

# Mechanical conceptual design of 6.5 meter telescope: Telescopio San Pedro Mártir (TSPM)

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## ABSTRACT

Telescopio San Pedro Mártir (TSPM) project intends to build a 6.5 meters telescope with alt-azimuth design, currently at the conceptual design. The project is an association between Instituto de Astronomía de la Universidad Nacional Autónoma de México (IA-UNAM) and the Instituto Nacional de Astrofísica, Óptica Electrónica (INAOE) in partnership with department of Astronomy and Steward Observatory of University of Arizona and Smithsonian Astrophysical Observatory of Harvard University. Conceptual design of the telescope is lead and developed by the Centro de Ingeniería y Desarrollo Industrial (CIDESI). An overview of the feasibility study and the structural conceptual design are summarized in this paper. The telescope concept is based on telescopes already commissioned such as MMT and the Baade and Clay Magellan telescopes, building up on these proven concepts. The main differences relative to the Magellan pair are; the elevation axis is located 1 meter above the primary mirror vertex, allowing for a similar field of view at the Cassegrain and both Nasmyth focal stations; instead of using a vane ends to position the secondary mirror TSPM considers an Steward platform like MMT; finally TSPM has a larger floor distance to m1 cell than Magellans and MMT. Initially TSPM will operate with an f/5 Cassegrain station, but the design considers further Nasmyth configurations from a Cassegrain f/5 up to a Gregorian f/11. The telescope design includes 7 focal stations: 1 Cassegrain; 2 Nasmyth; and 4 folded-Cassegrain. The telescope will be designed and manufactured in Mexico, will be design in Queretaro by CIDESI and built between Queretaro and Michoacán manufacturing facilities; it will be preassembled in 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.

**Keywords:** Telescope, TSPM, Conceptual Design, Mechanical Design, San Pedro Mártir, 6.5 meters, Visible/Infra-Red Wavelength

## 1. INTRODUCTION

IA UNAM has an agreement and a letter of intention to build a 6.5 meter telescope at the Observatorio Astronomico Nacional (OAN) located at the Sierra San Pedro Mártir in Baja California. This agreement was made with INAOE, Steward Observatory of the University of Arizona and Smithsonian Astrophysical Observatory of Harvard University. On 2012 IAUNAM and CIDESI team had a meeting; the purpose of this meeting was to order CIDESI to make a feasibility study for the construction in Mexico of a 6.5 meter telescope by Mexican institutions. One of the main design and manufacturing directives was the use of existing technologies and designs to diminish the risk of the project. Two visits were arranged in order to see different technologies used in 6.5 meter existing telescopes like Magellan's Baade, Clay and MMT. With the support of the University of Arizona, on April of 2013 was done a visit to evaluate the specifications and characteristics of the MMT telescope to take decisions about the possible implementation on some concepts on the TSPM design, on June of the same year was arranged a visit to Las Campanas Observatory (LCO) where are located the Magellan telescopes in order evaluate other concepts used on them. The main points to evaluate during these visits were: optical performance, mechanical performance, operation, manufacturing feasibility, implementation

cost, all considered in the TSPM scenario, that includes, site and access road characteristics, desired optical performance, manufacturing capabilities in Mexico, present and future instruments consideration, among others.

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## 2. REQUIREMENTS

Some of the requirements and constraints affecting to the TSPM design are listed below.

- Use 6.5 meter mirror owned by INAOE And UA (cast at Steward Observatory Mirror Lab)
- Compatibility with instruments commissioned in Magellan and MMT like Hectoechelle, Hectospec, MMIRS and Megacam and Binospec.
- Possibility of mounting correctors used in Magellan
- Compatibility with Magellan and MMT f/5 secondary mirror cell.
- 1 degree field of view on Nasmyth focal station
- Possibility of using different instruments in one night

## 3. DESIGN BASIS AND CONCEPTS

For the conceptual design for the TSPM, several characteristics were analyzed:

- Requirements fulfillment.
- Cost of the solution.
- Weight
- Manufacturability
- To be designed and built in Mexico
- Technical feasibility to be developed in México.
- Among others

The TSPM telescope design was conceptualized with the following options:

- Telescope with the same focal ratio between Cassegrain and Nasmyth focus (Confocal telescope)
- Telescope based on MMT 6.5 m telescope design.
- Telescope based on Magellan Baade or Clay telescopes design.
- Telescope based on Magellan's and MMT design.

### 3.1 Confocal telescope

This concept was the first concept evaluated; it has the same focal distance between Nasmyth and Cassegrain focal stations. The center of gravity (CoG) of the primary mirror cell (see figure 1) is far from the elevation axis in order to have confocal stations. The optics support system (OSS) has a central ring with bearings on each side to mount the elevation axis. Primary mirror cell is mounted under a flange join to the central ring by trusses. The tube is short and is the support of the spider that holds secondary mirror and its cell. In order to do collimation is attached to the tube a vane end system, concept used in Magellan Baade & Clay telescopes designed by Gunnels<sup>[2]</sup>. Nasmyth platforms work giving stiffness to the OSS with a cross design that mix a thin central fork structured with trusses in order to increase modal frequencies to diminish the wind effects over the structure and control. The azimuth disk is mounted on 6 equally spaced hydrostatic bearings to support axial loads of the rotating mass, 4 hydrostatic bearings to support the radial loads. Having a bearing to support the OSS has advantages over hydrostatic bearings to support the OSS. One advantage is avoid hydraulic pipe routing on the rotating mass, the other advantage is to have a stiffer anchorage to the OSS. A geared system is proposed to rotate in the azimuth and elevation axis, 4 motors with encoders in each system are proposed working in pairs to reduce backlash in the system. The main difficulty of this design is very different from the concepts of the telescopes already commissioned and this increases risk in a high manner.

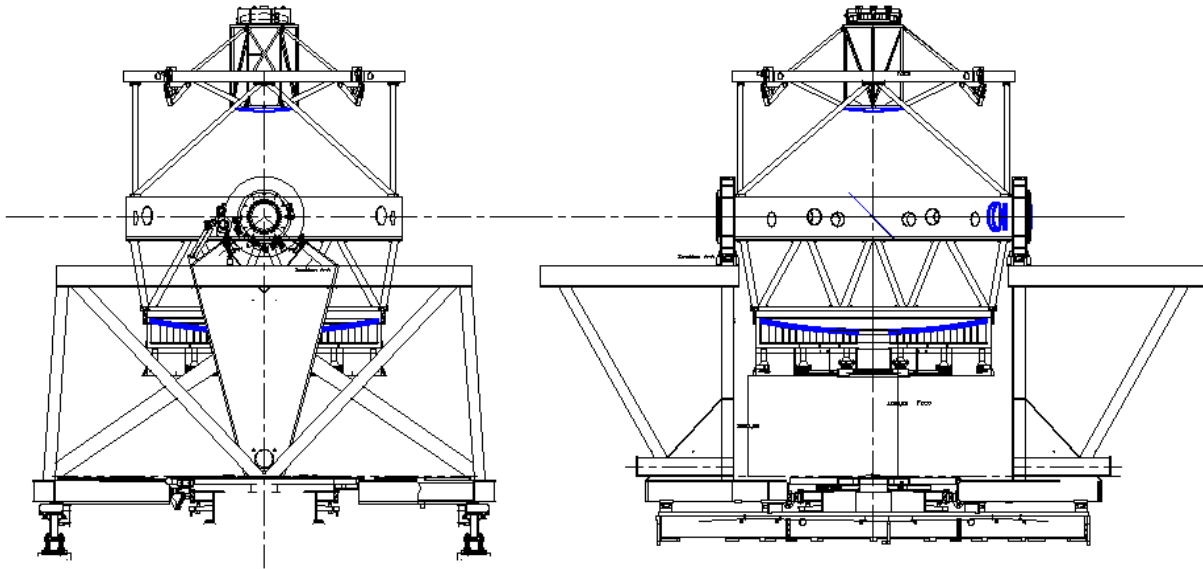


Figure 1. TSPM concept with the same focal distance to Nasmyth and Cassegrain mounted on bearings and hydrostatic bearings.

This solution has several difficulties:

- Telescope balance; is required to add more mass to the counterweight system, and more weight must be added on the telescope tube.
- Azimuth track will need to increase diameter to support Nasmyth platforms and to allow primary mirror cell cart be placed under the OSS to dismount it to aluminizing; this will cause higher loads to the pier.

### 3.2 Design Based on MMT

The MMT is an Alt-Azimuth telescope<sup>[1]</sup>, with a fork structure mounted on a central bearing and 4 boogies to support the rotating building enclosure that allows azimuth rotation coordinated with building rotation. This telescope only has Cassegrain focus available;

TSPM design is consider having the optics support system (OSS) mounted in a fork , the rotation axis is located higher than MMT, the main reason is because is needed more room below the primary mirror cell and this kind of design makes a heavier telescope mount. The fork only allows one focal station and is going to be mounted over an azimuth disk (figure 1) to place aluminizing mirror cart below the OSS and the primary mirror cell to be transported to the aluminizing chamber located inside the building next to the telescope. Nasmyth platforms are considered and placed on the Azimuth disk and is necessary to analyze the use of huge diameter pillow block bearings. The field of view is going to be limited by doing this, and very difficult to reach 1 degree field of view without increasing considerably the weight of the telescope. According to the TSPM requirements, will be needed an increase on the tube structure length if it is compared with MMT. The tube of the telescope needs to allow an f/11 Gregorian configuration adding more weight to the design and more room inside the enclosure in order to accommodate the telescope.

The figure 2 shows the telescope configuration analyzed for TSPM.

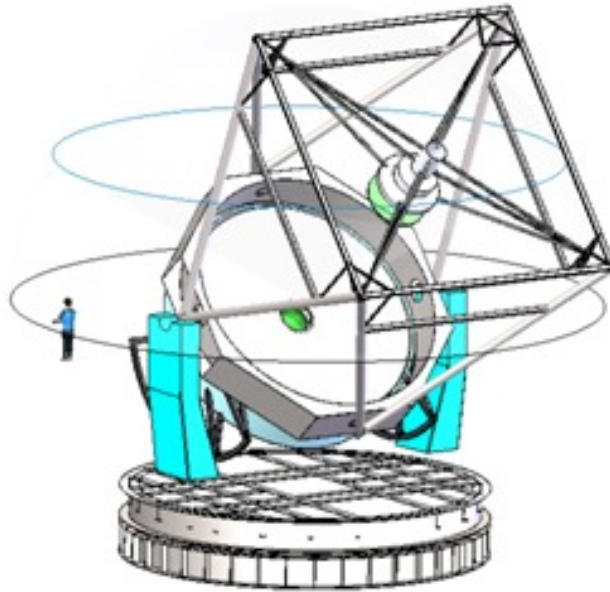


Figure 2. TSPM design concept based on MMT mounted on a disk using hydrostatic bearings instead of bogies for Azimuth rotation instead of central bearing.

TSPM will require more space between the floor level and the Cassegrain focus than MMT and Magellans in order to allow more room for bigger instruments envelope. The telescope enclosure will be independent from the telescope, not as on MMT where because of the lack of space in the mountain the whole building rotates with the telescope for a rotating mass of approximately 450 tons<sup>[5]</sup>.

Brake system will be a variation of the MMT system, mounted direct on the azimuth track and elevation track, the encoder will be mounted direct on the traction disc and another in the azimuth disc in the center where it is connected to the pier.

Traction of elevation and Azimuth axis could be by a geared system, using a geared bearing system with 4 servomotors in order to diminish backlash. Another option is to use friction drive system like in Magellan's<sup>[2]</sup>, to reduce the backlash inherent to geared systems.

A Spider will hold a Steward platform carrying secondary mirror, it is considered 1 Steward platform for each focal configuration which use a different f size mirror.

### 3.3 Design based on Magellan Clay & Baade

The Magellan telescopes Baade and Clay with structural design by Steven Gunnels<sup>[2]</sup> of Paragon Engineering, These are two very similar Alt-Azimuth telescopes. They include two Nasmyth platforms with 24 arc-min unvignetted field of view, 2 Nasmyth platforms and vane end system to position secondary mirror. They are more modern than the MMT because they start operations in 2001<sup>[3]</sup>.

In this TSPM Telescope concept is considered to use most of the proven concepts used in Magellan with some modifications to accommodate the design requirements in order to accomplish them. Requirements like field of view of 1 degree at Nasmyth Focal stations in order to have the possibility of use f/5 Nasmyth configuration and mount 2 or more f/5 instruments in one night. It will accommodate 2 Nasmyth focal stations, 2 folded stations and a Cassegrain Station, it is consider to have bigger instrument envelope on Cassegrain station.

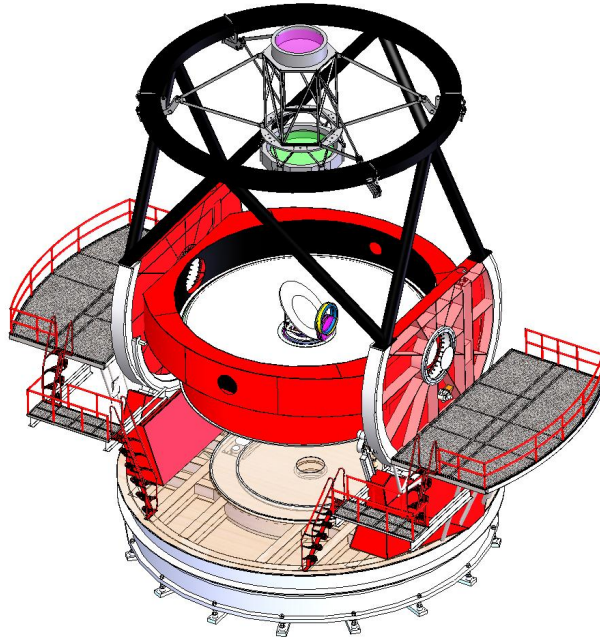


Figure 3. TSPM design based on Magellan Baade and Clay designed by Paragon Engineering

Elevation and Azimuth system of Magellan Telescopes are a very precise systems, reliable and cost effective solutions for the TSPM design. The concept is a very similar design configuration respect to Magellan telescopes, azimuth and elevation system follow the next considerations:

- Azimuth track is divided by sectors with a calibration or adjustment system like Magellan, is a solution very easy to implement and feasible to manufacture in Mexico with local suppliers, like the big machining companies in Morelia México. With the calibration system is possible to compensate the pier uncontrolled surfaces where concrete melting makes difficult to have errors during the construction of the pier and telescope foundations
- TSPM concept uses hydrostatic bearing system for azimuth and elevation systems like.
- Friction drives are a convenient solution for all traction systems of the TSPM to prevent backlash on the elevation and azimuth rotation axis, this is compact in size and weight. The reliability of this kind of system has been proven on the Magellan telescopes.

Rotator system for the TSPM would be a geared mechanism with 4 servo motors working as pairs and will have the following constraints:

Primary mirror and its cell will be manufactured by the Steward Observatory Mirror Lab. The cell must accept instruments like MMIRS and Binospec, this define the interface with rotator and instruments, and must have the same hole pattern to accept the instruments already commissioned on MMT and Magellan, and must have a cone , just like the primary mirror cell used on MMT.

Tertiary mirror has an elliptical shape in order be used between the Nasmyth and Folded Cassegrain without changing the mirror and optimizing the size and weight.

### 3.4 Design based on Magellan and MMT telescopes

This concept use most of the features described on the design based on Magellan Clay & Baade with some differences like to have 4 folded stations instead of 2, and the tube design has flat surfaces to interface with the spider ( see figure 4) in order to have an easier way to adapt the spider changes between the different configurations. This concept consider the use of a Steward platform for each different mirror configuration, and the tertiary mirror is going to be placed on the same interface plate are going to be mounted the Cassegrain correctors.

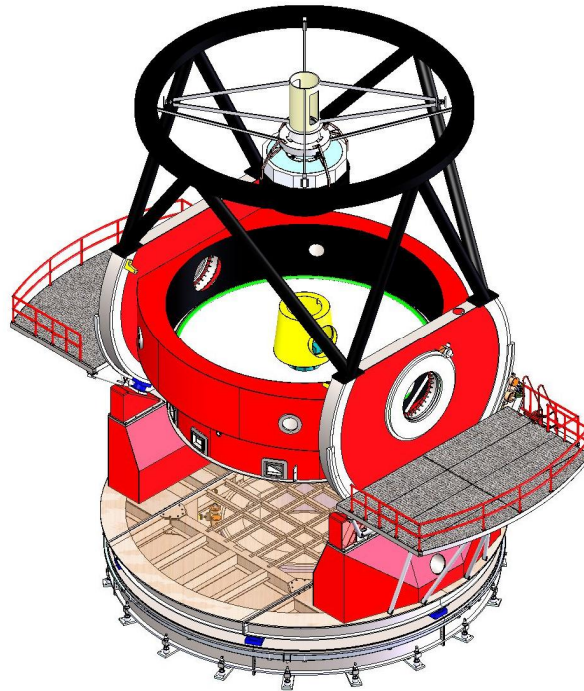


Figure 4. TSPM concept using concepts of Magellan Baade and Clay and MMT, increasing the field on Nasmyth and folded Cass stations

### 3.5 Comparison between concepts.

Main differences between the concepts explained before were compared with Magellan telescope in order to summarize the concepts and are shown in the table 1.

Table 1. Comparison chart between Magellan' and other configurations<sup>[3]</sup>,

Magellan	Magellan Based Design	Magellan & MMT Based Design	MMT Based Design	Confocal Design
<u>Nas Field of view:</u> 24 arc-min unvignetted 30 arc-min corrected	<u>Nas Field of view:</u> 1 degree unvignetted	<u>Nas Field of view:</u> 1 degree unvignetted	<u>Nas Field of view:</u> 30 arc-min unvignetted	<u>Nas Field of view:</u> 30arc-min unvignetted
<u>Focal Stations</u> 1 Cass 3 Folded ports 2 Nasmyth	<u>Focal Stations</u> 1 Cass 2 Folded ports 2 Nasmyth	<u>Focal Stations</u> 1 Cass 4 Folded ports 2 Nasmyth	<u>Focal Stations</u> 1 Cass 2 Nasmyth	<u>Focal Stations</u> 1 Cass 2 Folded ports 2 Nasmyth
Estimated moving mass: 155 tons	Estimated moving mass: 180 tons	Estimated moving mass: 185 tons	Estimated moving mass: 220 tons	Estimated moving mass: 220 tons
Total weight: 200 tons	Approximate total weight: 240 tons	Approximate total weight: 245 tons	Approximate total weight: 250 tons	Approximate total weight: 260 tons
Lowest resonant freq: 10 Hz	Lowest resonant freq: 9 Hz	Lowest resonant freq: 9 Hz	Lowest resonant freq: 5 Hz	Lowest resonant freq: 7 Hz



#### 4. TELESCOPE MECHANICAL DESIGN

Three optical configurations were considered for TSPM concept (see Figure 5):

- f/5 Cassegrain configuration
- f/5 Nasmyth configuration
- f/11 Gregorian configuration

The f/5 Cassegrain is considering to use the instruments from the MMT and Magellan , MMIRS, Megacam, Binospec  
The f/5 Nasmyth also to accomplish the specification of the ability to use more than one instrument per night .

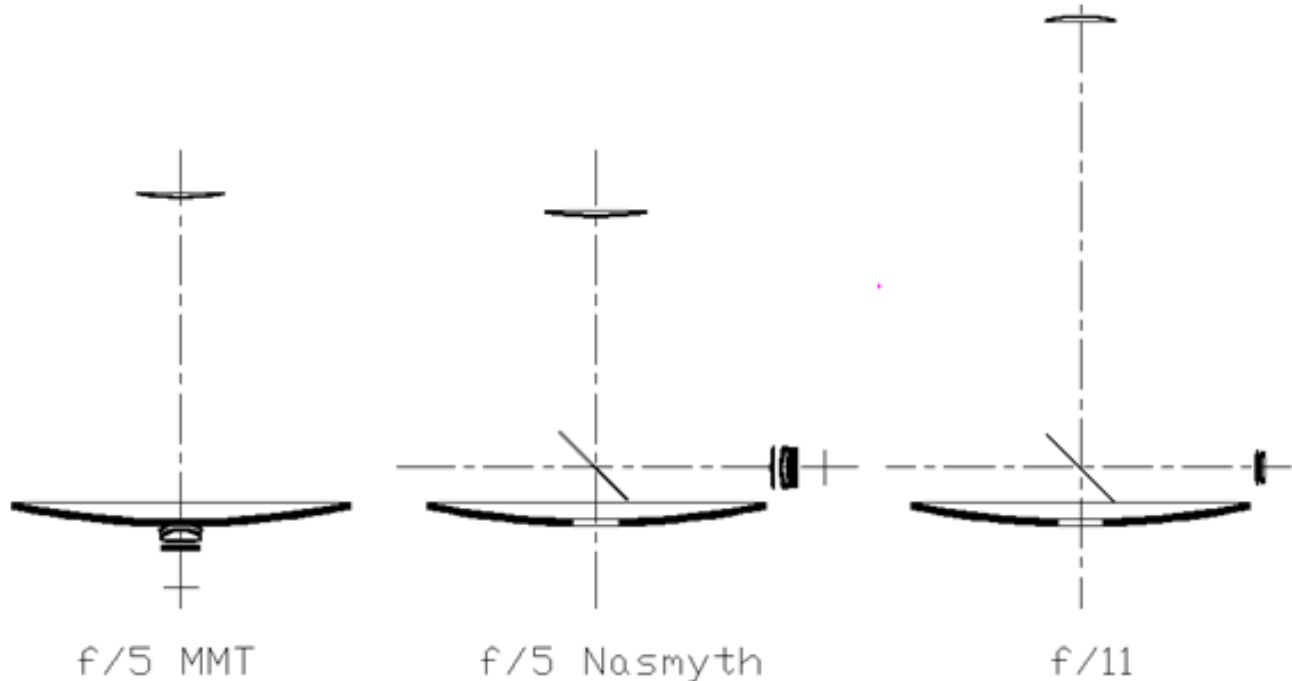


Figure 5. Optical Configurations for TSPM. drawing made by Jesus Gonzalez

Concepts used from Magellan design on TSPM concept Tripod disk, friction drive system, elevation ring, Nasmyth platforms, hydrostatic bearing system

Concepts used from MMT Design: Spider, Steward platform, Cassegrain rotator, primary mirror cell cone

The design covering this characteristics is the design based on Magellan and MMT telescopes, and this is going to be the one which is going to be developed strongly in the next stages of the project. Developing structural optimization , seismic analysis, wind analysis and other required analysis for the best telescope performance.

#### 5. CONCLUSIONS

During the preliminary design is needed an optimization of the telescope in order to make an efficient solution, optimizing geometry and mass to reach the goal of 10 Hz like or more to avoid wind effects instead of actual 9 Hz . This decrease in the stiffness of the structure is due to the weight added to the OSS in order to have 1 degree field of view and because the elevation ring increase in height to let 1 meter distance between the primary mirror vertex to the elevation axis. Also mass was increased due to the higher distance between the observing floor and the bottom of the cell to allow bigger envelope to the instruments allocated in the Cassegrain station.

## 6. ACKNOWLEDGEMENTS

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