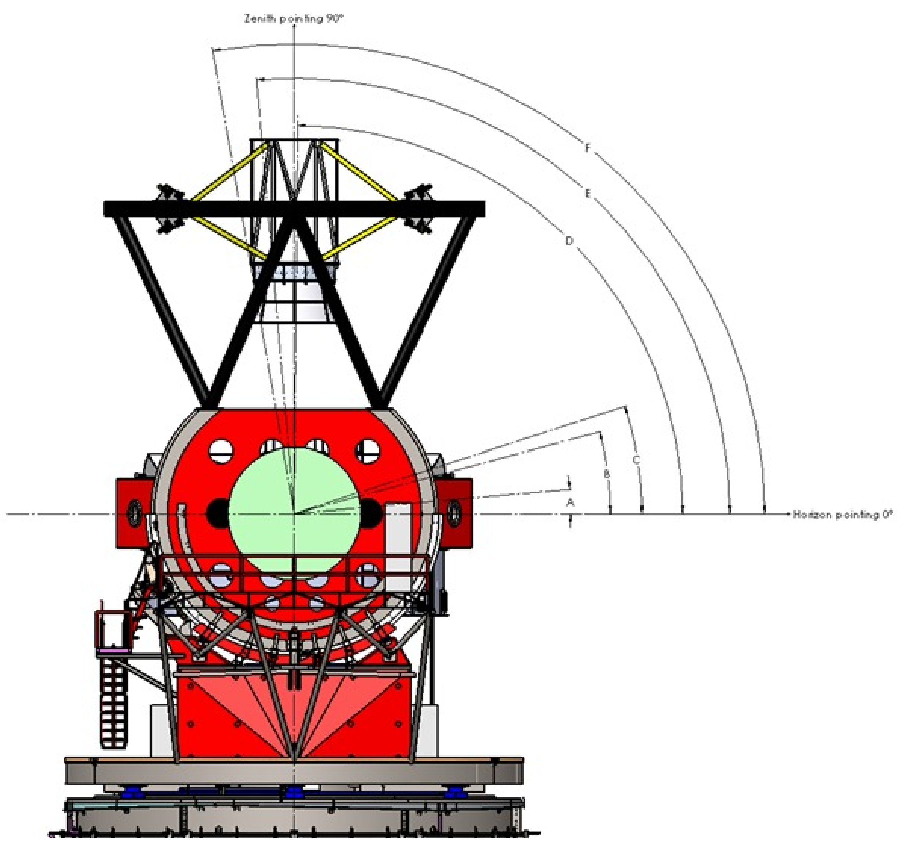

Figure 3. TSPM motion ranges in Elevation

4. TELESCOPE FOCAL STATIONS

The telescope is designed to have 7 focal stations: 2 Nasmyth focal stations (NF-A, NF-B), 4 folded Cassegrain focal stations (FC-D, FC-E, FC-F, FC-G) and 1 Cassegrain focal station (F-C). In the Figure 4 are shown the positions of the focal stations available to allocate instruments. These instruments maximum envelope are shown also in the Figure 4 as cylindrical shapes.

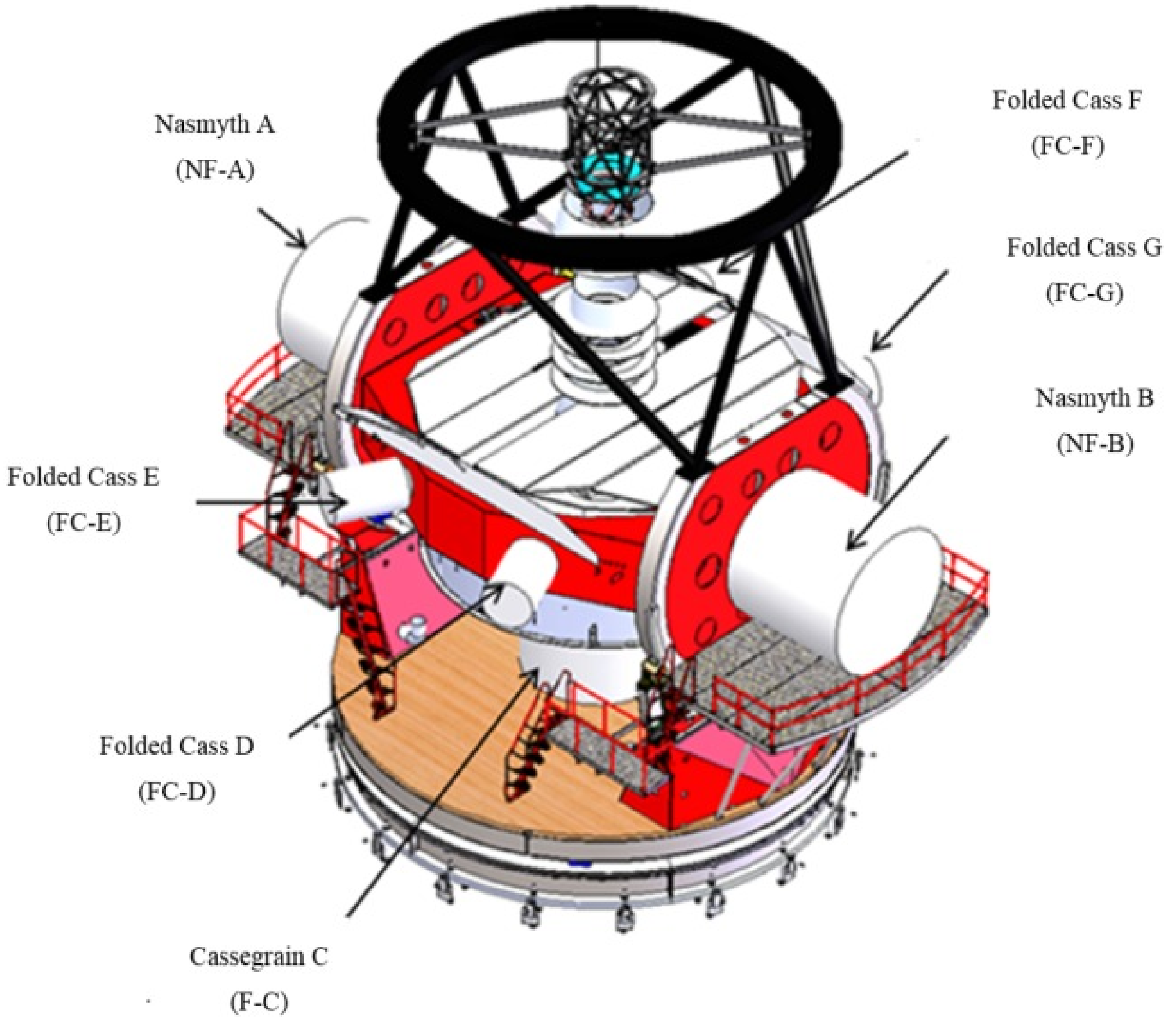

Figure 4. TSPM available focal stations

Table 3 list the focal stations available in the telescope in order to describe their envelopes and center of mass. Envelope maximum diameters and lengths for each focal station are declared at the column "Instrument envelope". The maximum mass for the instruments to be placed on each focal station is indicated in the "instrument mass" column. The maximum distance for the center of mass measured from the flange of the instrument interface with the telescope is defined at the "Center of Mass" column.

Table 3 . TSPM Maximum weights and envelopes

Focal Station	Instrument envelope ø/Length (m)	Instrument mass (kg)	Center of Mass position from flange (m)
NF-A NF-B	3/2.7	4000	@ 1.5
F-C	3/2.7	2700	@ 0.76
FC-D FC-E FC-F FC-G	1/1.5	1500	@ 0.75

5. TSPM FEM SIMULATIONS

The finite element method (FEM) analysis at the preliminary design of the TSPM for the f/5 Cassegrain and f/5 Nasmyth[9] configurations are described in the following section in a simplified manner, showing the analysis procedure used to understand the Sam Pedro Mártir design and based on the results it was improve it. Static, modal and thermal and other analyses were performed in order to review if the proposed design could accomplish with the TSPM requirements[10] and all the analysis performed up to the preliminary design review are deployed in the flowchart of the figure 5. The flow chart describes the interconnections between requirements, design, analyses and results.

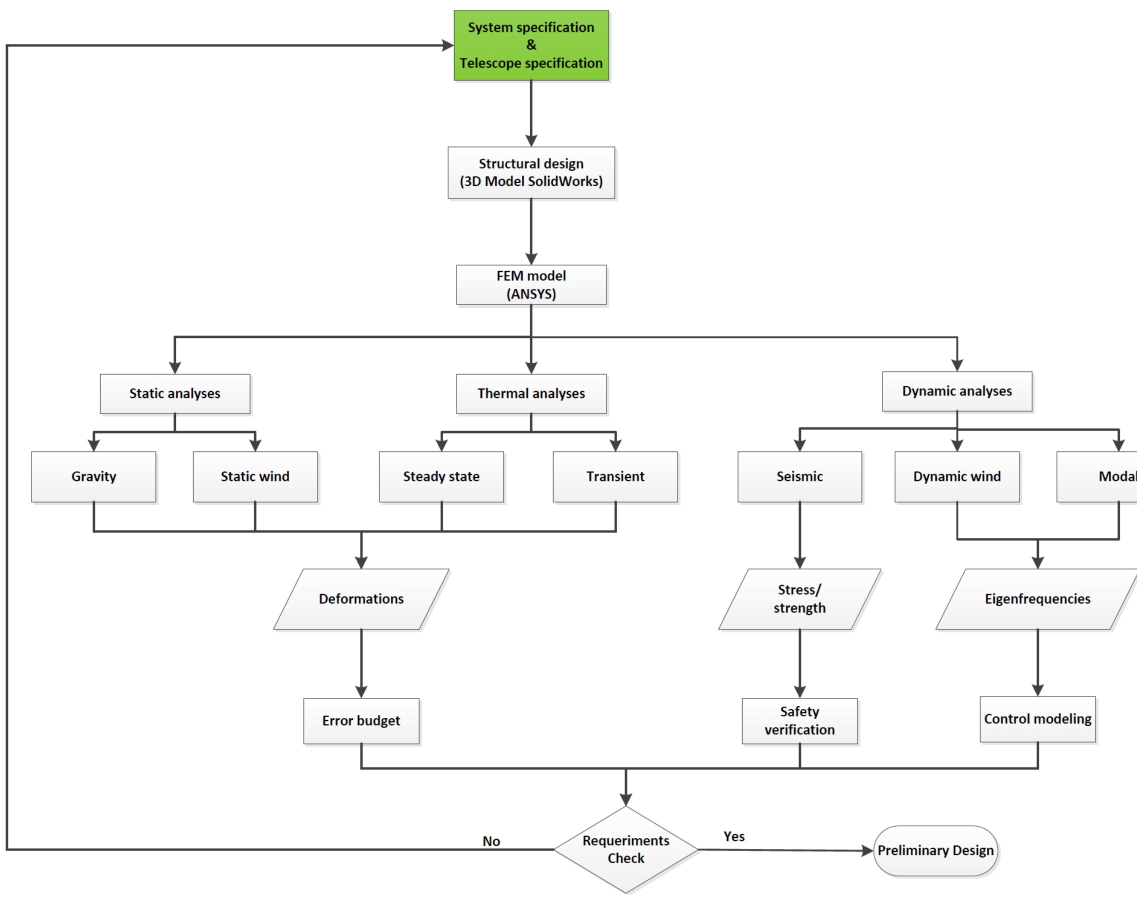

Figure 5. Flowchart of TSPM FEM and design process

In order to analyze the telescope performance, according to system and telescope specification for the Telescope San Pedro Mártir, is necessary to perform telescope analysis when subjected to disturbances associated with gravity, thermal loads, and wind and seismic, The TSPM was modeled using a 3D modeling software, and then this model was simplified and exported to a simulation software were it was meshed, see figure 6.

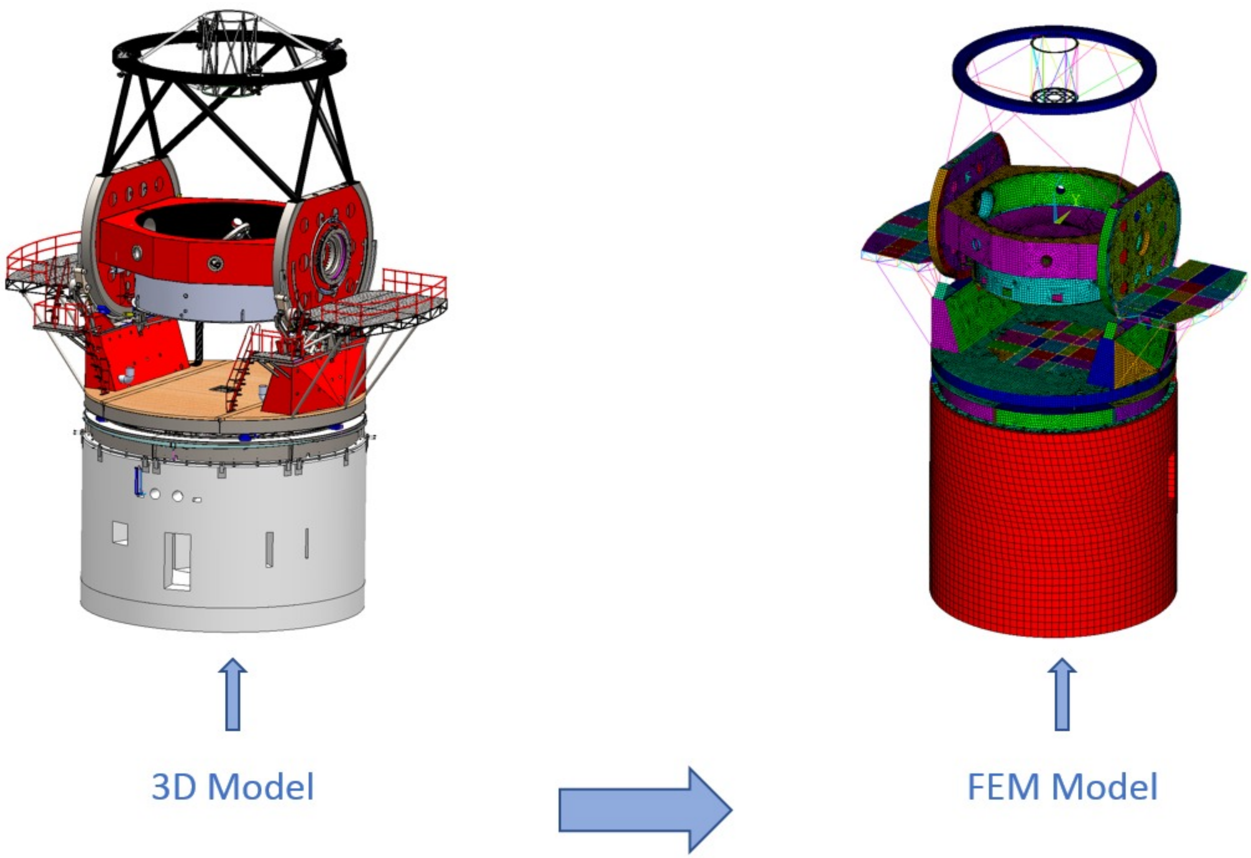

Figure 6. Comparison between 3d Model and FEM model

In this paper are deployed only the results of modal analysis.Modal analysis shows the dynamic behavior of the telescope structure for each optical configuration of the telescope and are very important to determine the best structural design of TSPM. Three different configurations were created in order to evaluate the geometry effects and how the telescope is affected when is pointing to different positions.
Configuration 1: Is the configuration for Day One (f/5 Cass)
Configuration 2: Fully equipped with all the focal stations with the maximum weight. (f/5 Cass)
Configuration 3: Modeled with f/5 Nasmyth
For each configuration were performed 3 modal analysis of the telescope. For each configuration was modeled pointing to Zenith, pointing to 18 degrees and pointing to horizon.

In the Table 4 are shown the results for one of the 3 different modal analysis, the Zenith pointing analysis for the 3 different configurations. At the figure 7 is shown the front bending representation augmented 100 X for better visualization of this mode as an example of it

Table 4 . TSPM Modal Analisys Fem Results for Zenith position

Mode Description	Frequency (Hz)		
	Configuration 1	Configuration 2	Configuration 3
Lateral telescope bending	6.04	5.58	5.60
Front bending of telescope	8.18	7.63	7.71
Torque in secondary structure	8.96	8.96	7.93
Bending of Nasmyth platform	10.81	10.81	10.83
Rotation of altitude assembly respect to altitude axis	14.91	14.50	14.19
Local torque of Nasmyth platform	12.30	12.22	12.31
Rotation of telescope respect to azimuth axis	15.66	14.25	14.35

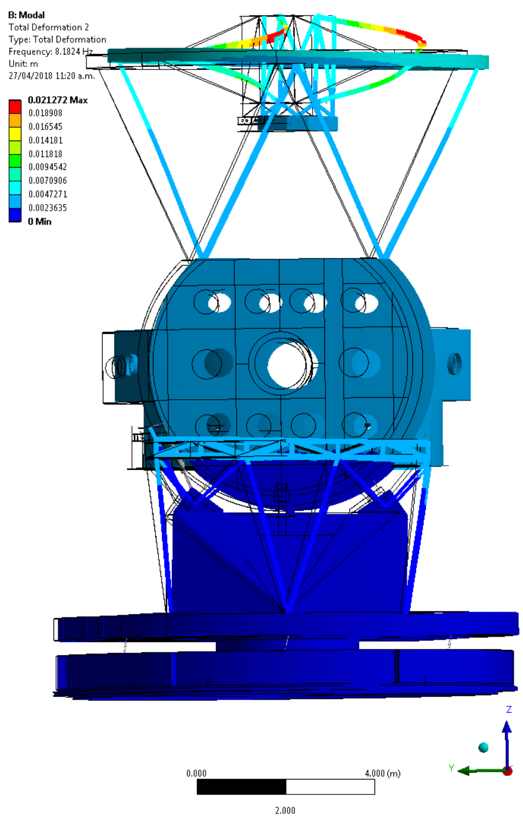

Figure 7. Front Bending at 8.18 (deformed 100X)

6. CONCLUSIONS

According to all the analysis performed to study the mechanical design of the TSPM we get the following conclusions:
For the static structural analysis with gravity load the telescope has the following maximum deformations in references nodes:

•The defocusing between primary and secondary is 0.76 mm for f/5 Cassegrain configuration (configuration 2), this value is lowers than the specification 1 mm.

•For decentering between primary and secondary is 0.88 mm for f/5 Cassegrain configuration (Configuration 1) and this value is minor than specification 1.5 mm.

•Parallelism between primary and secondary is 2.11 arcmin when the telescope changes form zenith to 18° position, the value is greater than specification of 0.5 arcmin, therefore the telescope does not fulfill the requirement.

•Stresses for the structure are minor than the tensile strength yield of the material structural steel A36 (250 MPa).

•Nasmyth platforms and rotating floor can support a uniformly distributed load of 490 kg/m2.

•Minimum safety factor under dead load is 3.55.

•The primary mirror-secondary mirror thermal defocusing is 2.1 mm, this value considers a temperature range of 18°C to -5°C.

Recommendations:

The actual telescope design present a loose of parallelism of 2.11 arcmin when is pointing to 18°, this behavior of the telescope should be revisited in next development phase doing more detail models.

The telescope has a low frequency when front bending mode is presented, being the lower frequency 7.35 Hz, this could be related to the considerations during the modulation process and should be revisited in order to improve the frequency values.

7. ACKNOWLEDGEMENTS

The funding for this planning phase of the TSPM project has been supported in Mexico by the IA-UNAM, the INAOE, and especially the "Consejo Nacional de Ciencia y Tecnología" through grants LN127736, LN232649, LN 260369, LN 271117, 224003, 264173, and the "Agencia Espacial Mexicana" who contributed to grant 248500. We gratefully acknowledge the Giant Magellan Telescope for permitting the TSPM project to adopt its control system as our model. We thank personnel at the MMT and Magellan telescopes for making information available.

REFERENCES

[1] Michael G. Richer, William H. Lee, Jesús González, et all, "The Telescopio San Pedro Mártir project," Proc. SPIE 9906, Ground-based and Airborne Telescopes VI, 99065S (27 July 2016);

[2] Gengis K. Toledo-Ramirez, Vicente Bringas-Rico, et all, "San Pedro Martir Telescope: Mexican design endeavor," Proc. SPIE 9906, Ground-based and Airborne Telescopes VI, 99060S (8 August 2016)

[3] Jorge Uribe, Vicente Bringas, et all, "Mechanical conceptual design of 6.5 meter telescope: Telescopio San Pedro Mártir (TSPM)," Proc. SPIE 9906, Ground-based and Airborne Telescopes VI, 99062E (27 July 2016);

[4] Steven M Gunnels., David Carr.,"Design of the Magellan Project 6.5 Meter Telescope: Telescope structure and mechanical systems," Proc SPIE 2199, 414-427 (1994)

[5] Stephen Shectman., Matt Johns., "The Magellan Telescopes," Proc. SPIE 4837, 910-918 (2003)

[6] Steve C.West., Shawn P. Callahan.,Et all, "Toward first light for the 6.5-m MMT telescope," Proc SPIE 2871,38 (1997)

[7] B. H. Olbert, J. R. P. Angel, J. M. Hill, S. F. Hinman, "Casting 6.5-meter mirrors for the MMT conversion and Magellan", Proc. SPIE 2199, 144-155 (1994)

[8] Jose Teran, William H. Lee, et all, "Telescopio San Pedro Mártir Observatory preliminary design and project approach," Proc. SPIE 9906, Ground-based and Airborne Telescopes VI, 99062D (27 July 2016);

[9] Joel Herrera Vázquez, María H. Pedrayes, Gerardo Sierra Díaz, Michael G. Richer, J. Jesús González, Carlos Tejada, "TSPM f/5 Nasmyth configuration" Upcoming presentation Proc SPIE, Optical and opto-mechanical designs, 10700-138 (10 June 2018)

[10] Michael G. Richer, William H. Lee, Leopoldo Altamirano, et all, "The Telescopio San Pedro Mártir project," Upcoming Presentation Proc. SPIE , Project Reviews :Early Construction, 10700-30 (12 June 2018);