TSPM operation concept

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1.A	20/09/16	All	All	New issue
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1.C	7/11/17	8.2.4, 9.2.2, 7.4.1, 7.4.2		Added: (1) plan to deal with primary mirror cell electronics replacement, (2) UA wind speed limit for wind screen use, (3) services to be contracted from the OAN-SPM, (4) access to the OAN-SPM

Applicable and Reference Documents

Nº	Document Name	Code
R.1	TSPM: List of acronyms and abbreviations	TEC/TSPM/001
R.2	TSPM: Glossary	TEC/TSPM/006
R.3	Miller, J. S. 2007, RMxAAC, 28, 24	
R.4	Bohigas, J., & Núñez, J. M. 2010, RMxAA, 46, 89	

R.5	Tapia, M., et al. 2007, RMxAAC, 31, 47	
R.6	Plauchu-Frayn, I., et al. 2016, PASP, submitted	
R.7	Echevarria, J., et al. 1998, RMxAA, 34, 47	
R.8	Skidmore, W., et al. 2009, PASP, 121, 1151	
R.9	Sánchez, L., et al. 2003, RMxAAC, 19, 23	
R.10	Otarola, A., et al. 2010, PASP, 122, 470	
R.11	Szentgyorgyi, A., et al. 2012, SPIE, 8446, 844628	
R.12	TSPM High Level Requirements	TSPM/HLREQ-001
R.13	TSPM System Specification	SP/TSPM/001
R.14	TSPM Preliminary RAMS Analysis	TEC/TSPM/012
R.15	Perez, F. 1994, SPIE, 2199, 542	
R.16	Shectman, S. 1994, SPIE, 2199, 558	
R.17	Gunnels, S., & Carr, D. M. 1994, SPIE, 2199, 414	
R.18	Chivens, D. R., & Chivens, D. E. 1999, SPIE, 3692, 123	
R. 19	Schöck, M. et al. 2009, PASP, 121, 384	
R. 20	GMT-ID-01466-Chapter_5_Site_Evaluation.pdf	
R.21	Cheng, J., The Principles of Astronomical Telescope Design	
R. 22	Perez, F. 1994, SPIE, 2199, 550	
R. 23	Shectman, S., presentation (cit01.ppt)	
R.24	MEC-TN-O-T-OP-SM-001_1A Secondary Mirror Mount System Evaluation.pdf	EXT/CIDESI-TSPM/025
R.25	Fata, R., & Fabricant, D. 1994, SPIE, 2199, 580	
R.26	Johns, M., 6.5m Primary Mirror Coating Technical Note	TEC/TSPM-PDR-OP-M1/001
R.27	MAGM-0400-06-01_ICD_Dwg.pdf, SAO provided	
R.28	MMIRS_MMT_ICD-400.pdf, SAO provided	
R.29	simulator_dimension.pdf, SAO provided	
R.30	Schöck, M., et al. 2009, PASP, 121, 384	
R.31	Els, S. G., et al. 2009, PASP, 121, 527	
R.32	Phillips, M. M. et al. 2016, SPIE, 6270, 627007	
R.33	Osip, D. J. et al. 2008, SPIE, 7016, 701609	

R.34	Williams, G. G. et al. 2016, SPIE, 9906, 99060V	
R.35	Summary of wind measurements at the Observatorio Astronómico Nacional in the Sierra San Pedro Mártir	ANA/TSPM/001
R.36	Summary of temperature variations at the Observatorio Astronómico Nacional in the Sierra San Pedro Mártir	ANA/TSPM/002
R.37	The vertical structure of the wind at the OAN-SPM	ANA/TSPM/004
R.38	TSPM Site Description	TEC/TSPM-PDR/004
R.39	f/11 to f/5 Engineering Procedure (Starting with MEGACAM)	EXT/SAO/010
R.40	F/5 Wide-Field Corrector Installation and Removal Procedure ADC and Lens 4 Assembly Swap-Out Procedure	
R.41	F5 Engineering Procedure (MEGACAM Removal MMIRS Installation)	
R.42	Mounting and Dismouting Procedure for TS and M3	TEC/TSPM-PDR-TL/013
R.43	Reglamento de la Ley General para la Prevención y Gestión Integral de Residuos: http://www.profepa.gob.mx/innovaportal/file/4140/1/reg_lgpgir.pdf	
R.44	Predicting the sunset temperature at the OAN-SPM	

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1. SUMMARY

This document provides the Operational concept of the TSPM.

2. INTRODUCTION

The aim of this document is to identify the operational requirements, constrains and guidelines that shall be taken into account during TSPM development and to produce the TSPM operation and maintenance plan.

The operational and maintenance requirements are considered an important and integral part of the design of the TSPM, with the aim of guaranteeing safety, maximizing the efficiency of the telescope while minimizing running costs, and simplifying maintenance.

The TSPM operation and maintenance plan will provide a general overview about all the activities that are going to be carried out during the TSPM operation for the scientific exploitation of the facility and to ensure that TSPM is kept in the required working conditions.

This document is addressed to all persons involved in the development, manufacturing, integration and future operation of TSPM.

3. ACRONYMS AND DEFINITIONS

Acronyms and definitions are included in R1 and R2.

4. DOCUMENT SCOPE

The scope of this document is to give an overview of all aspects linked to the future Operations for TSPM in the OAN-SPM. The document starts with several introductory sections that put in context the TSPM project, and then follows with the site description, including some historical notes. The main scope of this document is to provide an extensive review of the current requirements impacting the future operation of TSPM, from operational requirements, policies and constraints to safety requirements and personnel requirements for the future Operation and Maintenance team at the TSPMO. The document includes also a review of the system and the Operation and Maintenance processes to be implemented once the TSPM enters in operation.

5. THE TSPM PROJECT

5.1 Overview

The Telescopio San Pedro Mártir (TSPM) project intends to construct a 6.5m telescope to be installed at the Observatorio Astronómico Nacional in the Sierra San Pedro Mártir (OAN-SPM) in northern Baja California, Mexico. The project is an association of Mexican institutions, led by the Instituto de Astronomía at the Universidad Nacional Autónoma de México (IA-UNAM) and the Instituto Nacional de Astrofísica, Optica y Electrónica (INAOE), in partnership with the Harvard-Smithsonian Center for Astrophysics (SAO) and the University of Arizona's Department of Astronomy and Steward Observatory (UA). Most of the funding for the design and planning activities that have taken place so far has been provided by the Consejo Nacional de Ciencia y Tecnología (CONACYT).

The Magellan telescopes in Las Campanas, Chile inspire the telescope's mechanical design. 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. The enclosure design borrows elements from the Magellan telescopes (Las Campanas, Chile), but incorporating the needs of the particular site that will be used at the OAN-SPM. The primary mirror will be polished at the Steward Observatory's Richard F. Carris Mirror Lab. The telescope will initially use the f/5 Cassegrain secondary currently at the Magellan II Clay telescope. The TSPM will begin its scientific operations (Day 1) with the Megacam and MMIRS instruments, currently at the Magellan II and MMT telescopes, respectively.

Once completed, it is planned to operate the TSPM in collaboration with the UA and SAO. Jointly, the MMT and TSPM will form a binational astrophysical observatory serving astronomers from all partner institutions, with each site focusing upon its strengths. The TSPM, thanks to its wide field imaging capability, will allow state-of-the-art research on planetary, Galactic and extragalactic astronomy, variable sky studies, and large-scale surveys. TSPM will be complementary not only to the MMT for large scale, high-impact programs, but also to multi-frequency collaborations that could exploit current Mexican facilities, such as the Gran Telescopio Milimétrico Alfonso Serrano (GTM) and the High-Altitude Water Cherenkov Gamma-Ray Observatory (HAWC). The TSPM will also represent an excellent follow-up complement for the extremely large telescopes that will begin operation after 2020.

5.2 Brief history of the OAN and the OAN-SPM

The Observatorio Astronómico Nacional (OAN) as it exists today was established in 1873 by presidential decree. It was first set up in the Castillo de Chapultepec in Mexico City. A few years later, it was moved beyond the then capital to the nearby town of Tacubaya where it remained until the early 1950s. In 1929, when the UNAM received its autonomy from the federal government, it was entrusted with maintaining and developing the OAN on behalf of the nation. Long before the OAN's subsequent move to the town of Tonantzintla, near the city of Puebla, the light pollution from Mexico City made astronomical observation in Tacubaya impossible. Although Tonantzintla served as the main observing station of the OAN for only a relatively short time, it was a tremendously productive period. Nonetheless, by the early 1960s it was clear that the OAN needed to establish another research station in a location with dark skies if it was to remain competitive as an observatory. In the mid 1960s, a concerted effort was made to identify the most suitable locations within Mexico considering not only the availability of clear, dark skies, but also the likelihood of their remaining so for decades to come. By 1967, the Sierra de San Pedro Mártir (SPM) in Baja California had been identified as this most suitable location (see Figure 1). That year, work began on the road to the present installations at the OAN-SPM and by 1970 the first permanent building at the site (cabaña roja) and first telescope (1.5m Harold Johnson Telescope) were built. The following year, the second telescope (0.84 m telescope) was brought into operation. By the mid 1970s, plans were afoot to construct the 2.1m telescope, which was inaugurated in 1979 and remains the largest telescope at the OAN-SPM. Currently, both the SPM and Tonantzintla stations of the OAN are maintained by the IA-UNAM.

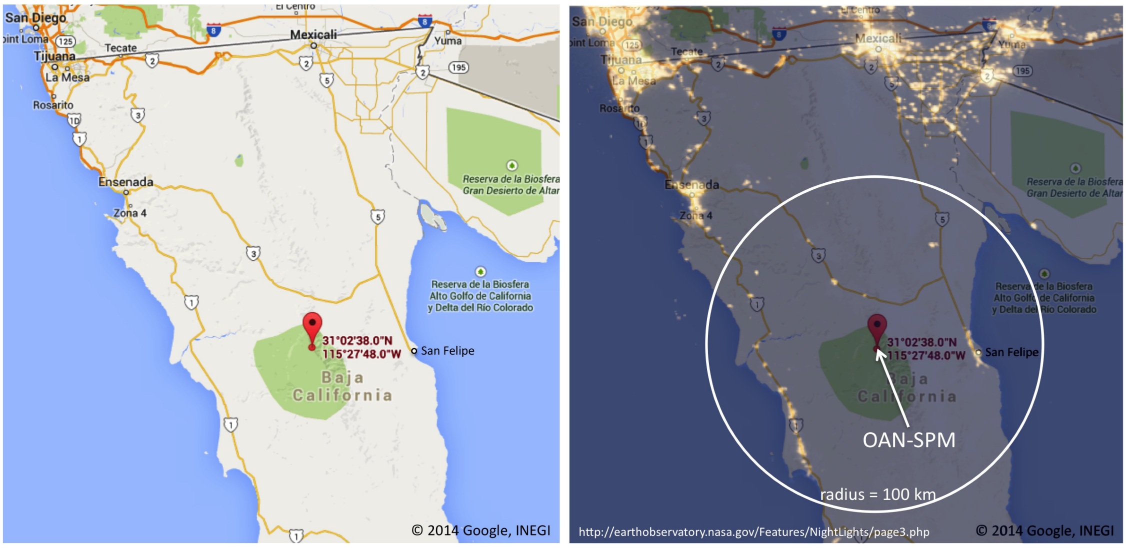

Figure 1: *The OAN-SPM is located in northern Baja California on the highest mountain range in the state. As the right panel shows, it is still a dark, isolated location.*

The OAN-SPM is located within the Parque Nacional Sierra de San Pedro Mártir (PNSSPM) as a result of a presidential decree in 1975. The PNSSPM itself had been established by presidential decree in 1947. The OAN-SPM participated in drafting the management plan for the PNSSPM that was published in 2009. This management plan was complemented in 2012 when a perimeter containing 3048 ha surrounding the OAN-SPM were legally reserved for astronomical use through an agreement between the UNAM and the Comisión Nacional de Áreas Naturales Protegidos (CONANP), part of the Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT).

Given its history of fleeing from light pollution, for several decades the OAN-SPM has been active in promoting regulation to protect its dark skies, particularly within the municipality of Ensenada, where it is located. In 2006, the municipality of Ensenada enacted the first legislation within Mexico that included light pollution as part of its environmental protection. As part of the effort related to the International Year of Astronomy in 2009, the IA-UNAM lobbied the state government to include similar legislation at the state level, which came into effect in 2010.

International collaborations have long been a part of the OAN-SPM. The first telescope installed at the OAN-SPM was a collaboration between the IA-UNAM and the UA, motivated largely by Harold L. Johnson. Since then, many projects have been carried out in collaboration with international partners. At present, three operating instruments are hosted at the OAN-SPM as a result of collaborative agreements with the Observatorio Astronomico di Brera (Boller & Chivens spectrograph), the University of Manchester (Manchester Echelle Spectrograph; MES), and a collaboration involving the IA-UNAM, University of California, Arizona State University, and the NASA Goddard Space Flight Center (Reionization And Transients InfraRed project; RATIR). The BOOTES-5 telescope was installed in 2015 as a collaboration between the IA-UNAM, Spain's Agencia Estatal Consejo Superior de Investigaciones Científicas (CSIC) through the Instituto de Astrofísica de Andalucia, and the Sungkyunkwan University in South Korea. Currently, the IA-UNAM is building the TAOS-II project at the OAN-SPM in collaboration with the Academia Sinica Institute of Astronomy and Astrophysics (ASIAA) and the SAO.

5.3 OAN-SPM operations relevant to the TSPM project

Although the TSPM will be located at the OAN-SPM, it will not be part of the OAN-SPM. Rather, like the BOOTES-5 and TAOS-II telescopes (§4.2), it will be hosted at the OAN-SPM. Hence, the TSPM will benefit from (contract) various services and common infrastructure at the OAN-SPM, but will be operated and maintained by the consortium involved in its construction. An as yet undefined legal entity will construct and eventually operate and maintain the TSPM on behalf of this consortium (§7.5.1). This legal entity is expected to exist by the end of 2017. It is expected that all of the personnel involved in the construction, operation, and maintenance of the TSPM will be contracted through this legal entity. Similarly, the equipment required for the routine operation and maintenance of the TSPM will belong to this legal entity or be provided by the partner institutions within the TSPM consortium.

Given that the foregoing necessarily implies interaction between TSPM operations and OAN-SPM operations, it is useful to describe some aspects of the OAN-SPM's operation. Many of the OAN-SPM's practices are the result of its experiences with severe winter storms (§§5.7,9.5.2). Typically, in November, the full complement of fuel tanks is filled (60 kl), which are sufficient for four months of power generation. Also, the OAN-SPM makes a habit of maintaining a considerable stock of non-perishable food, typically sufficient for more than a month's supply, but this is also topped up before the beginning of winter.

5.4 TSPM scope

The First Light scope for the TSPM is to provide a telescope that is functionally equivalent to the f/5 Cassegrain configurations at the MMT and the Magellan Clay telescopes with the Megacam instrument. Operation with the MMIRS (Day 1) instrument would occur approximately ten months later. Once experience is gained with these two instruments, other instruments will be brought online. These subsequent instruments could be existing MMT instruments or new instruments.

Post-Day 1, the general goal is to implement additional focal stations according to the needs and interests of the partners. The TSPM design specifically contemplates two extreme configurations whose impact is very important in the design of the telescope and enclosure. The first is a Cassegrain f/5 configuration at Nasmyth with the same field of view available as at the Cassegrain focal station (Day 1). The second is a Gregorian f/11 configuration at Nasmyth that would have about half the field of view available at f/5 Cassegrain. These two configurations are considered extremes and it is expected, though beyond the scope of the TSPM project, that it will be possible to implement other optical configurations operating within the physical boundaries that the above two configurations imply (lengths, masses, physical field of view). The Nasmyth focal stations should designed to accommodate larger instruments than are feasible at the Magellan Nasmyth focal stations, if possible, with instruments weighing up to four tons.

5.5 TSPM scientific goals and objectives

At present, the TSPM science case is based almost entirely upon efforts and interests of the Mexican astronomical community. A near-term goal is to involve the UA and SAO communities to a much greater extent. Discussions among the institution directors have already taken place to involve faculty at each institution on the science team.

A long-term goal, stated in the LoI (§4.3), is to operate both the TSPM and MMT as a joint bi-national astrophysics laboratory, with access to both telescopes by all of the communities involved in the TSPM project, and the implementation of complementary and large-scale programs that will take advantage of the specific capabilities of each telescope.

The science cases considered so far for the TSPM span a very wide range of interests, from stellar and Galactic studies to cosmology, using techniques from single object spectroscopy to deep optical and near-infrared surveys. These are documented in detail elsewhere. To realize all of these science cases will require a greater diversity of instrumentation than will be available at Day 1 or shortly thereafter. The goal of jointly operating the TSPM and MMT is a quick path toward making the required instrumentation available.

Given that the TSPM will operate in the era of the Giant Magellan Telescope, the Thirty Meter Telescope, and the Extremely Large Telescope and its planned operation with the MMT as a binational observatory, the TSPM should focus on wide-field science. On the other hand, given that the TSPM will not compete with facilities such as the Large Synoptic Survey Telescope, the relevant wide-field science case is likely to be in wide-field spectroscopy. Hence, the TSPM should plan space for large fiber-fed spectrographs (though this capability will not exist at Day 1).

5.6 The TSPM project

Over a period of at least two decades, the IA-UNAM and INAOE formulated a variety of proposals to build a large, modern telescope on behalf of the Mexican astronomical community.

These efforts were merged in the mid-2000s in the form of the Twin Project. The TSPM project is a successor to that project.

The TSPM project is based upon a Letter of Intent (LoI) signed between INAOE, IA-UNAM, SAO, and UA in August 2012 whose objective is to construct, operate, and maintain a 6.5m telescope at the OAN-SPM. This LoI specifies the contributions and responsibilities of the partner institutions: The IA-UNAM contributes the site; INAOE and UA contribute the 6.5m primary mirror system; the SAO and UA contribute the secondary mirror, wide field corrector optics (1° field of view), and first light instruments currently in use at the MMT and Magellan telescopes; and the Mexican partners contribute the enclosure, telescope structure, and control system. The LoI also states that the partners agree to explore the joint use of the TSPM and the MMT as a binational astrophysical observatory open to astronomers in Mexico, SAO, and UA. The Mexican astronomical community, UA, and SAO conform the TSPM consortium. Eventually, a more complete legal structure must be constructed to account for the specifics of each partner's contributions and how these are reflected in terms of observing time for each partner.

For the Mexican astronomical community, the TSPM should be a general-purpose facility that may undertake a wide range of astronomical research, similar to such facilities as the Gemini Telescopes, the European Southern Observatory, the Magellan telescopes, or the MMT. The TSPM is expected to be a workhorse instrument for at least the next four decades. Since a large fraction of the TSPM's financing will come from federal sources, the TSPM is also expected to be a driver for the development of technology, design, and manufacturing capability in Mexico. As such, it is hoped that the TSPM's impact extends considerably beyond the astronomical and academic communities to enhance Mexico's competitiveness and capabilities in engineering and technological development. However, in order to minimize the risk involved in the telescope design and construction, it should follow existing designs when possible.

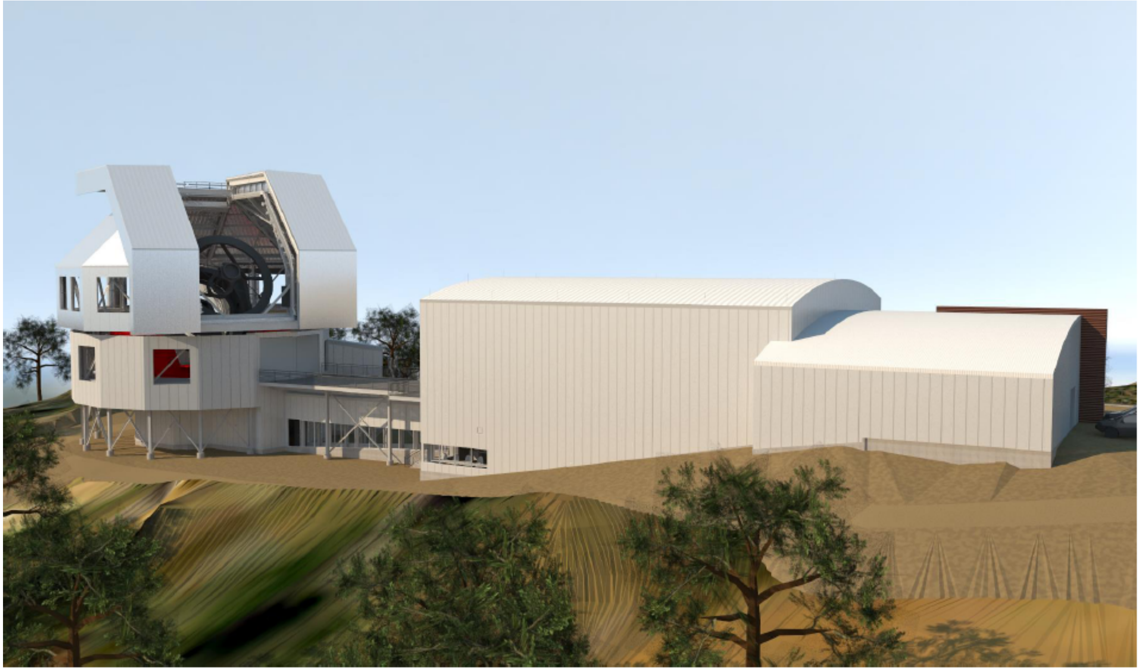

Figure 2: *Concept rendering of the TSPM telescope enclosure and support building, courtesy of M3.*

Figure 2 presents a rendering of the TSPM telescope enclosure and support building. The support building is on the higher ground, to the east-northeast of the telescope enclosure.

As Figure 2 makes clear, the Magellan telescopes are the model for many aspects of the TSPM project, though it borrows important elements from the MMT. However, the TSPM is not a copy of either telescope. During the feasibility study, the options of copying either the Magellan or MMT telescopes were considered, as were modifications of these designs to various degrees. The TSPM design allows "modest" wide field instruments (up to 1° field of view) combined with the ability to mount and use several instruments interchangeably. As a result, the TSPM resembles the Magellan telescopes, but has several important changes. The most fundamental of these is that the elevation axis is 20 cm farther from the primary mirror in order to allow a physically larger field of view at the Nasmyth focal stations. There is also 40 cm more clearance between the floor and the underside of the primary mirror cell, to accommodate larger instruments. The Nasmyth platforms are likewise sized to allow larger instruments, up to 4 tons. Finally, the design of the primary mirror cell is very similar to that of the MMT. The first of these changes has the greatest impact upon the telescope's mechanical structure since it forces the TSPM be significantly more massive than the Magellan telescopes.

The TSPM design specifically considers three optical configurations, as shown in Figure 3. The first is the Day 1 configuration, which is a Cassegrain f/5 configuration that is functionally equivalent to the Cassegrain f/5 configurations at the Cassegrain focal stations of the MMT and Magellan Clay telescopes. This configuration has a 1° field of view at the Cassegrain focal station. The second optical configuration is an f/5 Nasmyth focal station with the same field of view as at the Cassegrain focal station. This configuration requires moving the telescope's elevation axis 20 cm farther from the primary mirror than at Magellan to provide a physically larger focal surface at the Nasmyth focal station. Although these two optical configurations share the same focal ratio, they require different secondary mirrors and are not confocal. The third optical configuration is a Gregorian f/11 configuration at the Nasmyth focal station. This configuration fixes the maximum length of the telescope and so also fixes the size of the dome. Initially, the TSPM project will implement only the Day 1 configuration, i.e., the Cassegrain f/5 configuration at the Cassegrain focal station.

The enclosure is also modelled on that at the Magellan telescopes (see Figure 2). The telescope enclosure is an octagonal dome with bi-parting shutter doors. There are ventilation windows on both the fixed and rotating parts of the dome. Inside the dome, there is a crane that can access the entire central area of the dome, including the telescope's Nasmyth platforms. There is also a platform from which the secondary mirror may be serviced. The lower level of the telescope enclosure is partly open, to promote airflow as at Magellan. The lower level includes space for a future spectrograph room, but this will not be implemented initially. The upper level of the telescope enclosure is linked to the support building by a bridge, over which the M1 cell will travel during the aluminization process and the instruments when they are exchanged. The support building is uphill from the telescope enclosure, towards the east-northeast. Thus, the bridge connects to the upper level of the support building, and this level is at ground level on the side of the support building opposite the telescope enclosure, where the delivery bay is located. This orientation of the telescope enclosure and support building perturbs the terrain as little as possible and is also reasonable match to one of the minima in the wind rose (Figure 4). The telescope control room is on the lower level of the support building. A tunnel, below the bridge, connects this level to the lower level of the telescope enclosure.

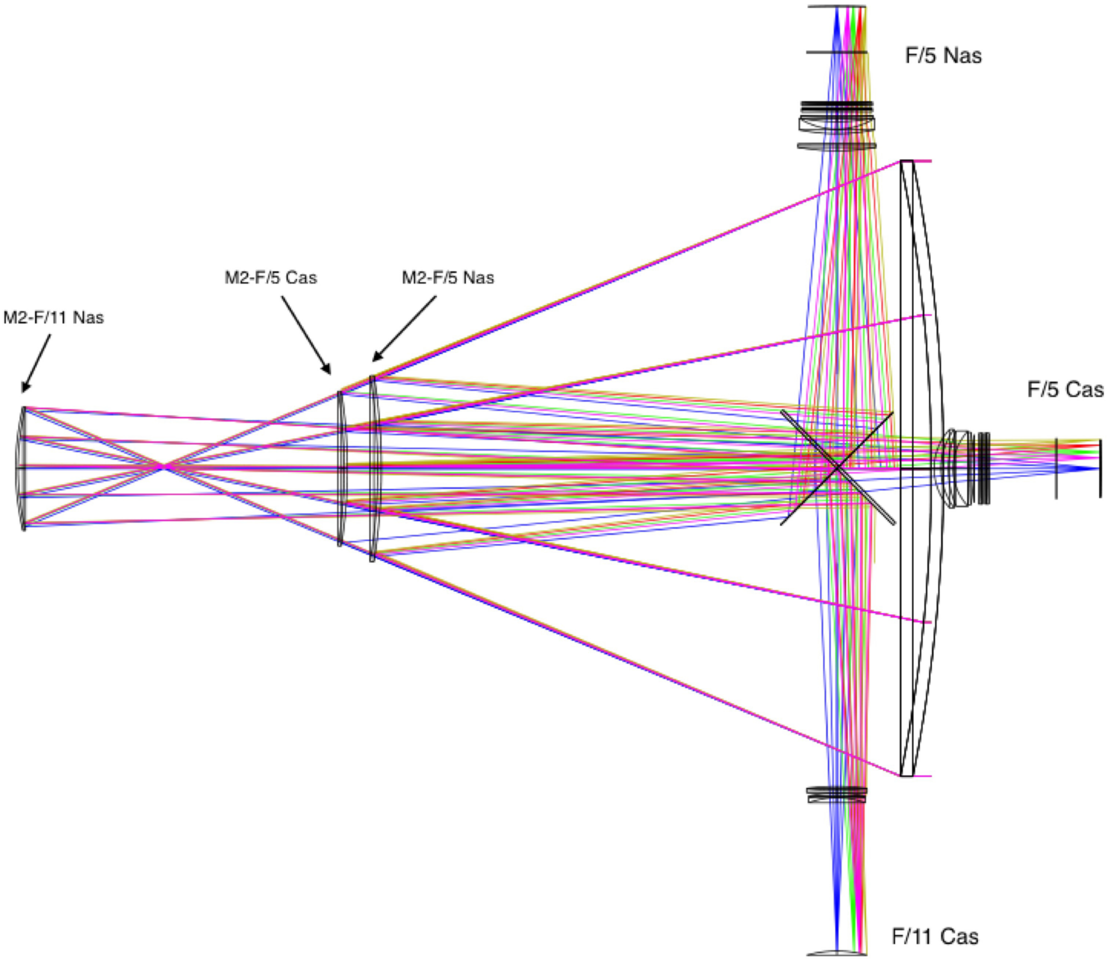

Figure 3: *The TSPM project formally incorporates three optical configurations. The First Light/Day 1 configuration is the f/5 Cassegrain configuration at the Cassegrain focal station.*

Figure 4 shows the location of the TSPM site within the overall site plan of the OAN-SPM. The TSPM is at the western end of the ridge where most of the telescopes are located. (The TAOS-II project is being built to the east of the map shown in Figure 4.) BOOTES-5 is not shown either, but is on the hill west of the 2.1m telescope.) For reference, a wind rose is also shown (see §5.7 for details).

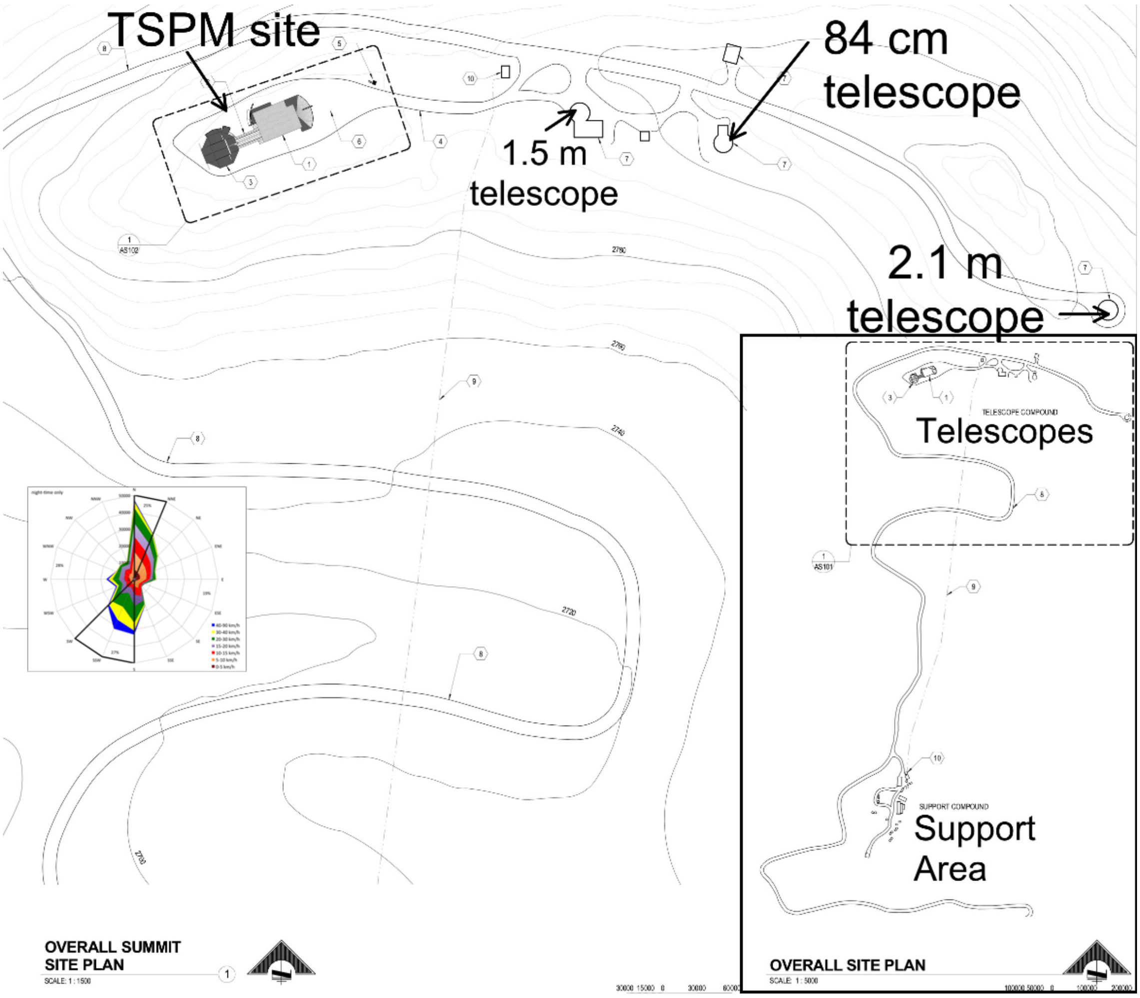

Figure 4: *This map shows the overall OAN-SPM site plan. The telescopes are located on a narrow ridge that runs approximately east-west. The TSPM site is at the western end of this ridge. The wind rose from the OAN-SPM's mechanical anemometer is also shown. The emergency power generator is located just to the west of the 1.5m telescope.*

5.7 TSPM Site

The OAN-SPM is located at approximately 2800 m above sea level (telescope area) in the north-central part of the state of Baja California, Mexico. There have been studies of the climate at the OAN-SPM since its inception, so the conditions are well known, including severe weather conditions. Indeed, the latter have contributed to establishing many of the policies practiced at the OAN-SPM. Many more details of what follows may be found in R.35, R.36, and R.37.

There is a clear seasonal variation in temperature at the OAN-SPM (Figure 5, top left). The summers are mild, with daytime temperatures rarely exceeding 25 C. In winter, the coolest monthly mean temperature is near zero, but temperatures as low as approximately -18 C have been recorded. There is greater variation of the temperature in winter than in summer and greater variation during daytime than at night. The median daytime and night time temperatures (2009-2013) are 10.4 C and 6.8 C , respectively, and the median daily temperature excursion, from daytime high to night-time low, is 5.9 C (Figure 5, top right), most of which occurs during daytime hours (Figure 5, bottom). On average, sunrise is the coolest moment of the day and the temperature at sunset is about 1 C warmer, with a dispersion of about ±2 C (Figure 5, middle right). After sunset, there is about an hour during which the temperature cools quickly, but thereafter a much slower cooling takes place until sunrise. The median temperature excursion at night is only 2.5 C and the hourly temperature gradients are 0.6 C/hour or less 84.6% of the time. The largest temperature gradients occur just after sunrise and just before sunset (Figure 5, middle left).

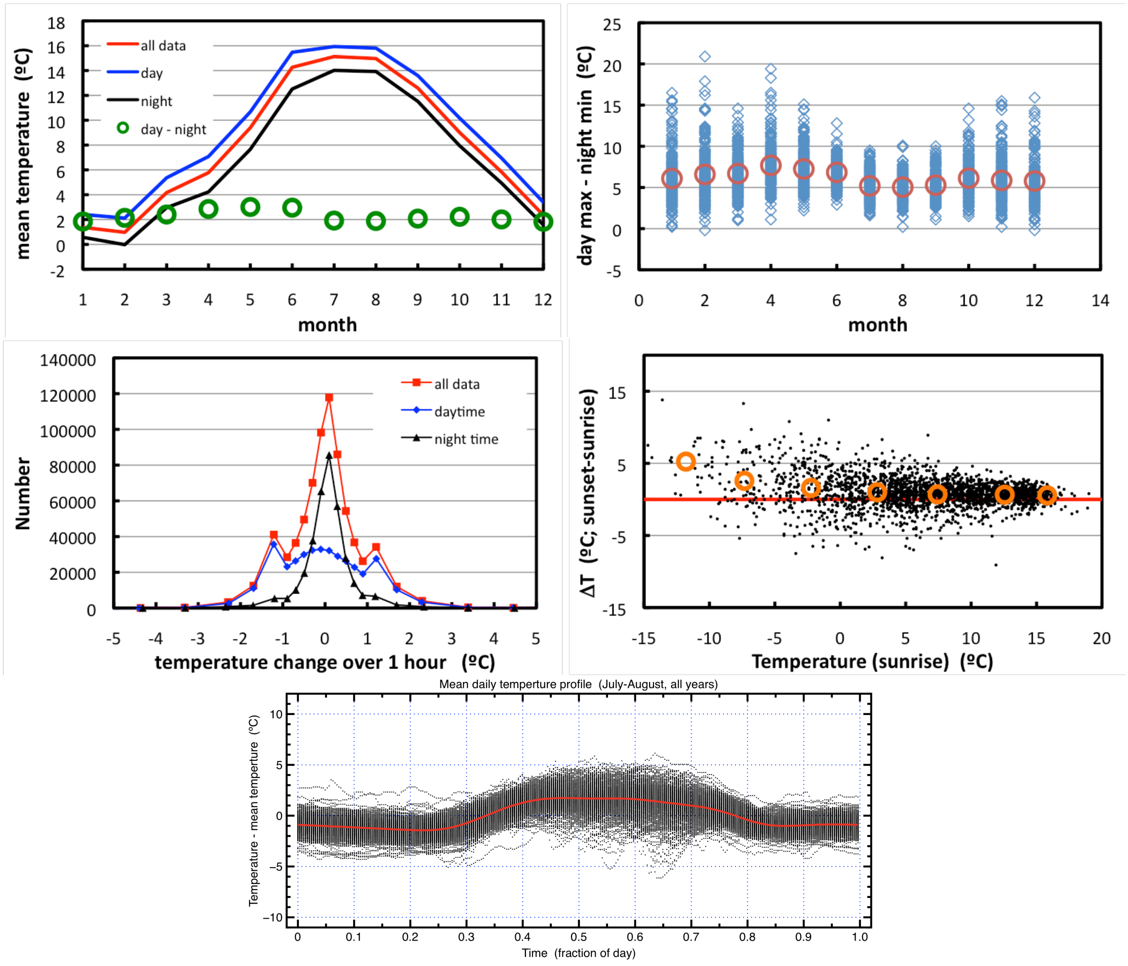

Figure 5: *The top left panel shows the annual variation in mean monthly temperature at the OAN-SPM. The top right panel shows the daily temperature excursion as a function of month through the year. The middle left panel presents the distribution of hourly temperature gradients. The middle right panel presents the difference in temperature between sunset and sunrise each day as a function of the temperature at sunrise. The bottom panel presents the mean temperature profile for days in July and August (temperature – mean temperature).*

Precipitation falls as snow during the winter. There is also a period in summer, of approximately six weeks' duration, usually centered on August, when afternoon thunderstorms are common. The amount of precipitation can vary dramatically on an annual basis.

Figure 6: *This photo shows the dome for the 1.5m telescope as access was restored to the OAN-SPM after the severe winter storm in January 2010. Photo courtesy of Ignacio González.*

Historically, severe weather only occurs in the form of winter snowstorms. These can deposit of order 1.5 m of snow in periods of 24 hours or less. On various occasions, these have not only closed the observatory, but also trapped personnel onsite with no means of escape. The frequency of these severe storms is once or twice per decade, with the most recent events in 1998 and 2010 (Figure 6; more details in §9.5.2). The OAN-SPM is the only organization in the area (and one of only two in the state) with snow removal equipment. What has proven most feasible in these cases is to prepare the installations by draining pipes, shutting off generators, etc., and then evacuating both personnel and snow removal equipment before a storm hits. Once the storm passes, the roads are cleared, the personnel return, and the installations are brought online again. These storms inevitably arrive from the Pacific Ocean and their existence is known days in advance. However, their exact paths are much more uncertain, and it may be impossible to decide whether to evacuate until the day before the storm hits. The head of the OAN-SPM has taken the decision to evacuate personnel. The return to operations can be delayed significantly due to the precipitation that falls as rain at altitudes lower than the observatory, which can cause flooding that has occasionally taken out bridges on the transpeninsular highway. Access to the OAN-SPM is only possible once such collateral damage has been repaired. Typically, access to the OAN-SPM is restored within two weeks of evacuation.

The winds at the OAN-SPM come primarily from two directions about 60-70% of the time: N to NE and S to SW (Figure 7, lower left). Winds from the N to NE are more frequent during the day, and those from the S to SW are more frequent at night (Figure 7, lower left). At night, winds from the S to SW dominate in the first half of the year (Figure 7, lower middle), but winds from the N to NE are more common in the second half (Figure 7, lower right). In all of these cases, the dominant winds only have a slight advantage over the other dominant direction. The wind at the OAN-SPM is not especially strong. The sustained wind speed (5-minute average) is less than 35 km/h 95% of the time (Figure 7, upper left) at a height of approximately 9 m above the ground. Wind gusts are within 20 km/h of the sustained wind speed 95% of the time (Figure 7, upper left). The maximum wind speed observed over a period of nearly 9 years is approximately 130 km/h, but the fraction of time with wind speeds or gusts in excess of 100 km/h is less than 0.05%. The vertical wind speed is 6 km/h or less 99.9% of the time (Figure 7, upper right). Winds are somewhat stronger at night than during the day (Bohigas & Núñez 2010).

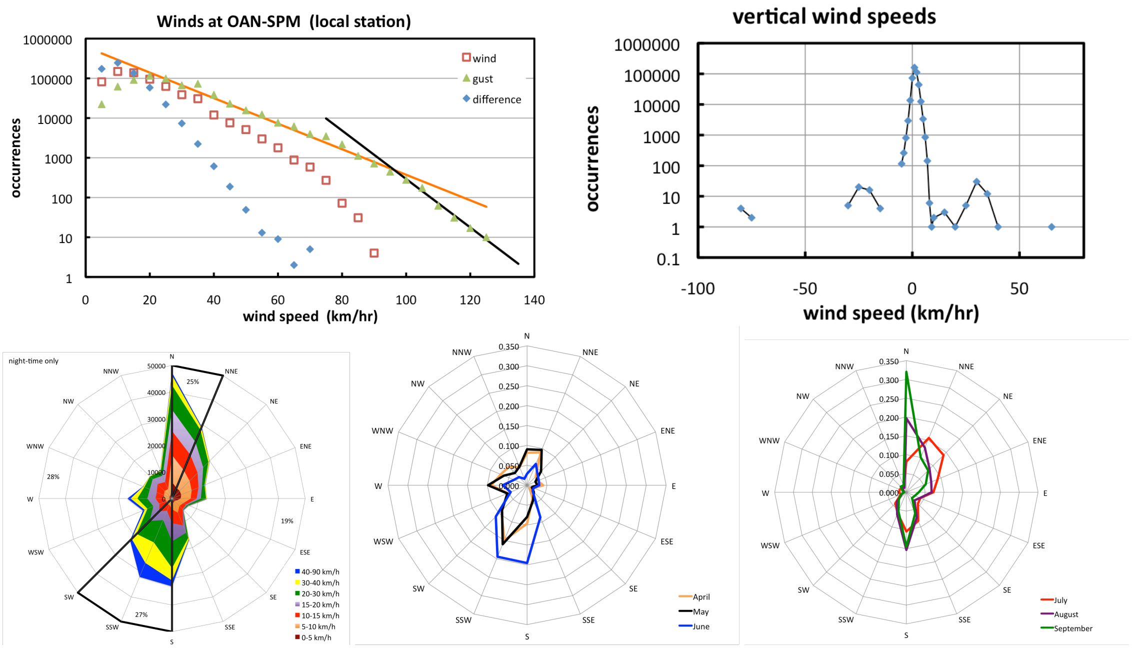

Figure 7: The panel at top left presents the distribution of sustained wind speeds (5 min. average) and gusts (instantaneous) from the OAN-SPM's mechanical anemometer. At top right is the distribution of vertical wind speeds measured using the LSST/TMT's sonic anemometer. The bottom row presents wind roses (OAN-SPM's mechanical anemometer) for all data acquired at night (left), at night during April-June (middle), and at night during July-September (right), demonstrating the two main wind directions as well as their seasonal variation.

In recent decades, approximately 70% of nights are photometric and 80% spectroscopic (Tapia et al. 2007). The night sky is very dark (Figure 8), with recent (2013-2016) measurements indicating sky brightness of 22.6 and 21.6 mag/□" in the B and V bands, respectively (Plauchu-Frayn et al. 2016), though this is expected to depend upon the phase and strength of the solar cycle (the current cycle is weak). The median seeing at 5000Å is 0.79". The seeing is known to degrade with wind speed, but not its direction (Echevarria et al. 1998, Skidmore et al. 2009). The ground-layer turbulence at the OAN-SPM is known to be significant (Skidmore et al. 2009), but it has also been found that much of this turbulence is within 10 m or so of the ground level (Echevarría et al. 1998; Sánchez et al. 2003), a trend that continues unabated to an altitude of approximately 100m (Schöck et al. 2009; Els et al. 2009). The comparative site study undertaken by Bohigas et al. (2008) supports such a thick ground layer, as they found little variation of the seeing, temperature, humidity, and wind speed at five sites in the neighbourhood of the OAN-SPM. The precipitable water vapor median value is 3.4 mm (Otarola et al. 2010).

Figure 8: *The skies at the OAN-SPM remain very dark.*

Northern Baja California is crisscrossed by various fault systems, generally related to the interaction of the Pacific and North American tectonic plates. Although there has never been a strong earthquake at the OAN-SPM, they are not impossible and small earthquakes do occur. Several institutions maintain seismometers at the OAN-SPM given its proximity to the Mexicali valley, where many earthquakes related to the San Andreas fault do occur. A detailed geotechnical study of the TSPM site, including a site specific seismic hazard analysis, was done in the first half of 2016 based upon extensive field studies undertaken in late 2000 and late 2015 (see §9.5.3). This study was reassessed in 2017 and its recommendations were tightened.

At the latitude of the OAN-SPM, there are 4319 hours per year between sunset and sunrise and each of civil, nautical, and astronomical twilights represent about 1 hour each day[1]. Therefore,

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[1] http://aa.usno.navy.mil/data/docs/RS_OneYear.php

excluding civil and nautical twilight, there are up to 3589 hours available yearly for astronomical observations and calibrations under skies that are at least nearly dark. That figure does not account for time lost to weather, which is likely to be about 20%, leaving approximately 2871 hours yearly.

The OAN-SPM is located within the PNSSPM. The park is subject to a management plan to which all users must adhere, including the OAN-SPM and any installations it hosts. In practice, complying with the requirements of the management plan begins when the TSPM project seeks permission to build the project.

The following summarize the conditions that the TSPM project must survive (survival limits):

- Relative humidity range: 0% to 100%
- Temperature range: -25^{o} to $+35^{o}$ C
- Atmospheric pressure range: 710 mbar to 740 mbar
- Maximum precipitation rate: 300 mm in 24 hours and 120 mm in 1 hour.
- Wind: 170 km/h
- Snow load: 400 kg/m^2
- Ice height: 100 mm (density 917 kg/m^3)
- Earthquake peak spectral accelerations: horizontal 0.856g, vertical 0.571g (CFE study update 2017, see §9.5.3)
- Electrical storms
- Winter storm evacuation period: 2 weeks maximum

Note that the installations will not necessarily be in use during these survival conditions, e.g., observing, but generally there will be personnel present. In this context “survive” means that the observatory is completely undamaged and no corrective maintenance is required to return the observatory to normal operations once the conditions relent.

The operating limits, including those for reduced performance (affects temperature only), of the TSPM are taken to be:

- All the survival limits except the following:
    - No precipitation or electrical storms
    - No high levels of suspended particulates
    - Sustained wind speed limit: 50 km/h
    - Wind gusts speed limit: 70 km/h
    - Sustained wind speed limit for dome closure: 80 km/h (max)
    - Relative humidity limit for dome closure: 90% or at condensation point
    - Temperature range: -18°C to +30°C (optimum: -2°C to +18°C; goal: -5ºC to +18ºC)

These conditions span 100% of the temperature range (considering the frequency of occurrence). It will not be feasible to attempt to cool the oil for the TSPM’s hydrostatic bearings over this range, so a more restricted range (“optimum” above) is defined that covers 90% of the temperature range (in frequency of occurrence; the range given as goal covers 95%).

The limit of 50 km/h on the sustained wind speeds covers 98.9% of all wind speeds measured at the OAN-SPM (measured by the facility mechanical anemometer).

6. PREVIOUS INFRASTRUCTURE

Currently, the OAN-SPM operates three telescopes whose primary mirror diameters are 0.84 m, 1.5 m, and 2.1 m. The OAN-SPM also hosts the BOOTES-5 (see §4.2), COATLI, and DDOTI telescopes. The OAN-SPM is also the site where the TAOS-II project is being built (see §4.2). At present, the SAINT-EX and COLIBRÍ projects are in design or under construction and will be located at the OAN-SPM. COATLI is a collaboration between the IA-UNAM and Arizona State University. DDOTI is a collaboration between the IA-UNAM, Arizona State University, and the University of Maryland. COLIBRÍ is a collaboration between the IA- UNAM and CONACyT in Mexico, and Centre National d'Etudes Spatiales, Centre National de Recherche Scientifique and Aix-Marseille Université in France. Finally, SAINT-EX is a collaboration between the IA-UNAM and the SAINT-EX Consortium, composed of the Center for Space and Habitability at the University of Bern, the NCCR PlanetS, the University of Cambridge, and the University of Geneva.

All of these installations share (or will) an electricity grid as well as fiber optics network and microwave antenna for telecommunications, all of which are maintained by the OAN-SPM as common facilities. Likewise, they share in the use of the lodging and dining facilities, and all benefit from the road maintenance undertaken by the OAN-SPM, especially snow removal in winter. The OAN-SPM also has a waste holding facilities that all of these installations use. It is expected that the TSPM will also make use of this common infrastructure and provision of services through agreements with the IA-UNAM.

The OAN-SPM is not connected to the national electrical grid, but produces its own power using diesel generators. There are three main generators, each of which are operated in turn for two-week service periods. Between these service periods, the OAN-SPM personnel undertake any maintenance that the generators may require. The three main generators feed the entire electrical grid, including both the telescope area and the support compound (see Figure 4). Should the power from the main generators fail, there is an additional emergency generator in the telescope area that is usually configured to provide power to the telescopes only. (The electrical transfer can be configured to provide power to the entire observatory, if necessary.) The emergency generator is equipped with sensors that bring it online automatically within 30 seconds of a power loss from the main generators. The emergency generator transfer feeds the same electrical lines that are used by the main generators. Internally, each telescope divides the power feed into "normal" and UPS power circuits according to the needs of the equipment.

Currently, an electricity line is under construction that will connect the OAN-SPM to the national electricity grid (further details in §9.5.1). This will replace the energy currently produced via diesel generators, but is not otherwise expected to affect the internal electricity grid. The electricity line will also include a fiber optic connection. In addition to the fibers used for telecommunications, the OAN-SPM will have 6 additional dark fibers for future applications. Once completed, these facilities will be available to all of the users at the OAN-SPM, including the TSPM project.

7. OPERATIONAL OVERVIEW AND REQUIREMENTS

The TSPM High Level Requirements (HLRs; see R.12) stipulate the following. However, the HLRs have not been vetted by all of the partners, so it is feasible that some details may change.

- TSPM shall be suitable for general science projects.
- TSPM shall minimize risks by following existing and proven reference designs (e.g., the MMT and Magellan) where appropriate and possible.
- TSPM shall start operations with the f/5 Cassegrain focus.
- TSPM shall permit upgrades to provide two Nasmyth and four Folded Cassegrain focus.
- TSPM shall not exclude the future development of the capacity to use multiple Nasmyth and Folded-Cassegrain stations in one night. Note that the Cassegrain focal station shall not be available concurrently the Nasmyth and Folded Cassegrain stations (i.e., daytime actions are required for changing between Cassegrain and the other focal stations).
- The following observing modes shall be considered: engineering, queued, classical, remote and robotic (TBC) modes. These modes shall be defined as follows:
- Engineering mode is when the TSPM usage is not part of a science program, and is performed by the observatory staff for development, maintenance and calibration of the telescope, subsystems or instruments.
- In queue mode, a staff astronomer directs astronomical observations.
- In classical mode, a member of the proposing team directs observations on site.
- In remote mode, a member of the proposing team directs observations remotely.
- In robotic mode, an autonomous system directs observations.
- TSPM should, where appropriate, minimize engineering time, down time and set up time, and ensure clear and simple operations.
- TSPM shall be maintained and operated by specialized and dedicated support and operation staff.
- TSPM shall provide adequate training, simulators, and documentation for support and user astronomers as well as operations and maintenance staff.
- TSPM shall provide appropriate tools and systems to plan and carry out observations efficiently in the implemented observing modes.
- TSPM shall provide the appropriate tools and systems for quality control of the observations.
- The allowed MTBF for small scale events requiring a MTTR of one hour or less shall be one week. The allowed MTBF for intermediate events requiring a MTTR of 24 hours shall be 3 months. The allowed MTBF for major events requiring a MTTR of one week shall be one year. Therefore, the annual downtime percentage shall be a maximum of 4.5%.
- The TSPM state and services shall be continuously monitored.
- A long-term data base of TSPM calibration and state data shall be implemented for fault and performance analysis.

- The relevant aspects of TSPM monitoring for operations shall be displayed and proper fault and diagnostic alarms implemented.
- TSPM observing (meteorological and atmospheric) conditions shall be an integral part of the control system.
- The annual operation cost should not exceed 11.5 (goal 5.75) million USD (2014).
- The scientific lifespan of TSPM shall be at least 40 years, counted from the start of science operations.

7.1 Operational objective

The primary operational objective of the TSPM project is to deliver a telescope and associated instrumentation that permit world-class astronomical research. The Mexican astronomical community expects the TSPM to be a general-purpose facility that can address a wide range of scientific interests. As such, the TSPM should focus on the wavelength range from the near ultraviolet to the near infrared (0.3 to 2.5 μm), though it should not absolutely exclude observations at mid-infrared wavelengths even though its efficiency may be penalized in the mid-infrared. At optical and near-infrared wavelengths, the telescope should contribute minimally to the background, while its contribution to the background in the mid-infrared should be similar to that of other general-purpose telescopes. The TSPM should take advantage of the good natural seeing in SPM.

In its initial configuration, the TSPM should be functionally equivalent to the f/5 Cassegrain configurations at the MMT and the Magellan Clay telescopes. To that aim, the TSPM will incorporate several important elements that already exist (e.g., M1, M2, Cassegrain wide field corrector, instruments). Hence, it is hoped that the project may be implemented quickly since these components and needs fix a number of the design decisions that would otherwise be open. Likewise, it is expected that many of the design solutions implemented in the Magellan and MMT telescopes can be applied to the TSPM project. Given the limited experience in implementing such projects, the TSPM project intends to use the MMT and Magellan telescopes as references when possible, from both design and operational perspectives. Even so, it would make sense to extend the capabilities to some extent when possible. For example, the TSPM should allow larger instruments at the Nasmyth focal stations.

Eventually, the TSPM project should permit the development of other focal stations, instruments, and observing modes that may be different from those at the MMT and Magellan telescopes. These future capacities will give the project greater flexibility to adjust to observing conditions, perhaps even the use of several instruments in a given night. These capacities should make the TSPM a cornerstone upon which Mexican astronomy may develop during the next several decades as new scientific interests and priorities emerge.

7.2 Safety requirements

Safety requirements are identified at the TSPM HLRs (see R.12).

- TSPM shall be as safe as similar international facilities.

- The safety priorities of TSPM shall be (in order of importance):
- Human integrity and protection
- TSPM facility safeguarding and integrity
- Science data protection
- TSPM shall comply with applicable national and international safety regulations.
- TSPM operation and maintenance procedures shall be documented and validated.
- The TSPM operation plan shall explicitly address the safety implications of human factors.
- All acquired equipment or any services subcontracted shall comply with TSPM safety standards.
- TSPM shall implement hardware and software limits for the operation of all relevant systems.
- The TSPM shall not be operated beyond its defined operational limits.
- For safety reasons, it shall be possible to shut the dome in under 2 minutes.
- The TSPM premises should be protected from the access of unauthorized persons.
- The TSPM control and communications systems should be protected from unauthorized access at the premises or through the Internet. Access codes and privileges should be established for the different classes of users.
- TSPM operation and maintenance procedures should provide protection against accidental loss of scientific data.

The OAN-SPM's remote location makes personnel safety the highest priority. Although the OAN-SPM has a doctor present at all time (as of 1 February 2017), as a result of an agreement between the IA-UNAM and UNAM's Facultad de Medicina, the OAN-SPM's infirmary is intended to deal with minor injuries only. The nearest permanently staffed clinic is in San Quintín, within about a three-hours' drive, and the nearest hospital is in Ensenada, five hours away. Hence, personnel safety, based upon preventive measures and practices, must be the highest priority and must be implemented from the beginning of the project's construction phase. The mountain supervisor has the final word on safety issues at the OAN-SPM. The TSPM project will implement an equivalent figure to oversee safety issues within its installations.

In order to make safety the highest priority for the TSPM, its personnel must comply with national and international safety regulations. It will be necessary to develop and document operations and maintenance procedures that likewise comply with these safety regulations and that make human safety the highest priority, regardless of whether these activities are carried out by TSPM personnel or outside contractors. An important part of human safety is defining and scrupulously respecting hardware- and software-defined limits for the operation of all mechanisms. All moving systems shall have braking mechanisms that bring them to rest in 5 seconds or less. The TSPM shall implement an interlock and safety system to further protect personnel and visitors from injury. In particular, the interlock and safety system shall have motion sensors in the dome that disable telescope or dome motions if motion is detected during operation controlled from the telescope control room. Finally, the TSPM shall limit physical and programmatic (computer) access to its installations so that unauthorized persons are not present and that personnel unfamiliar or untrained in the operation of the installations do not operate them, though all will have access to emergency stop buttons.

The foregoing also serves to preserve the physical integrity of the TSPM facility and its equipment, which is the second safety priority. Since the weather can sometimes change very quickly, the dome should close completely (shutter doors and ventilation windows) in less than 2 minutes. Given that severe winter weather can sometimes force the evacuation of the OAN-SPM, **the TSPM will implement or contract from the OAN-SPM the generation of safe, autonomous backup power in order to allow the safe and controlled shutdown of cryogenic instruments that could be damaged by simply cutting the power supply and to keep pipes from freezing during a prolonged absence**.

The final safety priority concerns data. The TSPM will implement backup systems, on- and off-site, and procedures that guard against accidental data loss. While not strictly a data safety measure, given the amount of electronic and electrical equipment in the TSPM computer and IT rooms, these areas will be equipped with a fire-suppressant system.

The foregoing is formally codified in a Safety Requirements Specification (SP/TSPM/002) based upon a Safety Analysis (PRO/TSPM/006) and the associated studies pertaining to the Hazard Analysis (TEC/TSPM/011), Reliability, Availability, Maintainability, and Safety (RAMS) Analysis, and a Failure Mode, Effects, Criticality Analysis (FMECA). While safety is strictly impossible to guarantee, it is being considered in design choices, imposed to the extent possible in the implementation of the interlock and safety system (ISS), and will be further developed in detailed manuals and procedures for specific subsystems and maintenance operations.

7.3 Design choices: The site's influence and the heritage from other projects

As previous sections indicate, the TSPM project inherits many design choices and solutions from the MMT and Magellan telescopes. Here, these features are enumerated and the reasons for adopting them are given. Note that some features are common to the MMT and Magellan telescopes. The specific site chosen for the TSPM also influences fundamental aspects of the TSPM design.

7.3.1 Design choices arising from the site

building orientation: The issues that dominate the choice of the building orientation are the site's topography and the wind rose. Figure 9 overlays the building design and wind rose on a topographic map of the site. As already noted, the TSPM site is on a narrow ridge oriented WSW to ENE, with the access to the highest point being from the ENE. The winds at night blow most commonly from the S to SW (December to June) and from the N-NNE (July to November; §5.7). The minimum in the wind rose is for directions between ESE and SE, which is approximately at a 45° angle to the slope off the ridge. The winds blow from these directions 13% of the time. Clearly, if the telescope enclosure were placed at the highest point of the site, mirror handling and many maintenance activities would entail the use of an elevator, unless the support building were raised considerably over the terrain. While the latter could be done with less impact from the wind flowing over the telescope enclosure if the support building were located to the SE, it would be costly, because of the extra height of the building, the need to build on a steep slope, and the need to take measures to prevent erosion. Including an elevator, while also maintaining the support building a reasonable distance from the telescope enclosure also increases the cost. Therefore, given the topography and the height chosen for the elevation axis of the TSPM (see below), the orientation of the main axis of the TSPM enclosure and support building could be accommodated on the site (1) as chosen, (2) reversed, or (3) oriented slightly more east-west with the telescope enclosure to the east. The exact site for the enclosure is not expected to be critical given the atmospheric turbulence properties above the TSPM site (§5.7).

Figure 9: *The proposed TSPM facility design and wind rose are overlaid on a topographic map of the site. The telescope enclosure is "downslope" and close to "cross-wind" from the support building (**Figure 2**). The terrain modifications will place ground level for the telescope pier at 2794 m above sea level and the far end of the support building at 2800.5m above sea level. The ground level for the pier is above the surrounding terrain in all directions, except towards the north, where it is 1 m lower, and for the directions where the wind will blow over the support building. In this last case, which occurs 17.5% of the time, the roof of the support building is approximately at the level of the elevation axis.*

Of these options, the chosen orientation simplifies many construction, operation, and maintenance issues. The chosen orientation is also that which leaves the telescope enclosure most isolated from trees at the site and most directly exposed to winds from the south, west, and north, accounting for 82.5% of the time, which, it is hoped, will minimize the degradation to the inherent image quality of the site. While this geometry does not place the telescope enclosure at the highest point of the site, it is not significantly below the surrounding terrain. Only the terrain immediately to the north is higher, and only by 1 m, excluding the directions from which the wind flows over the support building. For the 17.5% of the time that the wind will arrive at the telescope enclosure after passing over the support building, the entire telescope enclosure is likely to be within the effective ground layer and so the image quality will be degraded because the roof of the support building is at approximately the same height as the elevation axis. Unfortunately, these directions, from NE through ESE, have a higher than average fraction of low wind conditions, 25.9% of the time when the wind speed is below 15 km/h, which are the conditions when the image quality is best (§5.7). Even if the support building were oriented towards the SE, it would still interfere with 20.8% of the winds with speeds below 15 km/h if its relative height is maintained.

height of the elevation axis above grade: Various studies of the seeing at the TSPM site and its variation with height indicate that the seeing improves considerably 10m or more above grade (Echevarría et al. 1998; Sánchez et al. 2003; Skidmore et al. 2009). This consideration, as well as consideration of the costs for the telescope enclosure and support building, motivated the decision to locate the elevation axis at a height of 12m above grade. (Increasing this height requires a taller support building.)

mirror handling: Given the success of the Magellan design, it was decided that the observing chamber and mirror wash/coating areas should be on the same level, if possible (see "mirror coating, §7.3.1). This is possible if the support building is located on higher ground than the telescope enclosure, as is the case for the chosen building orientation. An additional benefit in the case of the TSPM is that this allows almost all maintenance activities as well as all instrument traffic to take place on a single level.

severe winter storms: Given that severe winter storms may close the observatory occasionally (§§5.7 and 9.5.2), their consequences must inform the TSPM's operations. In particular, in the event of an evacuation, which is the standard procedure, it is important that pipes do not freeze and to provide the means to allow instruments that have long warm-up times to warm up under controlled conditions. **THIS WILL BE DONE…TBD**

7.3.2 Magellan Heritage:

compact, octagonal dome: Used at ESO NTT (inaugurated 1989), WIYN (1994), Magellan Telescopes (2000, 2002), Discovery Channel Telescope (2015) and various others (including military). Advantages include lower mass (thermal inertia), easier construction and maintenance. These are useful advantages and the reason that the TSPM adopts to use a dome as small as possible.

open soffit: Magellan chose this approach to perturb the air flow as little as possible, allowing the ground layer of air to flow under the telescope enclosure instead of forcing it to flow up and over it (Perez 1994, thermal control). This goal also motivated the open area under the bridges to the Magellan support building. To study the effect of the TSPM's soffit and closed bridge (it will be fitted with many windows), CFD studies are about to be performed. At SPM, it is clear that the seeing due to the ground layer (especially within 10m or so of the ground level) has an important impact upon the total seeing (Echevarría et al. 1994; Sánchez et al. 2003; Schöck et al. 2009), but it's not clear that this is the case at LCO (GMT-ID-01466-Chapter_5_Site_Evaluation.pdf). The CFD studies will consider whether it is beneficial to have this lower layer of air flowing through/into the dome via openings in the walls (see below) or if it is better to exclude it, using only the openings on the dome (or roof, if implemented; see below). The CFD studies will also consider whether opening up the area under the bridge is beneficial and whether a partial closing of the open soffit (to construct a spectrograph room) would be detrimental.

ventilation openings in the (fixed) enclosure walls and rotating dome/roof: These openings facilitate and promote passive ventilation of the enclosure. They were implemented at Magellan based upon water flow studies (Perez 1994, thermal control). Experience shows that the louvers on the roof at Magellan leak, so gutters were implemented to contain and drain the water that comes in. However, they are apparently important for the complete flushing of the telescope enclosure. At present, the TSPM design does not include ventilation openings on the sloped roof of the dome, but only on the vertical walls of the enclosure and dome. All of these openings are equipped with fans. To determine whether openings on the roof are useful, thermal and CFD studies are required. One complication with openings on the dome roof is that it snows very regularly at SPM, sometimes very heavily (§5.7), which could further complicate the design of these ventilation openings. CFD and thermal studies would help inform a definitive decision on whether there should be ventilation openings in the roof.

moonroof: The Magellan telescopes include a moonroof to shield the telescope from unnecessary stray light. For these reasons, the TSPM also includes this feature.

windscreen: The Magellan telescopes include a wind screen to protect the telescope from buffeting by high winds (or limit their effects). For the same reason, the TSPM also includes this feature.

telescope pier: The design of the Magellan telescope piers consists of two nested cylinders connected by a flat disc. The outer cylinder takes all of the telescope's vertical load (against gravity) while the central cylinder (or pintle) takes the horizontal load during earthquakes. The TSPM design follows this example very closely, though there are important modifications to account for the TSPM's larger mass and to comply with changes in the seismic requirements in the construction codes.

ventilated telescope structure: The goal was to help thermalize the telescope structure as quickly as possible (Pérez 1994, thermal control). Air is drawn in through the telescope's upper end ring. From there, it passes through the rest of the structure and is vented below the azimuth disc. See additional comments below. At present, the TSPM design does not explicitly include this feature, but it would be useful to implement as the telescope design advances. The enclosure includes forced ventilation from below the azimuth disc, to which the telescope ventilation could be connected.

thin plate steel construction: The goal was to help the telescope structure thermalize as quickly as possible (minimize its thermal inertia; Perez 1994). Since the temperature gradients at SPM and LCO are similar, the benefit to adopting this feature at the TSPM should be the same as in the Magellan design and should be pursued.

hydrostatic bearings: Used at the Hale Telescope (inaugurated 1949), William Herschel Telescope (1987), Keck (1993, 1997), VLT (late 1990s), Magellan (2000, 2002), and many others. Advantages (from The Principles of Astronomical Telescope Design, Jingquan Cheng): low friction, very high stiffness, high load bearing capacity, ease of manufacture. Disadvantages (same reference): the ring beam requires high rigidity (only a few points of contact), complex control of oil flow, heat generation (requires pre-cooling the oil), and the temperature dependence of the oil's viscosity. In particular, hydrostatic bearings avoid non-linear start-up friction and so improve telescope control (Chivens & Chivens 1999). The TSPM design adopts this feature.

direct friction drives: This type of drive system was designed for the Magellan telescopes and many years of use have shown that it provides excellent telescope control (Gunnels & Carr 1994). Among the virtues of direct friction drives are high stiffness, long life (if properly aligned), and good control. On the other hand, direct friction drives do suffer from some rolling element bearing friction (Chivens & Chivens 1999), which can become apparent when guiding at very low speed. In the Magellan telescopes, this is controlled by including a closed loop force control on the friction drive. On the basis of this heritage, this feature was adopted for the TSPM.

f/11 Gregorian secondary: The principal motivation is/was the design of the wide-field spectrographs with excellent image quality that were planned (refracting collimator; Shectman 1994). Other advantages are: less aspheric than Cassegrain secondaries, simpler to specify and test, its location makes installation and removal simpler. The focal ratio was again a result of the spectrograph design (optics sizes playing a role). The resulting focal plane (including corrector optics) is curved (RoC 1220 mm). At present, the TSPM project has decided to adopt the Magellan design, as is, since this is feasible and complies with the HLR to provide this focal station. For TSPM, the f/5 Nasmyth focal station is a higher priority since it provides a field of view similar to the f/5 Cassegrain focal station.

Nasmyth/folded Cassegrain focal stations: These focal stations multiply the number of instruments available simultaneously and reduce the investment in downtime due to instrument installation, movement, and set-up. All of these motivate the inclusion of these focal stations in the TSPM design. Multiple Nasmyth/folded Cassegrain focal stations comply with the High-Level Requirements to have multiple instruments available simultaneously.

M1 cell is part of structure: According to Stephen Shectman's presentation (cit01.ppt), this is an integral part of increasing the rigidity of the telescope structure (not mentioned in Gunnels & Carr 1994). It's not clear how integral this is to the TSPM's telescope structure, but CIDESI should study how to achieve and optimize this.

mirror coating: The bottom part of the coating chamber also serves as the cart that is used to remove/install M1 on the telescope and to transport it throughout the coating process. This process is documented in Pérez (1994) and in the description provided by Matt Johns (5 April 2016). The implications and virtues of the Magellan procedure are described by Pérez (1994, aluminizing): everything occurs on a single level, sealing chamber when not in use, etc.. Given its proven functionality, the TSPM adopted this feature. The difference between Magellan and TSPM is that all mirrors are planned to be aluminized onsite at TSPM. (At Magellan, M2 and M3 are aluminized at the Dupont telescope.) The exact implementation of the mirror washing bridge at TSPM also differs, but that will not affect its functionality.

instrument handling for f/5 Cassegrain: It is the project's understanding that the TSPM will not inherit "bare instruments", but that Megacam and MMIRS will be transferred along with their handling and storage fixtures, including "CartZilla", which is/was used to transport and install these instruments at Magellan (II/Clay). The flooring of the bridge that connects the TSPM telescope enclosure and support building does not have the capacity to support CartZilla, let alone loaded with an instrument. Hence, the TSPM project will install tracks (as at Magellan), either temporary or permanent, to allow CartZilla to transit across the bridge and the floor of the telescope enclosure (the floor in the support building is already adequate).

M2 vane-end system: Given the range of secondary mirrors that are planned for the TSPM, particularly the f/11 Gregorian configuration, a vane-end system is more versatile than a hexapod mechanism. The vane-end system places active heat sources behind the secondary in use, facilitating infrared observations.

7.3.3 MMT Heritage:

M1 cell design (cone on backside): This structural feature of the backside of the cell ensures that the TSPM will be compatible with Binospec. The Cassegrain rotator will be identical to those implemented at the Nasmyth focal stations, so its load-bearing capacity will exceed that of the MMT's Cassegrain rotator.

Cassegrain rotator: The Cassegrain rotator at the MMT uses a gear mechanism. The Magellan telescopes use friction drives on the rotators at the Nasmyth and Cassegrain focal stations. The TSPM follows the MMT example to better guarantee its compatibility with Binospec.

7.3.4 Common MMT/Magellan heritage:

f/5 Cassegrain secondary: The main motivation for adopting this focal ratio at the MMT was to obtain a very wide field of view (for the time) that was used first for spectroscopy (Hectospec, Hectochelle) and then imaging (Megacam, MMIRS; Fata & Fabricant 1994). In the case of Magellan (II/Clay), the f/5 Cassegrain configuration was a later adaptation. The original optical design didn't include it, but stated that the telescope structure was adaptable to faster focal ratios than f/11 Gregorian (Shectman 1994). A study by Gunnels determined that its implementation was feasible. The TSPM project adopts this focal ratio for two reasons. First, using this focal ratio makes a lot of MMT and Magellan instrumentation compatible, at least in principle. Second, the project's focus on the "modest" wide field astronomy accords very well with the one degree field of view available at this focal station.

M1 assembly: Honeycomb borosilicate mirrors of the MMT/Magellan/TAO/TSPM type require active support to maintain their optical figures (and image quality; TAO = Tokyo Atacama Observatory). The M1 assembly is an in-kind contribution of INAOE+UA. The active support system is also used to correct residual thermal deformations. In the Magellan design, the M1 assembly is an important structural element in the telescope structure (presentation by Shectman; see 7.3.1).

M1 thermal system: Honeycomb borosilicate mirrors of the MMT/Magellan/TAO/TSPM type suffer from thermal deformation. To maintain image quality, it is important to eliminate temperature gradients within the mirror to the extent possible. (What remains is taken out using the M1 support system.) The TSPM thermal system inherits features from the MMT, Magellan, and TAO projects.

f/5 Cassegrain wide field corrector (WFC): The f/5 Cassegrain optical configuration has excellent image quality on axis, but it degrades quickly as the field of view increases. For this reason, the MMT and Magellan telescopes incorporate WFC optics to greatly increase the useful field of view. Since wide-field science is a stated goal of the TSPM project, it too must incorporate a WFC. The WFC that will be used at the TSPM is the one currently in use at Magellan (II/Clay), which is an SAO+UA in-kind contribution. This WFC is required to use Megacam (see below).

Megacam and MMIRS: These operating instruments (both have been used at both the MMT and Magellan/Clay) will be the Day 1 instruments and are an in-kind contribution of UA+SAO. Operationally, Megacam will be easier to install and use to commission the scientific operation of the telescope. MMIRS has demands that are considerably more severe and so will be installed once the telescope and control system are ready for it. MMIRS incorporates continuous wavefront sensing whereas Megacam requires an auxiliary wavefront sensor be used between exposures.

7.4 Operational requirements, constraints and policies

7.4.1 Services contracted from the OAN-SPM and other providers

Services that the TSPM project will contract from the OAN-SPM are:

- room and board: The TSPM will house its on-site personnel in dormitories maintained by the OAN-SPM. Likewise, these on-site personnel will take their meals in the OAN-SPM's dining facilities.
- electricity: The TSPM will be connected to the OAN-SPM's medium voltage power network as described by Quirós et al. (2018) through a **TBD kVA** transformer. By the time of the TSPM's operation, the OAN-SPM will be connected to the national electricity grid. The OAN-SPM's emergency generator will also provide emergency power when the feed from the national electricity grid fails. However, emergency power will not be sufficient to cover the TSPM's normal operational needs and special operating procedures will be used. For further details, see §6 and §9.5.1. Like the other telescopes at the OAN-SPM, the TSPM will receive both regular and emergency power via a single connection to the OAN-SPM's internal electricity grid.
- communications: The TSPM will be connected to the OAN-SPM's fibre optic backbone as described by Quirós et al. (2018). This will provide a **TBD Mbits/s** connection to the internet.
- snow removal: The OAN-SPM will be responsible for clearing snow using its equipment.
- storage of solid chemical waste: The OAN-SPM maintains a temporary storage facility for chemical waste. These wastes must be disposed of according to national regulations, specifically R.43. The TSPM will have to contract the proper disposal of these wastes and maintain on file the certificates that confirm this proper disposal from certified service providers.
- storage of oil for the hydraulic bearing system: The TSPM's hydraulic bearing system will need topping up occasionally. The (small) quantity of oil required will be stored where the OAN-SPM stores other similar products, in its facility with a passive containment system.
- M1 transport box: The TSPM will contract a suitable space to store the primary mirror transport box.
- occasional access to the OAN-SPM's machine shops: The TSPM will negotiate adequate access to the OAN-SPM's machine shops. This will include access to both the vehicle repair shop as well as the fine machining shop.
- **emergency medical evacuation:**

Services that the TSPM project will contract from other providers are:

- domestic water: The concession from the Comisión Nacional del Agua for the OAN-SPM's well is insufficient to cover the TSPM's needs of approximately 40,000 l/month, so domestic water will be contracted from other local suppliers.

- domestic waste water: Domestic waste water must be disposed of according to R.43. The TSPM will have to contract the disposal of these wastes and maintain on file the certificates that confirm this proper disposal that the contractor delivers.
- chemical waste water: The chemical waste water resulting from the mirror aluminization process or from chlorine spills must be disposed of according to R.43. The TSPM will have to contract the disposal of these wastes and maintain on file the certificates that confirm this proper disposal that the contractor delivers.
- liquid nitrogen: The TSPM will have to contract liquid nitrogen for the instruments from one of the various local suppliers.

Maintenance service contracts:

- fire extinguishers and fire alarms: Fire extinguishers must be inspected periodically by certified service providers. These same providers can also inspect the proper operation of the smoke detectors and the fire alarm system.
- potable water plant: The safety showers require potable water, which the project proposes to produce via chlorination. The TSPM will have to send samples regularly for chemical analysis
- specialized personal protection equipment: Items such as oxygen tanks and masks that must be used in case of nitrogen or helium leaks will require periodic inspection and maintenance by certified service providers.
- elevator: The elevator will require periodic maintenance. The OAN-SPM's experience is that this is best done by dedicated service providers.
- vehicle maintenance: It is probably more cost-effective to contract vehicle maintenance to local service providers. As a backup, the OAN-SPM maintains a vehicle maintenance shop staffed by mechanics. Vehicle maintenance covers both vehicles used to transport personnel to and from the OAN-SPM as well as more specialized equipment, such as personnel lifts, used for maintenance within the TSPM telescope enclosure and support building.
- **mechanical equipment**
- **electrical installation**
- lightning grounding system: This system will require periodic inspection, testing, and maintenance to ensure it functions properly. Given the generally poor grounding at the OAN-SPM, this maintenance is very important for the protection of electrical and electronic systems.
- liquid nitrogen storage tank: This tank will be exposed to the elements, so periodic inspection and maintenance will be required by dedicated service providers. Certified service providers must also inspect and maintain the oxygen sensors in areas where leaks could allow high concentrations of nitrogen to accumulate within the TSPM support building.
- compressed air systems (general, primary mirror): These two critical systems have different specifications and will require periodic inspection and maintenance given their continued use.

- glycol water systems, chillers, pumps: These systems will require periodic inspection, chemical analysis, and maintenance to ensure they function properly and their lifetimes are not compromised.
- air conditioning/HVAC system: This is best done by dedicated professionals. If the clean room is to maintain formal standards, certification by approved service providers will be required.
- cranes: Following the UA's recommendation, the bridge crane and vacuum lifting system should be inspected and certified each time it is used to lift the primary mirror. Other cranes should be inspected and given preventative maintenance regularly by dedicated service providers.
- **helium system**
- **instruments?**

7.4.2 Access to the OAN-SPM site

The largest items that compose the TSPM that will definitely be transported to the OAN-SPM fully assembled are the primary mirror and the primary mirror cell. Although the primary mirror cell may be shipped "naked", the primary mirror will be in its transport box, whose dimensions are approximately 7m x 7m x 3m. The raw dimensions of the primary mirror cell are approximately 7m in diameter and 1.7m in height. Other similarly-sized items include the aluminizing chamber, whose overall dimensions are approximately 7m in diameter by 6.3m in height when its two sections are fit together. The two sections have similar heights: 3.1m for the bottom section and 3.2m for the top.

The TSMP project has access to the transportation surveys carried out for the
- LSST project: carried out in January 2006 by Precision Heavy Haul Inc. from Tucson, AZ through San Diego, CA/Tijuana, B.C. to the OAN-SPM.
- TMT project: carried out in August 2016 by M3 Engineering & Technology Corp from the port of Ensenada, B.C. to the OAN-SPM.

While the LSST survey was done a long time ago, it did consider a primary mirror of 8.3m in diameter and its route is very similar to the trip that the TSPM's primary mirror will have to navigate. Few of the loads for the TMT exceed 7m in width. On the other hand, the survey undertaken by the TMT is reasonably detailed and much more representative of the current conditions between Ensenada and the OAN-SPM.

Both surveys explicitly emphasize that it will be necessary to conduct more detailed surveys of the transport routes, and that recommendation will be followed, particularly as concerns crossing the border between Mexico and the USA. Fortunately, both surveys indicate that there were no apparent absolute impediments for the routes that they considered. Nonetheless, there are important restrictions along the route. At at least one point on the road that leads to the OAN-SPM, the road width between the guardrails (65cm high at that point) is as little as 5.9m, making clear that a detailed survey of the transport route for the primary mirror is necessary.

From the LSST survey, it is unclear where the primary mirror and its cell may cross the border between Mexico and the USA. The largest truck crossing is between San Ysidro, CA and Tijuana, BC at the Otay Mesa crossing. Should crossing the border at Otay Mesa prove impossible, … option … crossing the border … sea routes

While the above transportation surveys are useful to evaluate the feasibility of the delivery of the primary mirror, the primary mirror cell will have to travel to the telescope construction site, presumably in central Mexico, and then from there to the OAN-SPM. CIDESI … preliminary evaluation of transport route … by land

Should the options of shipping the primary mirror or the primary mirror cell … sea routes.

7.4.3 Environmental requirements

The choice of the OAN-SPM as the site for the TSPM requires that the TSPM project comply with the management plan for the PNSSPM and other environmental regulation (§5.2). In practice, this begins during the process of seeking the environmental permissions needed to start construction. Recent experience indicates that these permissions are easier to obtain if environmental impacts are limited, e.g., minimizing and containing any wastes emitted and disposing of wastes at government-qualified disposal centers, and if project lifetimes are defined or limited.

From an operational point of view, the two issues that clearly have implications regarding environmental safety are the chemicals used to aluminize the TSPM mirrors and the oil used in the hydrostatic bearing system. The TSPM should include a separate, double-contained chemical waste storage tank to accommodate the volume of chemically-contaminated water and other waste associated with aluminizing. This tank should also be connected to drains in other areas of the support building where chemical spills could be common, e.g., water chlorination. This tank should be small enough that it is necessary to evacuate it after each aluminization and dispose of the wastes according to environmental regulations. As for the oil used for the hydrostatic bearing system, two issues are relevant. First, the tanks that store this oil within the enclosure and support building will require appropriately-designed containment systems that accommodate 100% of their volume (a requirement from Protección Civil). These containment systems should not be connected to any plumbing system, such as the chemical waste storage tank. Second, the hydrostatic bearing system will require topping up with oil occasionally, and some suitable location with a containment system is required. Since the OAN-SPM already has a facility for storing similar products, access to this storage area should perhaps be negotiated.

7.4.4 Constraints on the design of the enclosure and support building

The design of the telescope imposes requirements on the telescope enclosure. First, the enclosure must accommodate the length of the f/11 Gregorian optical configuration with a clearance margin. Second, the telescope's field of view imposes a minimum projected width of the dome opening of 1°. However, to improve the performance of dome tracking, especially near the zenith, the projected slit width should be substantially larger than this minimum width. Third, alt-azimuth telescopes have only a small blind spot at the zenith, so the enclosure should allow the telescope a clear field of view over its entire observing range, from 18º elevation to the zenith. Fourth, at least one crane will be needed in the enclosure to cover maintenance activities such as exchanging instruments or optics. Finally, to allow the primary mirror to be aluminized, rails must be provided to support the cart that will transport the primary mirror between the telescope enclosure and the coating chamber in the support building.

The support building must provide the facilities required to operate and maintain the TSPM and its instrumentation, at Day 1 and thereafter. For operation, there must be space for electrical and mechanical equipment, including that required for the telescope's hydrostatic bearings, a water purification plant (safety showers, mirror washing), access doors suitable to transport the primary mirror and unload commercial containers. For maintenance, details are given in §§7.6 and 9.2, but their basic requirements are a mirror coating facility to aluminize M1, M2, and M3, including infrastructure to strip these mirrors, a clean room where instruments may be safely prepared, maintained, and repaired, storage space for instruments, optics, and their handling fixtures, cranes in various places with adequate capacities.

An important requirement is storage space for instruments, optical components, and their handling fixtures. §7.7 and Appendix A provide greater details concerning the known and foreseen space requirements for the instruments and other elements required for the different configurations of the TSPM project. In summary, the space available in the instrument bay in the current design, approximately 93 m^2 (see Figure 14), is sufficient for the f/5 Cassegrain configuration, including an additional post-Day 1 instrument the size of Binospec, and most of what can be foreseen for an ambitious instrument complement for the f/5 Nasmyth configuration or a mixed f/5 and f/11 Nasmyth configuration. It is clear that any equipment that is not needed for instrument storage and maintenance will have to be stored off-site.

7.4.5 Requirements for predictable events/problems

Following the procedures established in the TSPM Safety Analysis (PRO/TSPM/006), a general TSPM hazard analysis (TEC/TSPM/011) has been performed at system and subsystem levels in order to identify, evaluate and take the adequate measurements to control potential hazards that could affect personal safety in the first place and, then, to equipment and data.

In addition, on the grounds of the RAMS analysis, Failure Modes, Effects and Criticality Analysis (FMECA) have been produced for the Primary Mirror Assembly, Telescope and Enclosure & Services subsystems, where the potential failure modes of each system have been identified and evaluated. These analyses include recommendations to prevent the failure itself or to reduce either its probability or criticality.

Please note that the foregoing documents (TSPM Safety Analysis and FMECA analyses) are "live" documents, meaning that they are being updated throughout the project life whenever required.

The results of the Hazard Analysis have become the inputs for the Safety Requirements Specification document (SP/TSPM/002), that states first the safety priorities of the TSPM operation and maintenance, and afterwards defines the main safety strategies to mitigate risks in the project: subsystem design, Interlock and Safety System (ISS)), control system and procedures. Some requirements may not be related to a particular subsystem and should be implemented jointly by different subsystems and by the Interlock and Safety System. Finally, the “TSPM Safety Requirements Allocation” document (TEC/TSPM/010) analyzes the safety requirements and decides how to allocate them to the different safety mechanisms: subsystem design, hardwired interlocks, key-interlocks, interlock and safety system (ISS), control system or procedures. Once allocated, the requirements have been flown down to the correspondent subsystem specification (when the associated risks are controlled at subsystem level), to the Interlock and Safety System (when they have to be controlled by the ISS) or to the Operation and Maintenance Procedures (when they cannot be controlled by hardware and must be considered in the procedures).

Having followed the sequence of action described above, we can highlight the following main requirements that need to be applied to all subsystems and interlocks (for the complete list please check the Hazard Analysis table).

In the event of a power outage:

- It must be possible to close the shutters and ventilation windows in the enclosure.
- The air supply to the primary mirror cell must allow the primary mirror to be lowered safely.
- The telescope brakes shall be activated when power is removed.
- The oil supply to the hydrostatic bearings must be sufficient for the brakes to stop all telescope motion before the hydrostatic bearing pads come into contact with the azimuth ring.
- The most critical equipment shall be connected to the UPS system.
- Any crane load shall not be released.

To avoid impacts between moving elements and people or other elements

- By design, potentially dangerous movements shall not be allowed (e.g., the crane cable drum shall not be active while the crane is moving).
- There must be safety interlocks preventing some potentially dangerous movements:
  - Key interlock shall exist to remove power supply to the telescope, the instrument rotator, rotating enclosure or shutter when maintenance tasks take place.
  - Emergency stops that shall allow all subsystems to be stopped in case of emergency.
- There must be operational and maintenance procedures to prevent those potentially dangerous movements.

To avoid system elements from moving beyond their range of operation

- There must be software, electronic, and mechanical limits to prevent personal injury or equipment damage.

- Redundancies shall be added wherever required by the FMECA analysis. There must be operational and maintenance procedures to avoid or minimize this risk.

Redundancies in facility services:

- The air supply to the primary mirror must include redundant compressors (outgoing line).
- There must be redundant pumps in the hydrostatic oil system (outgoing and return lines).
- There must be redundant pumps for all chilled water systems (outgoing lines).

7.4.6 Requirements concerning the design of the control system

In a complex system like an observatory, the control system is a fundamental component. In addition, the control system exists in a very dynamic environment of changing software and hardware. Consequently, the TSPM control system should be modern and modular, but flexible, following examples implemented in other large telescopes. It should adopt standards and best practices. These characteristics should improve reliability of the control system and make it easier to update parts of the control system as needed, due to changes in either technology or scientific needs and opportunities. The control system should use commercial components when possible, easing the procurement process and its financial burdens. The software should be independent of hardware and operating systems when feasible.

The control system should allow the use of multiple instruments simultaneously. This is necessary from Day 1 (or before) to allow maintenance and commissioning of instruments while they are not mounted on the telescope. This will also be necessary when the Nasmyth and folded Cassegrain focal stations are enabled if multiple instruments are to be available during a single night.

The telescope and instrument control systems should implement automatic set-up, calibration, and diagnostic procedures. These should be run in late afternoon or at sunset in order to identify problems as early as possible and to minimize the time lost to maintenance activities at night (§9.1.7).

As discussed in the next section, the control system must implement at least two observing modes, as specified in the High Level Requirements: engineering mode and queue mode. In addition, the control system must implement a maintenance mode of operation. This is not an observing mode in the sense that it will never be used from the telescope control room. Rather, maintenance mode will only be used from local control panels in the telescope chamber while performing maintenance operations. In this mode, the telescope, dome, shutters, and ventilation windows will emit audible and visible warning signals before beginning their operation. The purpose of these warnings is to alert anyone present of impending motion.

7.4.7 Observing modes

The TSPM is to be built at the OAN-SPM. This choice of site imposes certain constraints upon the project. In particular, the site is remote (see Figure 1), requiring at least a four-hour drive from Ensenada. The first part of this drive is via the transpeninsular highway south from

Ensenada (140 km). The second part is via an access road that leads to the OAN-SPM through the PNSSPM (100 km). There is no viable alternate route to the site. It is not practical for the site support staff or visiting astronomers to commute daily, but instead they must reside at the OAN-SPM for the duration of their work period. Given that the TSPM is an international collaboration, there are practical constraints on the movement of people and material from the site to the UA and SAO or vice versa. While far from insurmountable, coupled with the remoteness of the site, it is clear that good planning and extensive operations support will be crucial to maximize efficient and high quality research from the TSPM.

Very generally, we may identify 6 observing modes that are used commonly in ground-based astronomy: engineering, classical, remote, service, queue, and robotic. The sequence of the last five modes is a sequence of extracting the user more and more from the actual observing process.

Engineering mode is indispensable, as it is necessary to debug problems and commission all components. In this mode, the control system allows the maximum control or intervention into the component being used, though it can be the observing mode with the most difficult user interface. While an inhospitable interface is a disadvantage, only highly trained personnel normally use it. This mode is usually necessary for commissioning and maintenance purposes.

In classical observing mode, the observer is at the telescope and acquires data according to a sequence and an instrumental configuration that are implemented in real time. In principle, this is the most flexible mode for the user as regards object selection and instrument configuration, but will almost always occur on pre-defined dates that may be ruined by poor weather. Classical observing mode implies that many astronomers will appear at the telescope, making a user interface that is friendly and robust very advantageous. Classical observing mode also implies transporting all users to and from the OAN-SPM, which will certainly increase costs for the partner institutions and for observatory operations.

Remote observing mode is like classical observing mode, except that the local user interface is implemented in a remote location, usually the user's home institution. This is an attractive alternative when only a few remote locations are involved, and provided that the network connections to all of them are fast enough that users may interact with the user interfaces in a natural way. The user interface requirements for remote observing is the same as those for classical observing, but augmented with the ability to run them remotely.

Service observing mode differs from classical observing mode only in that the user need not go to the telescope to acquire their data. Instead, a "local" astronomer acquires the data. This is useful for short observing programs, simple observations, or very standardized survey campaigns. Service observing also allows acquiring data for several programs on a given night. An advantage of service observing is that the astronomers who acquire the data become very familiar with the user interfaces, relaxing their requirements somewhat.

Queue observing mode is very similar to service observing, but differs in the sense that a computer algorithm (observation database) selects the observations to be carried out and configures the instrument, usually under human supervision (an astronomer). This mode easily allows distributing observations from a given program over the nominally optimal conditions, usually specified as part of the description of the observation.

Robotic observing mode differs from queue mode in that it dispenses with humans, as either telescope operators or astronomers. While this observing mode is often employed on small telescopes, no large telescope yet operates in this mode.

Given the foregoing, initially, the operation of the TSPM is expected to implement a limited number of observing modes. Engineering mode will be indispensable for commissioning the telescope and instruments and so must be implemented. It is clear that, at a minimum, it is necessary initially to implement at least one of classical, remote, service, or queue observing modes, in addition to engineering mode. Inevitably, this will be a decision for the TSPM consortium. Service observing mode might appear to offer a sweet spot in terms of programming effort, but queue observing is usually considered more efficient. Given the cost, in both time and money, to train and transport personnel to the TSPM, remote, service, or queue observing is of great interest since these modes minimize the number of personnel on-site, transported to the site, and that require training. Queue observing is often considered the most efficient. For scientific observations, it is likely that queue mode will be the most useful mode to implement initially, as this will allow (1) fewer personnel on site, (2) better training these personnel in the detailed use of the facilities, (3) minimizing downtime due to observer error, (4) minimizing travel from all partners to the site, and (5) minimizing operating costs. This choice, however, requires a greater investment in tools and services that not only allow the efficient planning, administration, execution, calibration, and distribution of high quality observations, but that also maintain the different user communities engaged with the TSPM, e.g., documentation, simulators, archives, and tools to monitor quality control, program execution, and completeness. All of these tools and services would need to be part of the TSPM control system.

Once the relevant experience has been accumulated with the system in operation, other observing modes, such as classical, service, remote, or robotic observing modes, could be implemented as needed. Presumably, this sequence will have the least impact upon the observing efficiency as these other modes will be able to take advantage of the support processes developed for queue mode.

7.4.8 Calibrations

To the extent possible (§§7.4.5, 8.2, 9.1.7), calibrations and maintenance activities should not occur during the night. A large fraction of all calibrations need not consume time at night (§9.1.7), but inevitably some will. Considering the figures from §5.7, excluding civil and nautical twilight, there are up to 3589 hours available yearly for astronomical observations and calibrations under skies that are at least nearly dark (ignoring the time lost to bad weather). Ideally, calibrations should consume no more than the equivalent of the daily hour of astronomical twilight, or 10.2% of the time available on a yearly basis between the end of nautical twilight in the evening and its beginning in the morning.

7.4.9 Engineering time and maintenance

Some time must be budgeted for night-time engineering and maintenance, such as when instruments are installed or when the telescope is aluminized. At the MMT, instruments may be changed in a single day at its Cassegrain focal station, so we adopt this example for the TSPM. Initially, the TSPM will use a bright-time and a dark-time instrument, MMIRS and Megacam, respectively, so it is reasonable to suppose two engineering nights per lunar cycle, equivalent to 25 nights per year or approximately 7% of the night-time available on a yearly basis (TBC).

When the Nasmyth and folded Cassegrain focal stations become available, instrument changes may become considerably more complex if the Cassegrain focal station is not decommissioned. This will clearly be a decision that the Project Board must take should it be necessary. Supposing that all of the focal stations remain active, the time required to change focal stations at the TSPM is likely to be similar to that required at the Magellan II/Clay telescope, which is apparently two days. (As at the Magellan II telescope, the Cassegrain instrument and WFC will have to be removed for the tertiary to be installed.) In the interest of maintaining the TSPM's scientific efficiency, changes from Cassegrain to other focal stations should be infrequent, as they are at the Magellan II telescope. If multiple instruments are available when the Nasmyth and folded Cassegrain focal stations are available, it should be possible to reduce the time required for night-time engineering from that indicated in the previous paragraph, so the figure given above should be considered an upper limit when Nasmyth and folded Cassegrain instruments are in use.

Re-coating the telescope's mirrors will take place on a two-year time scale (TBC, §9.3.3). This process will take several days, especially the first several times it is done. It is probably possible to avoid aluminizing the primary, secondary, and tertiary mirrors at the same time, except perhaps when only the Cassegrain focal station is available. Based upon the Magellan experience, aluminizing the primary mirror will occupy at least 5 days, so we estimate 7 days initially or 1% of the time available on a yearly basis. Once several secondary mirrors are available, aluminizing them need not necessarily imply a loss of time at night. Likewise, the tertiary mirror could be aluminized without a loss of night-time if the Cassegrain focal station remains in use. If not, re-coating the tertiary mirror or a single secondary mirror would imply a maximum loss of time of the order of 2-3 days, equivalent to less than 0.5% of the time available on a yearly basis.

The foregoing will eventually be the topic of TSPM Board decisions as will the time dedicated to commissioning new instruments and capabilities.

7.5 Personnel

This section shall describe who shall operate the TSPM.

7.5.1 Organizational Structure

The exact organizational structure that the TSPM project will eventually adopt is unclear at this moment. It is possible that the TSPM will be built and operated by different organizational entities. For the sake of clarity and to differentiate the TSPM from the organization that builds or runs it, the term TSPM Observatory (TSPMO) will be used for these organizations that may build or operate the TSPM. Despite the foregoing, certain outlines are clear or inevitable.

The TSPMO will not be part of the OAN-SPM. The TSPMO must be an entity to which its partner institutions can affiliate themselves, as part of a governing board for instance. Presumably, the TSPMO can be organized such that it must exercise the collective will of its parent institutions, as these will define the value of in-kind contributions, the overall distribution of observing time, and other high-level decisions and directives, such as operating modes, instrument upgrades, and new facilities. The TSPMO must be constituted in such a way that it may receive federal funds from the Mexican government, foreign governments, and private contributions, since the great majority of those parts of the project that do not already exist are expected to be funded by sources derived from the Mexican government.

From an organizational perspective, the TSPMO will have a figure similar to a director, responsible to the governing board. The TSPMO will have an administrative structure to deal with the responsibilities required for its operation (personnel, purchasing, budgeting, accounting, payroll, and logistics). The TSPMO will have a technical and scientific structure to (build and) run the TSPM on a daily basis. The personnel from both of these structures will be under the direction of the TSPMO director. All personnel hired by the TSPMO will be subject to Mexico's Ley Federal de Trabajo (LFT), which stipulates basic obligations, rights, and working conditions. If the TSPMO's partner institutions provide some of its personnel, presumably these personnel would be subject to the contractual conditions at the partner institutions.

A daily commute between Ensenada and the OAN-SPM is not feasible, so some extension of rights and compensation beyond that provided for by the LFT would be required (collective work agreement or something similar). In practice, this would likely imply that at least two maintenance/operations crews are needed to run the TSPM. One crew would be on duty in SPM while the other would be off-site, presumably in Ensenada, the nearest large population center.

The collective work agreement would also take into account the rotation and daily work schedules of the personnel stationed at the OAN-SPM, as well as their obligations when not at the OAN-SPM. For the sake of adopting a support model, we envisage a model like that used currently at the OAN-SPM: Technical support personnel (electronics, IT, mechanical, opticians; see below) are available from approximately 08:30 until 24:00 hours whereas the telescope operator and instrument scientists are available from approximately 16:00 until the dawn the following day. The technical crews would be rotated regularly, but the entire crew would probably not be rotated on a single schedule in order to better promote communication between the crews. These hours and the rotation schedule for the crews at the OAN-SPM would be specified in the collective work agreement.

The TSPMO's administrative offices will not be in SPM, as that is not practical or cost-effective. Much simpler would be to have at least the personnel who manage the day-to-day administrative tasks in Ensenada, as that is the closest location where most of the TSPM's daily needs could be met. Ideally, all of the TSPMO's administration will be in a single location, but this could depend upon how it is structured. **This document assumes that the TSPMO's administration will be located in Ensenada.**

The partners expect the TSPM to be an efficient facility, with operation and maintenance costs in line with other facilities run primarily by universities, e.g., MMT. The yearly operations and maintenance costs should be closer to the 5% end of the construction cost of the often-used 5-10% rule of thumb (e.g., Miller 2007). It is envisaged that most, or all, major development, upgrades, and repairs (instruments, software, etc.) will occur within the partner institutions, as that will simplify the accounting for each partner's contributions and will also keep the number of personnel within the TSPMO closer to the minimum needed to focus on its night-time operation.

7.5.2 Personnel profile

For its operation and maintenance, the TSPM will require *some fraction* of the following, though all of the roles may be required to some extent:

- Director: Is responsible for implementing directives and decisions taken by the TSPMO board of governors. Leads the TSPMO in its daily administrative, technical, and scientific duties. The director should be an experienced astronomer, perhaps on loan from a partner institution. (There would likely be issues to settle with the partner institutions to allow this.) The director should be bilingual (Spanish/English). Time is split between SPM and Ensenada.
- Administrative structure
  1. head of administration?: (Optional?) Is responsible to the TSPMO director and heads the administrative branch of the TSPMO. Coordinates longer-range activities, such as major purchases, hiring processes. MUST be bilingual. Time is split between SPM and Ensenada.
  2. personnel/payroll?: Is responsible to TSPMO director (or head of administration). Deals with issues such as payroll, health and safety, personnel training, hiring processes. Spends most of the time in Ensenada.
  3. budgeting /accounting: Is responsible to TSPMO director (or head of administration). Deals with issues such as budgeting, accounting, spending planning. Spends most of the time in Ensenada.
  4. purchasing: Is responsible to the TSPMO director (or head of administration). Deals with issues such as purchasing, importing, exporting, warehouse, inventory. MUST be bilingual (Spanish/English). Spends most of the time in Ensenada.

5. logistics: Is responsible to TSPMO director (or head of administration). Provides services to the other administrative and technical/scientific areas. Coordinates flows of people and material as required by the TSPMO. Time is split between SPM and Ensenada.
6. Secondary administrative staff?: These personnel, if needed, assist and are responsible to the heads of the different administrative areas. Spends all of the time in Ensenada.
7. Drivers?: Is responsible to the head of logistics. Transports people and material as required by the TSPMO. In principle, this could also be contracted, though this will significantly complicate safety issues that should be under TSPMO's control. Time is split between SPM and Ensenada.

- Technical/Scientific structure
  1. Head of scientific operations?: (Optional?) Is responsible to the TSPMO director. In charge of the daily scientific operations of the TSPM. Coordinates the activities of all technical and scientific personnel. This person should be an experienced astronomer. Should be bilingual (Spanish/English). Time is split between SPM and Ensenada.
  2. Telescope operators (1/shift): Is responsible to head of scientific operations or TSPMO director. Operates the telescope at night. Collaborates in telescope, instrument, and site calibrations. Ideally, will hold at least an undergraduate degree in physical or engineering sciences. Should be bilingual (Spanish/English). Spends most of the time in SPM.
  3. Electronics engineers (1-2/shift): Is responsible to head of scientific operations or TSPMO director. In charge of developing or solving electronics problems with the telescope, instrument, or other systems. Collaborates with IT specialists in developing and trouble-shooting the observatory control system. Will hold at least an undergraduate degree in electronics engineering. Should be bilingual (Spanish/English). Spends most of the time in SPM.
  4. Mechanical engineers (1-2/shift): Is responsible to head of scientific operations or TSPMO director. In charge of developing or solving mechanical problems with the telescope, instrument, or other systems. Will hold at least an undergraduate degree in mechanical engineering. Should be able to manufacture simple parts. Should be bilingual (Spanish/English). Spends most of the time in SPM.
  5. Opticians (1/shift): Is responsible to head of scientific operations or TSPMO director. In charge of developing or solving optical problems with the telescope, instrument, or other systems. Should have a graduate degree in optical sciences. Should be bilingual (Spanish/English). Spends most of the time in SPM.
  6. IT specialists (1-2/shift): Is responsible to head of scientific operations or TSPMO director. In charge of developing or solving IT problems with the telescope, instrument, or other systems, both in Ensenada and SPM. Will hold at least an undergraduate degree in computer sciences. Should be able to undertake programming tasks. Should be bilingual (Spanish/English). Time is split between SPM and Ensenada.
  7. Instrument scientists (a.k.a.: support astronomers; 2/shift, 1 of them in Ensenada): Is responsible to head of scientific operations or TSPMO director. Is the TSPMO's expert

for the assigned instrument(s) or system(s). In charge of trouble-shooting operational issues, developing data reduction solutions, or solving problems with these systems. This person should be an astronomer. Should be bilingual (Spanish/English). The instrument scientists split their time between SPM and Ensenada to allow them to support the TSPM operations both during the night and during the day (e.g., observing support, observing run preparation, etc.).

Based upon experience at the OAN-SPM and the operating models at the MMT and Magellan telescopes as we understand them (Phillips et al. 2006; Osip et al. 2008; Williams et al. 2016; Povilas Palunas, private communication), we envisage an on-site technical staff of about 8 people in San Pedro Mártir. The numbers in parenthesis after each category above provide our current estimate of the composition of the on-site technical staff. Hence the technical and scientific support staff will number a total of 8-11, if there is a head of scientific operation. (This number does not include the TSPMO director.) Of the technical and scientific support staff, an instrument scientist and the head of scientific operations will typically be located in Ensenada and the rest will be at the OAN-SPM.

7.6 Other support resources

SPM is a remote location that will affect the way that the TSPM operates. For the present purposes, it is assumed that the TSPM will contract housing (room and board), water, electricity, telecommunications, and snow removal from the OAN-SPM.

To transport its personnel and equipment to the OAN-SPM, the TSPM will require a fleet of vehicles. These vehicles should be adequate for winter use in snow. Much of the road from the transpeninsular highway to the OAN-SPM has a significant grade. The vehicles should be such that their motors can assist with braking, which is especially important when driving from the OAN-SPM (downhill). Otherwise, brakes can overheat and fail. In principle, the transport of personnel and equipment could be contracted with the OAN-SPM or some other provider, but this could complicate operations and would remove oversight of vehicle maintenance and operation, which would represent a safety concern.

The first two instruments that are foreseen in operation at the TSPM, Megacam and MMIRS, require liquid nitrogen for their operation. Their daily consumption will be several tens of litres. Current plans are to have a storage tank on site that is resupplied as needed by local suppliers of liquid nitrogen in Ensenada.

To confront severe winter storms, the TSPM should have access to emergency power. The power line under construction to the OAN-SPM will be an underground line through the area where it commonly snows, as is also the case for the power lines within the OAN-SPM. Experience shows that this greatly reduces the frequency of power failures during storms. In practice, it’s likely that power will remain available via this power line throughout a severe winter storm, unless damage occurs to the power line’s infrastructure outside the OAN-SPM. However, continuous access to electrical power cannot be guaranteed, so the TSPM should either include or contract from the OAN-SPM safe, autonomous electricity generation that comes online automatically in the case of a power failure. This would allow warming instruments up safely (e.g., MMIRS) and would keep pipes from freezing. Note that the OAN-SPM currently has a generator that comes online automatically during power outages, but its current practice is to turn off all power generation when it evacuates for severe winter storms.

The TSPM will contain a great deal of very specialized equipment. Many replacements parts may not be available locally in Ensenada. Inevitably, it will be useful to have the replacement parts that are needed most commonly on site in SPM.

The primary mirror (M1) and its cell will be shipped separately to the OAN-SPM. Thus, the TSPM will require a crane with sufficient capacity and height to install M1 into its cell (see §9.3.2). This crane would also be needed in the (unlikely) event of damage to some component within the M1 cell that may be accessed only by removing M1, e.g., a load spreader. (In this particular case, the M1 transport box will also be needed.)

Periodically, it will be necessary to aluminize the TSPM mirrors. The needs of this process are driven by the aluminization of M1. In this process, the TSPM intends to follow the procedure used at the Magellan telescopes (see §9.3.3). At the Magellan telescopes, the bottom part of the aluminizing chamber serves as the cart that is used to remove and install M1 on the telescopes. It moves on rails from below the aluminizing chamber to the dome and has jacks to raise and lower M1 to mate with the telescope's optical support structure. Between the aluminizing chamber and the dome, there is a washing area with a personnel bridge that provides easy access to the top surface of the mirror. The TSPM intends to implement a very similar procedure. In principle, the secondary and tertiary mirrors could be aluminized in the chamber at the OAN-SPM's 2.1m telescope, but it will be safer to aluminize them within the TSPM facility.

Maintenance of the telescope and instruments must be done on site given the remoteness of the OAN-SPM. Thus, the TSPM must include the facilities required to maintain the telescope and instruments. For the sake of simplicity and the safety of both personnel and equipment, all the movement of the instruments and secondary mirrors should ideally occur on a single level within the facility. The TSPM should specifically consider the shipping and receiving of its instruments and other large equipment. To the extent possible, this is done using commercial containers, so the TSPM should have a receiving bay and entrance large enough to accommodate items with envelopes of this size or, if possible, entire trucks. If the latter is possible, trucks should be able to back under the aforementioned crane in the mirror wash area to facilitate manipulating heavy instruments. A fork-lift or similar device should be able to circulate in this area.

The TSPM will require space to store secondary mirrors, instruments, and their associated equipment, such as carts and handling tools, when they are not in use. The ancillary equipment can easily occupy more space than the instrument itself. There will also be ancillary equipment related to the primary mirror and other components that must be stored, e.g., lifting fixture, transport box. Apart from the space requirement, this storage area may need a reinforced floor to accommodate the weight of the items in storage. More details on this topic may be found in §7.7.

The TSPM should include a cleanroom that is large enough to receive and accommodate its instruments and the personnel needed to maintain them. The cleanroom should be equipped with a crane of sufficient capacity to lift the heaviest instruments that are foreseen. This cleanroom should also be equipped with the usual infrastructure and diagnostic tools to deal with electronics and optics. The clean room should be of class ISO 7 (class 10,000).

The daily operation of the TSPM will occur from a control room. This control room should be located conveniently so that access to the dome is not difficult. The control room should be large enough to accommodate larger groups than will be present during normal operations, e.g., the personnel required for commissioning activities (5-10 people).

For the convenience of the telescope operators, technical staff, and astronomers, both resident and visiting, the TSPM should include office space, lockers, and a lunch/dining area.

The TSPM will contain a great deal of computing and other IT equipment. The computer room should be located so as to have convenient access to the dome (via conduits) and to the observing room. All of the TSPM's computing infrastructure and as much as possible of the communications infrastructure should be located here. For the protection of personnel, infrastructure, and data, this room should be protected with a fire suppression system given its potential as a fire hazard.

The only support facilities that will be nearby for the TSPM are those of the OAN-SPM. Apart from the infrastructure mentioned in §5.7, the OAN-SPM has a small nitrogen plant, a precision machine shop, an electronics laboratory, and a vehicle maintenance shop, as well as personnel trained in the use of these facilities. Depending upon the operations model eventually adopted by the TSPM project, it could be useful to negotiate occasional access to some of these facilities (e.g., precision machining, vehicle maintenance), since they will complement those available within the TSPM's installations. Likewise, it might be useful to consider similar arrangements for the facilities available at the IA-UNAM's branch in Ensenada. Note that the nitrogen plant currently operated by the OAN-SPM is incapable of meeting the TSPM's needs.

7.7 Instruments and associated equipment storage needs

The TSPM support building should include space specifically for instrument storage (Room 214, upper left in Figure 14). The current building floor plan allocates approximately 93 m^2 to this instrument storage area. It also includes an equipment room (46 m^2), though this space is primarily considered for the installation of permanent equipment, e.g., future helium compressors. As a general rule, handling carts and other components that will get regular use will be stored in this area while other components that are used only for shipping or infrequent repair will be stored off-site in a warehouse.

What follows is based upon varying degrees of certainty. For equipment that exists for the f/5 Cassegrain focal station, we attempted to include the best figures available, usually the interface control documents for this equipment at the Magellan II/Clay telescope, but we include additional information provided by the SAO. For components that do not exist, are not designed, etc., we base our estimates upon similar components from the f/5 Cassegrain configuration and the maximum instrument envelopes that are defined in the High Level Requirements. While the overall extent of what follows is ambitious (f/5 Cassegrain as well as f/5 and f/11 Nasmyth configurations, at least 2-3 instruments/focal configuration), this approach would appear prudent given the TSPM project's current status.

Appendix A summarizes the information in the sections that follow. In Appendix A, rigging, slings, hangers, spreader bars and the like are assumed to occupy no floor space since it is planned to hang this on the wall or store them on the instrument carts or in the TSPM equipment room. Some additional items have no floor space assigned, either because it is not clear whether they will be needed or whether they will be included as part of a handling cart. The f/5 Cassegrain configuration components require a total storage space of 52 m^2 in the instrument storage bay and 21 m^2 off-site, considering the Day 1 instrumentation and an additional instrument with the size of Binospec. The f/5 Nasmyth configuration components require a total storage space of 44 m^2 in the instrument bay and 18 m^2 off-site while the corresponding figures for the f/11 Nasmyth configuration are 40 m^2 in the instrument bay and 18 m^2 off-site. Finally, the folded Cassegrain configuration requires 8 m^2 in the instrument bay and 24 m^2 off-site. Clearly, the instrument bay will accommodate only f/5 Cassegrain and another fully-equipped focal configuration. An off-site storage location will be required should all focal stations ever be fully-equipped. Off-site storage will be required for M1-related equipment.

7.7.1 M1 transport box and lifting fixture:

The M1 transport box has dimensions of 7.01 × 6.99 × 1.88 m (l × w × h; without wheels, 2.49 m high with wheels) and weighs about 19.57 tonnes. The M1 transport box cannot be disassembled. It must be stored in case M1 needs to be removed from its cell to repair some element that is otherwise inaccessible (§9.3.6). The M1 lifting fixture is somewhat smaller and will be needed to install M1 in its cell as well as to remove it should that ever be necessary (§§0, 9.3.6). Once M1 is installed in its cell, the M1 transport box and M1 lifting fixtures will only be required in the case of an emergency. As far as the project is aware, such emergencies are rare and have never happened at either the MMT or Magellan telescopes. The use of the M1 lifting fixture requires a vacuum pump and hoses to provide the necessary vacuum to the lifting fixture's lifting pads. The vacuum pump and hoses could be of general use. In addition, rigging and/or a spreader bar will be needed to attach the lifting fixture to the mirror bay's bridge crane. This rigging could also be of general use. Given their dimensions and their expected infrequent use, both the M1 transport box and the M1 lifting fixture will be stored off-site. Those fixtures that are only used for these manoeuvres should be stored with the M1 transport box and lifting fixture. Other equipment, such as the vacuum pump, associated hoses, and rigging could be stored in the equipment room (Figure 14).

7.7.2 M1 dummy mirror

There is also a "dummy M1 mirror", which is a structure of steel plates and beams whose weight is approximately the same as the real primary mirror. The dummy M1 mirror could be useful should it ever be necessary to test the control system after significantly changing some components, e.g., electronics boards. The dummy mirror may be stored in the M1 transport box. There is as yet no decision on whether this component will be stored, but, if so, it would certainly be stored off-site in the M1 transport box.

7.7.3 f/5 Cassegrain M2

The First Light and Day One operation supposes the use of the TSPM in an f/5 Cassegrain configuration (§5.4). The Cassegrain f/5 secondary is currently in use at the Magellan II/Baade telescope. The mirror's cart has a footprint of 2.16 × 1.63 m. The mirror cart will be stored in the instrument storage bay in the support building (Figure 14). Any rigging or other support elements shall be stored on the handling cart or hung on the wall.

7.7.4 f/5 Cassegrain baffles

The system of baffles for the f/5 Cassegrain configuration includes two sections. One baffle section attaches to the secondary mirror while the other is suspended above the primary. Both sections have radii of up to approximately 1.2m from the optical axis and so imply diameters of order 2.5m. Presumably, the footprint of the handling carts will be of order 3 × 3 m. At most two carts would be required and both would be stored in the instrument storage bay in the support building (Figure 14). Any rigging or other support elements shall be stored on the handling cart or hung on the wall.

7.7.5 f/5 Cassegrain corrector

The f/5 Cassegrain corrector has a cart that is used to install (and store? TBC) the corrector at the Cassegrain focal station. There is also a cart to store the "fourth" lens. Based upon information provided by SAO (R.27), these carts have footprints of approximately 1.6 × 1.6m and 1.6 × 1.0m. Both handling carts will be stored in the instrument storage bay in the support building (Figure 14). Any other support elements shall be stored on the handling cart or hung on the wall. In the interface document delivered to Magellan, SAO estimates that the f/5 instrument suite (§§7.7.5-7.7.7) require a footprint of 4.6 × 4.6m, which includes space around the components (R.27).

7.7.6 Megacam

Megacam is the First Light instrument (§5.4). It is shipped on a shipping stand. At the observatory, it will be stored on its handling cart. This cart is also used when installing Megacam on the telescope. Based upon information provided by SAO (R.27), the handling cart has a footprint of approximately 2.6 × 1.6 m, though it is clear that the Megacam envelope exceeds this. The handling cart will be stored in the instrument storage bay in the support building (Figure 14), but the shipping stand will be stored off-site. Any other support elements shall be stored on the handling cart or hung on the wall. In the interface document delivered to Magellan, SAO estimates that the f/5 instrument suite (§§7.7.5-7.7.7) requires a footprint of 4.6 × 4.6m, which includes space around the components (R.27).

7.7.7 MMIRS

MMIRS is the Day One instrument (§5.4). It is shipped on a shipping stand. At the observatory, it will be stored on its handling cart. This cart is also used when installing MMIRS on the telescope. Based upon information provided by SAO (R.28), the handling cart has a footprint of approximately 3.2 × 2.4 m, including the space required to store MMIRS with its electronics cabinets mounted. The instrument cart will be stored in the instrument storage bay in the support building (Figure 14), but the shipping stand will be stored off-site. Any other support elements shall be stored on the handling cart or hung on the wall. In the interface document delivered to Magellan, SAO estimates that the f/5 instrument suite (§§7.7.5-7.7.7) requires a footprint of 4.6 × 4.6m, which includes space around the components (R.27).

7.7.8 Binospec?

Binospec is a potential post-Day One f/5 Cassegrain instrument. From photos provided, the associated stands include a handling cart and a simulator. Presumably, it will be shipped on a shipping mount (TBD). The simulator has a footprint of 5.5 × 2.2 m (R.29). The handling cart is not as long as the simulator, but is wider, so we estimate a footprint of 3 × 3 m. At the observatory, it will be stored on the handling cart. Installing it on the telescope will require TBD. The handling cart will be stored in the instrument storage bay in the support building (Figure 14), but the other components will be stored off-site (TBC). Any other support elements shall be stored on the handling cart or hung on the wall.

7.7.9 CartZilla

“CartZilla” is the vehicle used to install the f/5 Cassegrain corrector, Megacam, and, previously, MMIRS at the Magellan II Telescope. CartZilla, or some apparatus with its capabilities, will be required to install Megacam and MMIRS at the TSPM. At present, it is the TSPM project’s understanding that CartZilla will be part of the equipment that the SAO and UA will contribute as part of the Day One instrument suite. To the extent possible, the TSPM intends to use CartZilla as its general-purpose instrument transport cart. Normally, it will be parked in the vestibule of the support building.

7.7.10 f/5 Nasmyth M2

Post-Day One (§5.4), TSPM operation supposes the use of the Nasmyth focal stations, initially in an f/5 optical configuration. The f/5 Nasmyth and Cassegrain configurations require different secondary mirrors. At present, we assume that the f/5 Nasmyth secondary will have the space requirements that are 25% greater than the f/5 Cassegrain secondary. (The clear aperture of the f/5 Nasmyth secondary is 16% greater in linear size than the f/5 Cassegrain secondary.) The mirror cart will be stored in the instrument storage bay in the support building (Figure 14). Any rigging or other support elements shall be stored on the handling cart or hung on the wall.

7.7.11 f/5 Nasmyth baffles

Lacking a design for these baffles, we assume a single cart of the same area as used for the f/5 Cassegrain baffles. The f/5 Nasmyth baffle handling cart will be stored in the instrument storage bay in the support building (Figure 14). Any rigging or other support elements shall be stored on the handling cart or hung on the wall.

7.7.12 f/5 Nasmyth correctors

Given that the field of view and plate scale at the f/5 Nasmyth focal station are very similar to those at f/5 Cassegrain focal station, for the present we assume a similar footprint for the handling and storage cart required for the f/5 Nasmyth correctors. The specifications for the f/5 Nasmyth focal station indicates that there will be two correctors, one for the optical and the other for the near infrared. Hence, there will be two f/5 Nasmyth correctors, presumably each with its own handling and storage cart. In addition, some sort of insertion fixture will be needed, unless this is part of the handling cart. (This option should be pursued.) Any rigging or other support elements shall be stored on the handling cart or hung on the wall.

7.7.13 M3

The use of a Nasmyth configuration in the post-Day One operation of the TSPM will require a tertiary mirror. This tertiary mirror will be used for all of the Nasmyth and folded Cassegrain focal stations. At present, we assume that M3 will have the same space requirements as the f/5 Cassegrain secondary since its largest dimension is within a few percent of the clear aperture of the f/5 Cassegrain secondary. The mirror cart will be stored in the instrument storage bay in the support building (Figure 14). Any rigging or other support elements shall be stored on the handling cart or hung on the wall. In addition to the tertiary mirror itself and its cell, there will also be the tertiary tower, which may have two sections. It is likely that the tertiary mirror will require a specialized insertion mechanism or structure. At present, there is no full design of the tertiary tower nor a detailed plan for its installation. Until further information is available, it is difficult to determine how much extra space should be allotted for the tertiary mirror system, though it is clear that the total space will exceed that required to store the M3 mirror in its cell.

7.7.14 f/5 Nasmyth instruments #1 and #2

Based upon the instrument envelope defined for the Nasmyth instruments, a footprint of 3 × 3 m is estimated for both the handling cart and the shipping stand. The handling cart will be stored in the instrument bay, but the shipping stand will be stored off-site in a warehouse. Any rigging or other support elements shall be stored on the handling cart or hung on the wall.

7.7.15 f/11 Nasmyth M2

Post-Day One (§5.4), TSPM operation supposes the use of the Nasmyth focal stations, initially in an f/5 optical configuration, but later also an f/11. At present, we assume that the f/11 Nasmyth secondary will have the same space requirements as the f/5 Cassegrain secondary. The mirror cart will be stored in the instrument storage bay in the support building (Figure 14). Any rigging or other support elements shall be stored on the handling cart or hung on the wall.

7.7.16 f/11 Nasmyth baffles

Lacking a design for these baffles, we assume a single cart of the same area as used for the f/5 Cassegrain baffles. The f/11 Nasmyth baffle handling cart will be stored in the instrument storage bay in the support building (Figure 14). Any rigging or other support elements shall be stored on the handling cart or hung on the wall.

7.7.17 f/11 Nasmyth correctors

For the present we assume a similar footprint for the handling and storage cart as that required for the f/5 Cassegrain corrector. The specifications for the f/11 Nasmyth focal station do not indicate whether there will be one or two correctors. To be conservative, we assume there will be two f/11 Nasmyth correctors, presumably each with its own handling and storage cart. In addition, some sort of insertion fixture will be needed, unless this is part of the handling cart, an option that should be pursued. Any rigging or other support elements shall be stored on the handling cart or hung on the wall.

7.7.18 f/11 Nasmyth instruments #1 and #2

Based upon the instrument envelope defined for the Nasmyth instruments, a footprint of 3 × 3 m is estimated for both the handling cart and the shipping stand. The handling cart will be stored in the instrument bay, but the shipping stand will be stored off-site in a warehouse. Any rigging or other support elements shall be stored on the handling cart or hung on the wall.

7.7.19 Folded Cassegrain instruments #1, #2, #3, and #4

Post-Day One (§5.4), TSPM operation supposes the use of up to four folded Cassegrain focal stations. These focal stations will require a corrector, but these optics will be incorporated into the instrument itself. The instrument envelope defined for these instruments is 1 × 1.5 m (diameter × length). Hence, the footprint of the instrument handling cart should not exceed 2 × 2 m. There may also be a shipping stand, of similar dimensions. Since instruments installed at the folded Cassegrain focal stations are likely to be mounted semi-permanently, i.e., for the duration of the period they are used at the TSPM, the handling cart may also be stored off-site in a warehouse. The shipping stand will definitely be stored off-site in a warehouse. Any rigging or other support elements shall be stored with the handling cart or shipping stands.

7.8 Other storage needs

- oil to top-up the hydrostatic bearing system
- chemicals and supplies for aluminizing mirrors
- other chemicals, e.g., water treatment
- space for spares in the instrument storage bay or the TSPM equipment room: shelves, cabinets, etc.
- …

8. SYSTEM OVERVIEW

8.1 System Architecture

The TSPM project currently is divided into 16 work packages. Responsibility for these work packages is spread among the four TSPM partner institutions and several additional companies and institutions as shown in Figure 10. These work packages constitute a structure necessary to deliver the TSPM project scope for Day 1, as described above. In what follows, the work packages are presented hierarchically. Schematically, the work packages are shown in Figure 10. The work packages may be sorted into two groups. The first concerns management and science while the second concerns the hardware and software components of the TSPM project.

The top-level work package is the TSPM project direction. The TSPM project direction includes liaison with the TSPM project board, composed of the directors of the four partner institutions, decisions related to funding (requests, expenditures, etc.), top level supervision and decisions, all of the administration, and long-term planning. Currently, the TSPM project board is an informal entity whose basis is being signatories to the LoI that defines the TSPM project. Regardless, it is clear that some form of this entity will be necessary to exercise the will of the partner institutions and that the project director is the natural link between the project board and the rest of the project.

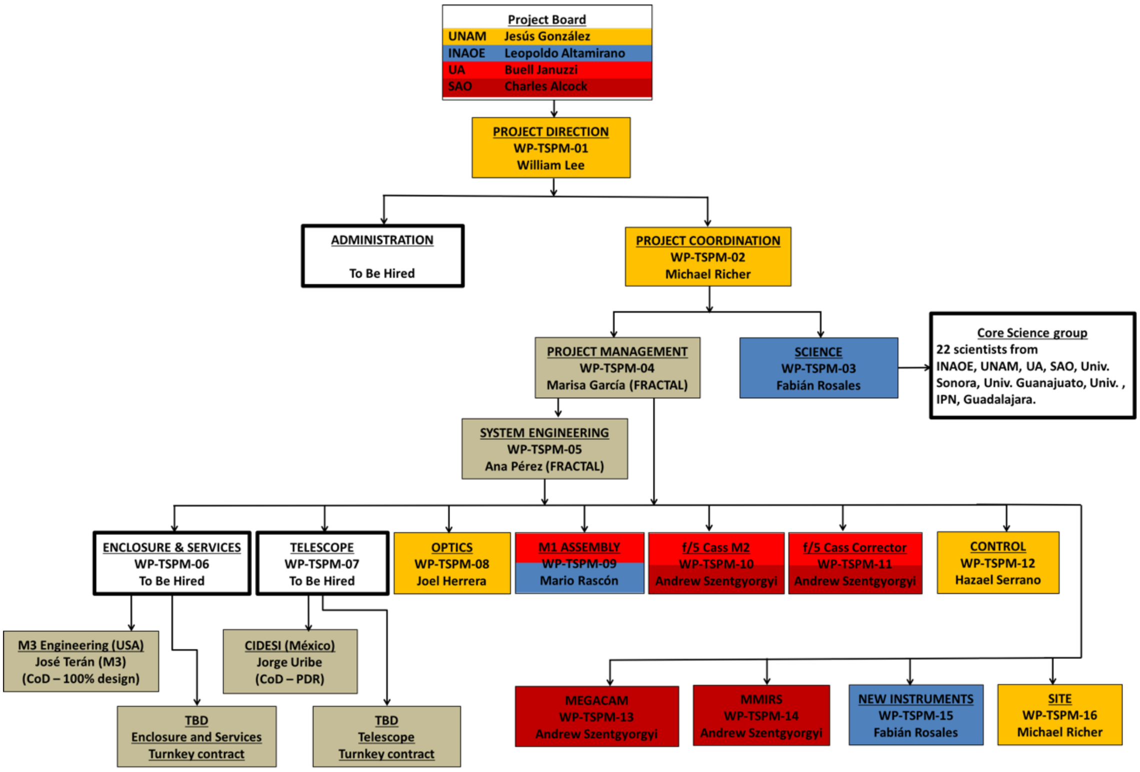

Figure 10: *The work package hierarchy in the TSPM project. This organization chart attempts to include the future structure of the entity that will build and possibly operate the TSPM. Differences are explained in the text. Eventually, all of the indicated work package managers should have a counterpart within this future entity.*

The next level in the organization chart includes the financial administration and project coordination work packages. These two work packages are separate and the project director is the link between the two. Hence, financial administration depends upon the project direction. Currently, the IA-UNAM's administration handles all of the project's administration, though that role should be transferred to the entity that arises to build the TSPM as soon as is feasible.

The project coordination work package includes coordination between different parts of the project as well as general, continuous supervision of all of them. Project coordination is the interface with the scientific needs of the TSPM project. Project coordination interacts primarily with the science, project management, and system engineering, but there is substantial interaction with all work packages and all participants in the project.

The science work package, with the management work package, is in the next level. The science work package is charged with developing the science cases and ensuring that the development of the TSPM project complies with the needs of the science cases. At the moment, this effort is largely restricted to participants from institutions within Mexico, but it is hoped to include personnel from both the UA and SAO shortly. As indicated earlier, the TSPM is expected to be a general-purpose facility for the Mexican astronomical community and its science cases currently reflect that. In particular, the initial instrument suite, Megacam and

MMIRS, will not meet all of the needs of the science cases currently proposed. It is clear that optical spectroscopy will need to be developed, unless these needs are to be met entirely as part of the collaboration with the MMT.

The project management work package supervises and coordinates all of the technical work in system engineering and all of the hardware and software subsystem work packages. Project management is charged with developing the management plan, the coordination, definition, and scope of all of the work packages, maintaining the schedule and budget information, identifying risks and developing plans to minimize or mitigate them, and implementing and coordinating the plans for construction, assembly, verification, commissioning, operation, and maintenance of the TSPM. This work package has been contracted to Fractal S.L.N.E. (henceforth, Fractal) as none of the partner institutions can currently provide the personnel required. Fractal has extensive experience in the management and systems engineering from many astronomical projects.

The only work package in the fourth level of the hierarchy is the system engineering work package. The function of the system engineering work package is to ensure that all of the hardware and software subsystems of the TSPM project work together to implement the needs of the TSPM project. In particular, the system engineer oversees the interfaces between all subsystems, ensuring that these guarantee that the subsystems will be functional as a complete system. As a result, the system engineer interacts with all of the hardware and software subsystems to define specific and detailed design requirements as well as clear means of demonstrating compliance with these requirements. This work package has been contracted to Fractal as none of the partner institutions can currently provide the personnel required.

All of the work packages related to the hardware and software subsystems of the TSPM project depend directly upon system engineering and project management. The management of these individual work packages is distributed according to the expertise required and that available within the partner institutions. In those cases where the partner institutions lack the expertise or personnel required, the work packages have been contracted to institutions or companies within Mexico, in accord with the arguments set out in §5.3.

The enclosure and services work package is charged with providing the telescope enclosure, support building, and the service infrastructure to operate and maintain the telescope and instruments. This work package includes the low-level control system for all of its component mechanisms. The enclosure and services work package currently includes the mirror coating chamber, but this will change once this work package proceeds beyond preliminary design. This work package has been contracted to M3 Mexicana S. de R. L. de C. V. of Hermosillo, Sonora, Mexico (M3), the Mexican affiliate of M3 Engineering Corporation, given the experience of the latter in the development of astronomical observatories, particularly with the Magellan observatory at Las Campanas in Chile, the inspiration for many of the design elements in the TSPM project. At present, it is envisaged that, in addition to designing the telescope enclosure and support building, M3 will also be contracted to manage the construction of these same elements. At present, the principal interfaces of the enclosure and services work package are with the site, telescope, and control work packages.

The telescope work package has the task of providing the mechanical structure of the telescope, including all of its mechanisms, save the primary, secondary, and tertiary mirror assemblies (M1, M2, and M3, respectively). This work package includes the low-level control system for all component mechanisms. The telescope work package has been contracted to the Centro de Ingeniería y Desarrollo Industrial (CIDESI), a federally funded research centre in Querétaro, Querétaro, Mexico dedicated to the development of industrial technology for industry. CIDESI has previously collaborated with and is currently collaborating with the IA-UNAM in the construction of Cámara de Verificación, OSIRIS, and FRIDA. CIDESI has also collaborated with the INAOE on MEGARA. All of the foregoing are instruments for the Gran Telescopio de Canarias (GTC). The principal interfaces of the telescope work package are with the enclosure and services, M1, M2 & Cass corrector, M3, instrumentation, and control work packages.

The optics work package is to provide the optical design, including the tolerance analysis for the three optical configurations that are formally contemplated in the TSPM design (§5.3). The optics work package also includes the development of the facility wavefront sensor and guider. This work package is being undertaken by the IA-UNAM, with some work subcontracted to Fractal. The IA-UNAM has a long history of instrument development for the telescopes at the OAN-SPM. Its experience with instrumentation for large telescopes is via projects for the Hobby Ebberly Telescope (HET) and the GTC. The principal interfaces for the optics work package are the telescope, M1, M2 & Cass corrector, M3, instrumentation, and control work packages.

The M1 subsystem work package is charged with providing the polished primary mirror (M1), its cell, the M1 support system and its control system, optical testing of M1 in its cell in the test tower, the design of the thermal control system, the M1 lifting fixture, the M1 transport box, a dummy M1 for support testing, spare parts, documentation for all of the foregoing, and packing and preparation for shipping. The M1 subsystem work package is the responsibility of the INAOE and UA. This is the fifth 6.5m mirror that the UA has provided for astronomical projects. M1 already exists and must be repolished. The project should supplement the contract between INAOE and UA to include items that are currently not covered by that contract, such as implementation of the thermal control system, transport of M1 to the OAN-SPM, transport of the M1 cell and dummy mirror to the site of the telescope assembly, and verification of the primary mirror system in situ at the OAN-SPM. The principal interfaces for this work package are with the enclosure and services, telescope, instrumentation, M2 & Cass corrector, M3, and control work packages.

The M2 & Cass corrector work package shall deliver the f/5 Cassegrain secondary mirror (M2) and wide field corrector currently in use at the Magellan II/Clay telescope. These elements were constructed so as to allow the Magellan II telescope to replicate the capabilities of the f/5 Cassegrain focal station of the MMT. Both have been in use since 2009 (Szentgyorgyi et al. 2012). Although the atmospheric dispersion correctors (ADC) were never implemented in this version of the f/5 Cass corrector, its components do exist, and so this capability could be added for use at the TSPM. This will be done *after* Day 1, since the instruments that will be used initially do not need this capability. The M2 & Cass corrector work package is the responsibility of the SAO. The principal interfaces for this work package are the telescope and control work packages.

The control work package has a very broad responsibility for the high-level control system for all of the other subsystems shown in Figure 10. The control work package also has responsibility for the observatory control software, including that required for observing proposal generation, implementation, data acquisition, and data archiving. Given that the user communities in Mexico, UA, and SAO have different institutional traditions regarding observing support, the part of the TSPM control system that interfaces with users must be flexible. As a general philosophy, the TSPM project has adopted the model of the control system developed by the GMT. Realistically, however, given that some components and their control systems already exist, it is clear that there will inevitably be “glue layers” at various subsystem interfaces within the complete control system. This work package is being undertaken by IA-UNAM, though it is hoped to include INAOE in the near future. Both institutions have experience in developing observatory control systems. The control work package has relevant interfaces with all of the other subsystems shown in Figure 10.

The instrumentation work package is the only work package that is subdivided into several subunits. Overall management of the work package is under the direction of the project scientist as is the subunit related to new instrumentation. There are subunits in the instrumentation work package for each of the Day 1 instruments, Megacam and MMIRS. Both of these subunits are managed by the SAO as the instruments were designed and built by SAO personnel. Both of these instruments are currently in operation: Megacam at Magellan II/Clay and MMIRS at the MMT. Both instruments have their own control systems and it is clear that this is one case where a “glue layer” will be needed as an interface to the TSPM control system (see also §7.4.5). The instrument work package has its principal interfaces with the telescope, enclosure and services, and control work packages.

The site work package has the responsibility to characterize the site, obtain the required environmental and construction permits, and provide access to the common infrastructure of the OAN-SPM. The site work package is not expected to provide management of the construction process, but it will likely retain the highest-level supervision. Presently, the IA-UNAM is responsible for this work package, but this responsibility should be transferred to the TSPMO (§7.5.1) once it exists. The principal interface of the site work package is with the enclosure and services work package.

The foregoing implicitly assumes that the party responsible for each work package has end-to-end responsibility of its work package(s). This is not likely realistic in all cases, the most obvious one being the M2 & Cass corrector work package, and will eventually be resolved via agreements between the partner institutions. Likely, this will entail devolution of the responsibility for certain aspects of these work packages to the TSPMO or another partner institution in Mexico.

8.2 RAMS

The RAMS (Reliability, Availability, Maintainability, and Safety) requirements are included as part of the TSPM System Specification (see R.13). A RAMS plan shall be implemented at all levels of the TSPM system in order to ensure that the final system design meets the availability, reliability, maintainability, and safety requirements that have been established.

The RAMS analyses that shall be carried out includes the following:

- Maintainability Analysis: The main system maintenance activities are identified and analysed to define how they will be performed in order to ensure their feasibility and to optimize their execution. §9.2 provides an outline of some of these activities.
- Transport Analysis: This activity analyses the constrains related to the access to the site in SPM. These requirements will be applied to all relevant components in order to guarantee the correct transport, handling, and integration of those elements during the design of the whole system.
- Failure Analysis (FMECA): This analysis identifies and evaluates the potential failure modes of the system.
- Reliability Analysis: This analysis estimates the percentage of time that the system could be unavailable for astronomical observation.
- Spare analysis: This analysis uses the outputs from the FMECA and reliability analyses in order to provide a spare parts list.
- Safety Analysis: This study attempts to visualize the possible hazards to the people involved in the use and maintenance of the system.

More detailed about the RAMS analysis to be undertaken are provided at the TSPM Preliminary RAMS Analysis document (see R.14).

8.2.1 System and subsystem verification

Each subsystem will implement a plan to verify that it complies with its requirements, through design, formal reviews, physical inspections, or specific tests and measurements. The TSPM as a system will likewise implement a verification plan.

8.2.2 System availability

Despite the measures in planning and maintenance that can and should be made, it is foreseen that component failures will consume some fraction of the time at night. It is foreseen that repairs requiring an hour will occur on a weekly basis (TBC), those requiring an entire day to repair will occur every three months (TBC), and those requiring a week to repair will occur yearly (TBC). If none of these overlaps and all of them occur at night, they imply a total time of 4.5% annually. The minimum time lost at night that these estimates imply is 3.0% of the time on a yearly basis (1 night lost every three months and 7 nights lost once every year).

8.2.3 Megacam and MMIRS

The TSPM is foreseen to begin its scientific operation circa 2023 using the Megacam and MMIRS instruments. Megacam and MMIRS were commissioned, respectively, in 2003 and 2009. Thus, their software and hardware components will be at least 14-20 years old when they enter operations at the TSPM. Clearly, the TSPM must begin a process to catalogue at least the hardware components and identify possible replacements. These instruments clearly pose a challenge for the TSPM control system from a software perspective: Their control systems are presently under-documented and some of those who were involved in their development may well have retired by 2023. The TSPM project must implement some means to mitigate this risk.

8.2.4 Primary mirror cell electronics

The expected lifetime of the TSPM project is nominally 40 years. This time scale is vastly longer than what may be expected for the lifetimes of electronics components or their procurement. Spare parts will be acquired to substitute the originals for the first **XX** years of operation. Five years before the expected exhaustion of these parts, plans will be implemented to re-design and re-populate the electronics components.

9. OPERATIONAL PROCESSES

9.1 Scientific Operation

Some aspects of all of the topics that follow will eventually have to be addressed by the TSPM Project Board. What follows are straw-man scenarios to guide those discussions.

9.1.1 Time allocation

No definite strategy for time allocation for the TSPM project exists at present and will only become clear as a result of the legal framework between the partner institutions. It is anticipated that the time will be divided among the partner institutions according to their contributions to the project, considering both cash and in-kind contributions. Given the different traditions within the partner communities, an MMT-like model for time allocation is foreseen, in which each partner allocates its time share. Within the TSPMO, these time allocations would be folded into a single schedule. Presumably, this schedule would also account for the time allocated to mirror coating, instrument development, and other engineering activities or time blocks for different observing modes stemming from decisions made by the TSPM Project Board (or a Scientific Advisory Committee or similar entity). Depending upon the observing modes that are finally implemented (§7.4.7), it will be necessary to track the observing time actually used by each partner and to implement some long-term mechanism to ensure that each partner effectively receives their entitlement.

9.1.2 Phase I proposal preparation

In principle, various tools could be used for phase I proposal preparation. However, since it will eventually be necessary to derive uniform descriptions of these observations for execution, it would be simplest if there were a single tool for phase I proposal preparation that is used by all partners. If the phase I proposals are to be the basis for subsequent observatory operations, such as observing proposal evaluation, instrument configuration, data acquisition and data archiving, the phase I proposal preparation tools should be implemented as part of the TSPM's control system. That would allow better integration with the subsequent execution of the observations and tracking of program completion. If so, off-site users would require appropriately-limited access to the databases implemented in the TSPM's control system via online tools for the phase I process.

9.1.3 Observing proposal approval

As commented above (§9.1.1), this aspect of TSPM operations is not yet defined. The partners envisage Time Allocation Committees (TACs) for each partner as well as some mechanism to implement a single observing schedule using each partner's time allocations. The time allocation process at each partner institution would need appropriately-limited access to the same databases used by the phase I proposal preparation tools.

9.1.4 Observation execution

How observations are executed will depend upon the observing modes available. If, as outlined in §7.4.7, queue or service mode are implemented, there are enormous advantages in implementing the execution of observations via some sort of phase II process that unifies all observations into observing blocks and configuration files. Even for classical or remote observing, this scheme has very clear advantages, as it requires a great deal of validation prior to executing the observations, thereby lowering the risk of configuration and other errors and the subsequent loss of observing time. For a multi-community observatory such as the TSPM, unifying all observations from all partners in a single format is an advantage, regardless of the observing modes that are implemented, since it will help minimize the number of execution errors.

We assume that a phase II process will exist and its purpose is to generate the observing block configuration files. These configuration files will contain at least coordinates, instrument configurations, observing sequences, if applicable, and integration time. Generating the phase II configuration files is the responsibility of the astronomers requesting observing time and so they will need appropriate access to the TSPM control system to allow this. They will be assisted in this task by the TSPM instrument scientists. At the telescope, depending upon the observing modes finally used, the visiting astronomer, instrument scientist, or the queue scheduler will be responsible for selecting the observing blocks to be executed, but the telescope operator will be final arbiter in their implementation and execution. Once observing blocks are executed, quality control will be assessed, ideally automatically, but inevitably the instrument scientists will have to provide some oversight.

The observing room should make observing efficient. There should be convenient access to the telescope enclosure for the telescope operator, astronomers, and maintenance technicians. Winter conditions should be taken into consideration (§5.7). There should be adequate space for the telescope operator, maintenance technicians, and astronomers. There should also be adequate space to display the information required to operate the facility and to monitor the state of its components. The control system should monitor the state of all components continuously. Faults and diagnostic alarms should be triggered automatically by the control system. To ease troubleshooting, state information should be preserved.

9.1.5 Data products and archiving

The TSPM must implement data archiving. A large part of modern astronomy is based upon using data acquired at multiple facilities to understand particular phenomena or objects. Consequently, data availability and re-use are critical. Raw data, pipeline-processed data, and the data reduction software should all be available in the TSPM data archive. Ideally, it should be possible to re-reduce raw data using parameters optimized for different purposes. Remote (or local) access to this archive will be necessary so that astronomers may access the data they require. Initially, it will be the astronomers who propose the observations who need access, but later others will be allowed access, so the TSPM control system will have to distinguish between the initial users and others. The TSPM control system should automatically alert astronomers when their data (or part thereof) becomes available so that they may download and assess it.

9.1.6 Engineering data

In a complex observatory environment, it is also very important to be able to investigate and sometimes to recreate the conditions that lead to malfunctions. If this is to be possible, state data and telemetry must be archived and adequate tools must exist to monitor and interpret this information. Since it is relevant for both scientific data and trouble-shooting, meteorological information should be archived and attached to the data (see §9.2.3).

9.1.7 The telescope, instruments, and calibrations

Pointing, tracking, guiding, offsetting, and Cassegrain derotation should all be very accurate over the entire pointing range, from 18° elevation to the zenith blind spot (0.5° radius). These movements should not impose significant time overheads, as this will sap observing efficiency. To avoid complicating the scheduling of observations, all parallactic angles should be available over the entire pointing range and it should be possible to maintain any parallactic angle during the entire time any object is visible. Similarly, non-sidereal tracking rates up to 5"/s relative to the sidereal rate should be available over the entire pointing range. The telescope should provide instruments and observing blocks a means to execute offsets programmatically, again in the interests of simplifying the scheduling of observations.

Given the philosophy that instrument development be the responsibility of the partner institutions, all instruments should incorporate guiding and acquisition capability. This requirement could be relaxed if guiding and acquisition are not required for instrument verification or if the facility acquisition and guiding capabilities, when they exist, do not imply reduced instrument performance. Ideally, each instrument should incorporate wavefront sensing as well, preferably continuous wavefront sensing, unless the facility acquisition and guiding system can provide adequate wavefront sensing capabilities. The calibration hardware required by each instrument should be an integral part of that instrument. While this may impose some duplication, it will simplify data taking and instrument control, verification, and commissioning. All new instruments should have a control system that conforms to the TSPM control system architecture.

Calibrations that do not require observing the sky should be done in late afternoon or early morning, when possible. To make more efficient use of the observing time at night (between evening and morning astronomical twilights), all routine instrumental calibrations should end during civil twilight. Set-up calibrations, such as tuning the active optics, should take place before the end of nautical twilight and then, if they cannot be done continuously in parallel with astronomical observations, they should be done during object acquisition throughout the rest of the night. Standard, cross-program calibrations, such as photometric calibrations should be obtained during astronomical twilight when possible. If obtained at night, they should be accounted for in the time available to each partner in proportion to each partner's use of the instrument in question. The time required during the night for other calibrations that are specific to a given scientific program should be charged to that program and accounted for in the time available for that program's institution or institutions.

9.2 Astronomical Observations

9.2.1 Daytime control of the temperature of M1 and inside the telescope enclosure

As summarized in §5.7 (details in R.36 and R.38), the largest rates of change of the temperature during the day in San Pedro Mártir occur in the hours immediately after sunrise and before sunset, with the temperature change often exceeding ±1ºC/hour. The cooling that occurs before sunset continues at a slower rate during the first hour after sunset, but after that the rate of change of the temperature slows very considerably throughout the rest of the night. The temperature change inside the telescope enclosure will be much smaller than that for the ambient air outside during the day since the enclosure temperature will be actively controlled. On average, the temperature at sunset is 1ºC ± 2ºC warmer than the temperature at sunrise and the cooling following sunset is less than 1ºC. Thus, active cooling of the enclosure should aim to achieve a temperature at sunset similar to the ambient temperature expected at sunset, though it should also take into account the actual temperature variation on any given day. When the humidity is low enough, active cooling of the enclosure as well as pre-cooling of the primary mirror should aim to achieve a temperature in the primary mirror that matches the expected temperature of the ambient air one hour after sunset, when scientific observations are likely to begin. This implies that the primary mirror will be a fraction of a degree colder than the ambient air at sunset, but this has little effect upon either mirror seeing or calibrations. The current plans for controlling the temperature of M1 and the air in the telescope enclosure contemplate maximum temperature changes of ±1ºC/hour and never exposing M1 to air whose temperature differs by more than ±5ºC (R.44).

9.2.2 Wind screen use

Figure 11 illustrates the deployment of the wind screen and moonroof in the TSPM enclosure. The wind screen can be raised to a maximum height of 9.6 m above the elevation axis (itself 12 m above grade). The telescope's nominal design implies a maximum extent of only 8.8 m beyond the elevation axis. So, the wind screen will be capable of completely shadowing the telescope from strong winds when the telescope is pointing to elevations above 58º. For lower elevations, more and more of the telescope's top ring and secondary will become exposed to winds as the observing elevation decreases. Maximum telescope exposure will occur when observing at 18º elevation.

Windshake and its mitigation through the use of the wind screen and the ventilation doors to moderate the wind flow through the enclosure will have to be studied during commissioning to determine the most effective observing strategy. For reference, the median wind speed (at 9 m above grade) at the OAN-SPM is 13 km/h. Also for reference, according to studies by UA, the wind speed limit at which the M1 control system works is approximately 24 km/h (6.6 m/s).

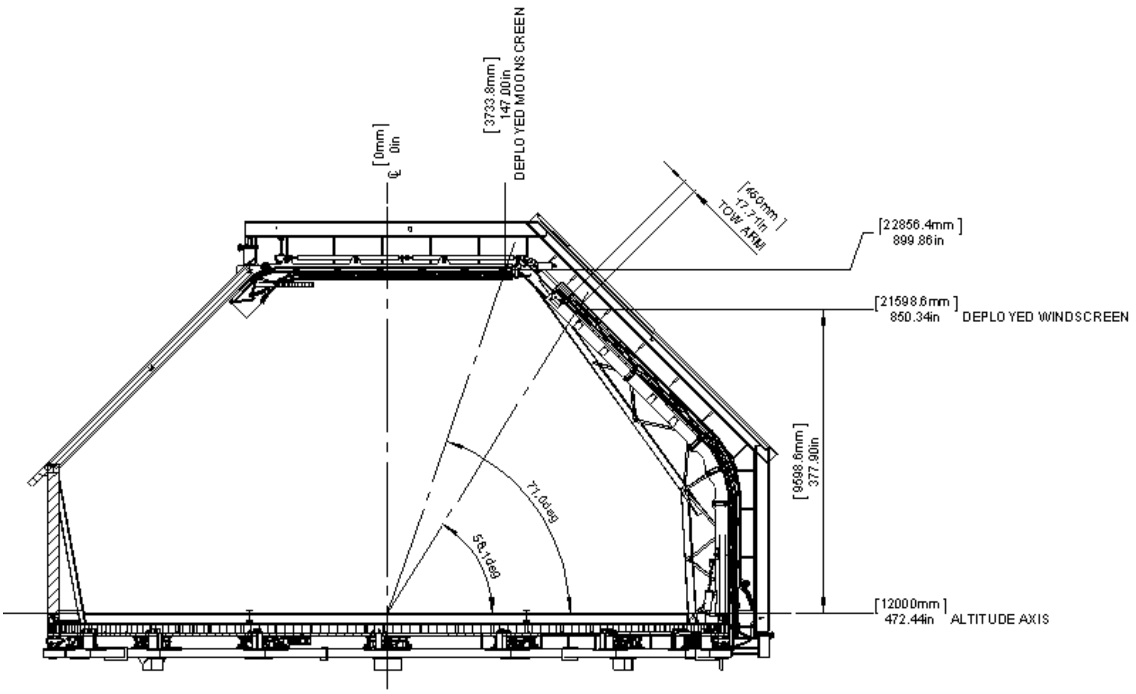

Figure 11: The deployment of the wind screen and moonroof permit shading the telescope from the wind and moonlight, respectively. The fraction of the telescope's upper end exposed to the wind increases as the observing elevation decreases, being maximum at the minimum observing elevation of 18º. As for the moonroof, it cannot obstruct observations for elevations below 71º. (Figure courtesy of M3.)

9.2.3 Moonroof use

As shown in Figure 11, the TSPM's moonroof will extend over the horizontal extent of the shutter in order to shade the telescope from moonlight. In practice, this means that the moonroof must be coordinated with the telescope movement for elevations above 71º. Below this limit, the moonroof cannot occult the telescope's field of view.

9.2.4 Weather station location

Figure 12: This figure shows the proposed location for the TSPM weather station. In this position, the telescope enclosure and support building fall in the minimum of the wind rose, and so should minimize directions from which the wind speed will be affected.

The proposed location of the weather station is shown in Figure **12**. There is no position near the TSPM where the wind vane will not be affected by the presence of the TSPM buildings. However, the proposed position locates the telescope enclosure and support building in the minimum of the wind rose, thereby minimizing the directions from which the wind speed measurements will be affected. Furthermore, when the wind blows from these directions, the wind speeds are very rarely high, so this location should not imperil the TSPM's exposure to high winds. This location is at the end of the ridge, with steep slopes towards the north, west, and south so it will be easy to locate the weather station well above any nearby trees and so should allow accurate wind speed measurements. Given its approximate distance of 37 m from the centre of the telescope enclosure, the wind vane may be up to 11 m above the telescope's elevation axis without affecting the field of view. This position is inside the polygon included in the environmental impact statement. Other positions along the north-west edge of this polygon (thick line in Figure **12**) could also be used. The distance from the telescope enclosure is sufficiently short that a wireless network connection would be adequate.

9.3 System Maintenance

System maintenance shall include all maintenance activities to keep the system in the required condition. The maintenance activities shall be identified and detailed in the maintenance plan, which shall include all the preventive, predictive and corrective tasks that will be identified during the design, manufacturing and verification of the subsystems.

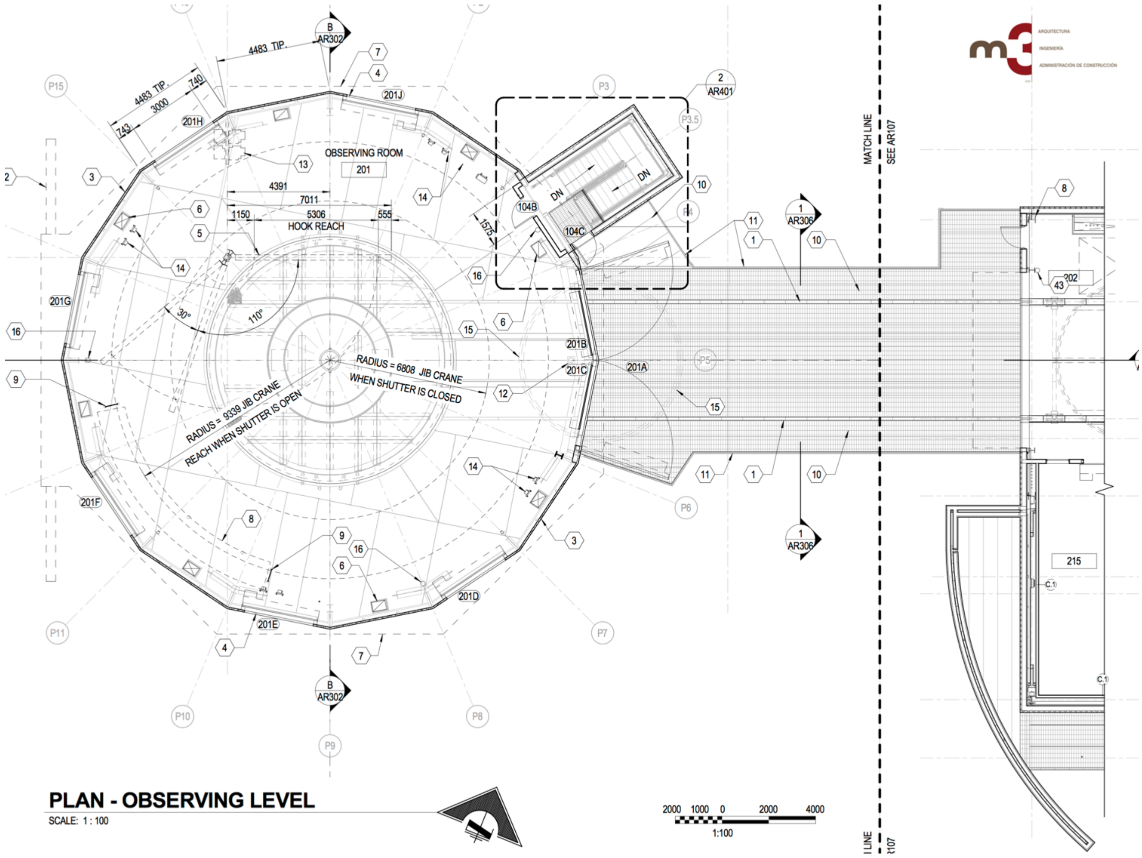

Figure 13: *Floor plan for the upper level of the telescope enclosure (courtesy of M3). The rails used by the M1 transport cart extend from under the telescope and leave the telescope enclosure, crossing the bridge to the support building on the right (ENE).*

The following list of information shall be requested to the subsystem providers for each task. This information shall be reviewed and compiled as part of the overall TSPM maintenance plan. The information will be recorded within the TSPM maintenance tool (TBD) in order to allow effective maintenance planning, optimizing time and resources.

- a detailed description of the task (step by step) or a link to an operation or maintenance procedure, where the task is defined in detail for execution
- the task periodicity (if applicable)
- links between tasks (if applicable, for those tasks that must be scheduled only if another one is executed)
- the estimated duration of the task
- the resources that are needed to carry out the task (equipment, spares, supplies, workshops, manpower profile, external services, additional documents …)

The following sections outline various important maintenance tasks and the resources required to accomplish them. Since most of the activities that will be discussed in this section occur on the upper levels of the telescope enclosure and the support building, Figure 13 and Figure 14 present floor plans of these areas for reference.

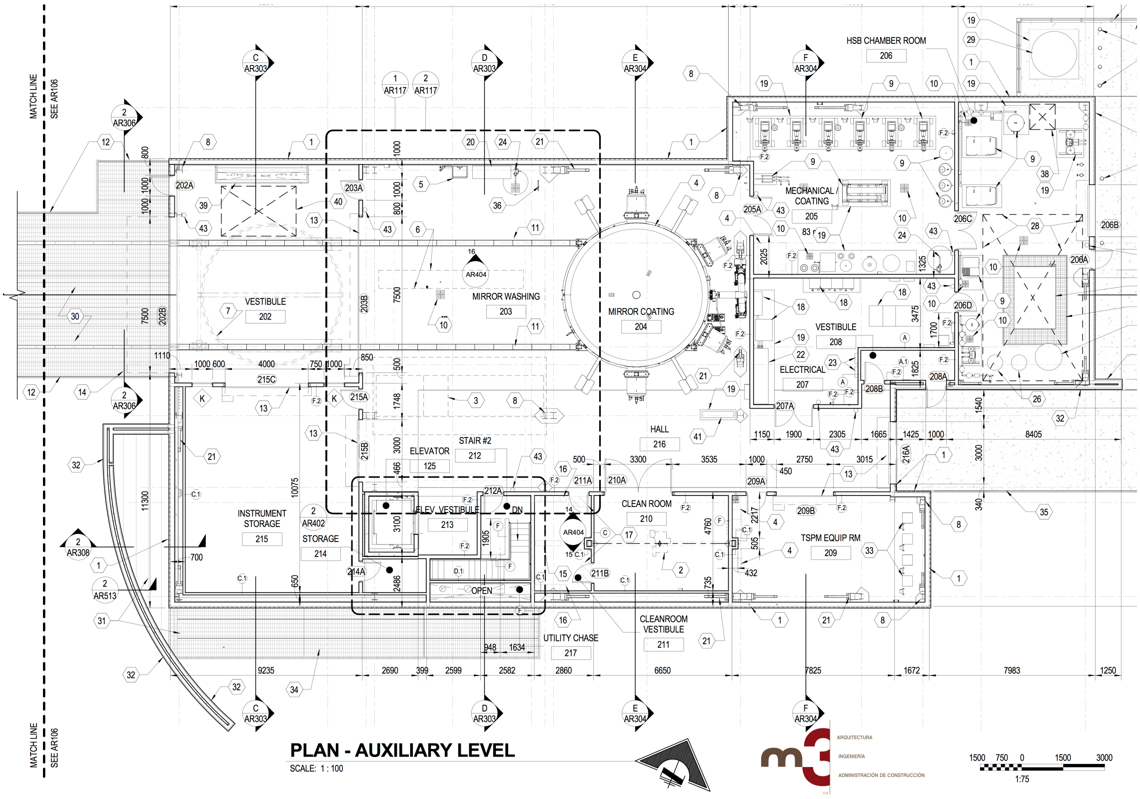

Figure 14: Floor plan of the upper level of the support building (courtesy of M3). The rails enter the support building from the left (WSW) and pass through the vestibule and mirror washing area to end below the mirror coating chamber (ENE). The mirror washing area has a 27-tonne bridge crane (hexagon "3") and a wash platform on rails (hexagon "6"). Next to the vestibule (room 215, bottom left) is the instrument storage area. The door entering the main hall at the end of the building is 3 m wide by 4 m high (216A, bottom right), sufficient to unload any standard commercial freight container.

Periodic and predictable maintenance work will be based upon documented procedures. These procedures should include all preparatory steps, including lists of the tools, safety equipment, and other accessories or preparations that will be needed. The procedures will include check lists that the participants will sign and boxes that will be checked off or initialed as the steps are completed.

9.3.1 Instrument and optics transport

Intrinsic to the structure of both the telescope enclosure and the support building are the rails that are required to transport the M1 cell from the telescope to the coating chamber. All movement of M1 will be done using either its transport box, which can be outfitted with wheels, or the bottom section of the aluminizing chamber (à la Magellan), which is denoted as the "M1 transport cart" below. Both the M1 transport box and the M1 transport cart will circulate only on the rails.

To transport M2, M3, wide field corrector optics, and instruments from the support building to the telescope enclosure and vice versa some other means will be required. Handling carts already exist for all of the existing components (f/5 Cassegrain secondary, f/5 Cassegrain corrector, Megacam, MMIRS). Likewise, future components will also have some sort of handling cart. The carts that exist were not designed for the rail spacing at the TSPM, which is the same as at Magellan. For the f/5 instrumentation for the Magellan II telescope, SAO developed "CartZilla", which is a transport cart that adapts the existing carts to the Magellan II telescope. CartZilla may work or it may be adapted it to work at the TSPM. At least initially, the TSPM project hopes to use CartZilla for other instrument and optics transport needs between the support building and the telescope chamber, as it is the project's understanding that CartZilla's weight carrying capacity should be sufficient. However, CartZilla will not be compatible with Binospec and is not compatible with the instrument envelope defined for the Nasmyth focal stations. CartZilla exceeds the weight-bearing capacity of both the bridge and the floor in the telescope chamber, so it will also require a track for its circulation (as is the case at Magellan). This track should be centered as are the rails in order to allow proper access to the telescope's Cassegrain focal station. Within the support building, the floor should be designed to allow CartZilla free circulation without special tracks since it will be necessary that the rails be completely cleared for the movements of M1. Future instrumentation for the TSPM (after Day 1) should be designed with handling carts appropriate for the installation of these instruments at the TSPM.

9.3.2 Installing M1 in its cell

The UA will ship M1 and its cell independently to the OAN-SPM. Indeed, it is likely that the M1 cell will be shipped to the site where the telescope will be assembled and tested prior to shipment to the OAN-SPM. Therefore, it is indispensable that the TSPM have cranes of sufficient capacity and areas sufficiently large to undertake this operation. In this process, the M1 transport box is outfitted with wheels so that it may circulate on the rails between the bridge and the mirror wash area. The M1 transport box will be moved using the M1 transport cart as a tug.

Before using the M1 lifting fixture, UA recommends detailed testing of all components, including rebuilding the vacuum pump if it hasn't been used for more than a year. Each lifting pad should be checked individually (with a steel plate) to ensure it holds a proper vacuum. Once attached to the mirror, UA typically achieves the vacuum in all of the lifting pads, turns off the pump, and then leaves them overnight. If there has been little or no loss of vacuum overnight, the pump is turned on and the mirror lifted. This ensures that the system is healthy and that a power cut while the mirror is suspended will not cause the mirror to fall. **This entire paragraph would probably be better in a manual devoted to this procedure.**

Briefly:

- The M1 transport cart lowers from the upper section of the coating chamber (see §9.3.3) and travels to the bridge.

- A mobile crane transfers the M1 cell from its transport truck to the M1 transport cart on the bridge.
- The M1 transport cart travels to the mirror washing area so that the M1 cell may be cleaned.
- The M1 in its transport box is transferred from its transport truck to the rails on the bridge.
- (If it is necessary to clean M1, the M1 transport box is towed to the mirror washing area where the mirror is cleaned. Once finished, the M1 transport box is pushed into the vestibule.)
- In the mirror washing area, the bridge crane is fitted with the M1 vacuum lifting fixture. (If this cannot be done with the M1 transport cart attached to the M1 transport box, the M1 transport cart travels under the mirror coating chamber.)
- The lifting fixture is lifted into position.
- The M1 transport box is towed into the mirror washing area.
- The lifting fixture is attached to M1 and M1 is lifted out of its transport box.
- The M1 transport box is pushed onto the bridge.
- The M1 transport cart (carrying the M1 cell) moves under M1 in the mirror washing area.
- M1 is lowered into its cell and the lifting fixture is detached.
- The M1 transport cart moves under the coating chamber and is raised to seal M1 in its cell in the coating chamber.
- The lifting fixture is removed from the bridge crane and stored.
- A mobile crane transfers the M1 transport box from the rails to its transport truck that will take it to its storage location.

9.3.3 M1 coating

Currently, the primary mirrors of the telescopes at the OAN-SPM are coated every two years at the coating chamber located in the 2.1m telescope building. While experience will dictate the frequency with which the TSPM mirrors will require coating, the two year frequency should be a reasonable initial estimate. The coating chamber at the 2.1m telescope uses aluminium filaments. Stripping the mirrors is done using caustic soda and cotton swabs. The mirrors are then cleaned first with detergent and water, then with distilled water, and finally with ultra-pure alcohol (99.99%). At present, all of the liquid used while stripping and washing the mirrors, including chemicals, is collected and disposed of according to applicable regulations. The facilities for doing so are rudimentary at the 2.1m, and the TSPM should contemplate this need from the outset. Since mirror coating is infrequent, it would be best if the holding tank for these chemical wastes were not oversized, as this will encourage the immediate disposal of all wastes. Based upon our current practice, to wash a 6.5m mirror, we estimate that the following will be needed: 2,000 l of normal water, 250 l of distilled water, 80 l of ultra-pure alcohol, 20 l of 50% caustic soda solution, and 10 l of neutral detergent, all of which must be contained. Dynavac estimates that 90 g of 99.999% pure aluminum will be evaporated.

Traditionally, mirror coating at the OAN-SPM takes place in May and June, when possible. At this time of year, the humidity is low and the temperatures are modest, with the average daytime temperature falling in the 10-20 ºC range. The months of July, August, and the first half of

September are usually avoided, since, in San Pedro Mártir, this is the period when the "summer monsoon" occurs (it lasts approx. six weeks) with its warmer temperatures and higher humidity. The TSPM will follow this practice and will plan mirror coating activities during May and June. This will simplify the whole process and avoid the need to implement an additional heating, ventilation, and air conditioning system in the support building for the area enclosing the aluminizing chamber and the mirror wash area.

The coating process for M1 at the TSPM is very closely based upon the procedure used at the Magellan telescopes, of which Matt Johns has provided a detailed list of the steps. The following time-lapse video shows the process

https://www.youtube.com/watch?v=JH3H3fXduVI

The coating plant at the TSPM will be in the support building, as indicated in Figure 14. Rails run from beneath the coating plant to beneath the telescope. These rails are meant to support the cart that transports M1 throughout the coating process. This cart is both the lower part of the coating chamber as well as the lift that allows removing and installing M1 on the telescope. Near the coating chamber, there is a mirror wash area. This area is equipped with a washing bridge that will support personnel during the mirror wash procedure. All water and solvents used in removing the aluminum coating from M1 will be collected and contained in a "chemical waste" holding tank that will be pumped out after each use.

Ideally, the mirror washing area (room #203, Figure 14) should be maintained with a positive air pressure and at clean room standards so as to avoid contaminating the mirror between stripping and aluminizing. Given the very large volume of this area, the cost of doing so would be prohibitive. Instead, temporary measures will be taken to prepare this area to better confront the task. Prior to beginning the process outlined below, the entire area, including floor, walls, ceiling, and suspended conduits, should be washed. Then, plastic sheeting will be used on a temporary frame to isolate the mirror washing area and so provide a cleaner environment than would otherwise exist. It may be feasible to temporarily maintain this area with a positive air pressure using blowers and HEPA filters.

Briefly, the process is envisaged as follows:

- All instruments and accessories are removed from the M1 cell and stored.
- The M1 transport cart is lowered from the upper part of the coating chamber. If need be, the M1 transport cart and coating chamber are cleaned.
- The M1 transport cart travels over the rails to the telescope enclosure and is raised to support the M1 cell, which is then disconnected from the telescope.
- The M1 transport cart lowers the M1 cell from the telescope and transports it over the rails to the mirror wash area in the support building.
- The M1 cell is sealed and the mirror is stripped of aluminium and washed in its cell.
- The coating chamber is charged with aluminium filaments.
- The M1 transport cart travels to the coating chamber and is raised into place, sealing the coating chamber.

- The coating chamber is evacuated, the filaments are fired, and the mirror is coated.
- The M1 transport cart lowers from the coating chamber and transports the M1 in its cell to the telescope enclosure.
- The M1 transport cart raises the M1 cell to mate with the lower end of the telescope's optical support structure.
- The M1 cell is attached to the telescope.
- The M1 transport cart lowers and returns to its position below the coating chamber.
- The M1 transport cart is raised into position, sealing off the coating chamber.

9.3.4 M1 cleaning

The primary mirror will need periodic cleaning, e.g., with CO_2 snow. This will require human access from a distance of approximately 0.5m with the telescope pointing at the horizon. This may be accomplished with a people lifter whose vertical reach is approximately 9m and horizontal displacement is 4m.

9.3.5 Access to M1 cell mechanisms

Access to most of the mechanisms in the primary mirror cell is via removable panels on the backside of the cell. This will require some sort of lift with a vertical reach of approximately 3.5m to place personnel within easy access of the mechanisms that need attention.

9.3.6 Maintenance of inaccessible elements in the M1 cell

Although this has never been necessary at either the MMT or the Magellan telescopes (a total of approximately 45 telescope-years of operation), it is possible that, at some point during the foreseen lifetime of the TSPM, it will be necessary to repair or replace elements in the M1 cell that are inaccessible unless the mirror is removed, e.g., the load spreaders. In order to undertake such a repair, *the M1 vacuum lifting fixture and the M1 transport box must be available*. What follows assumes (1) that the M1 transport box *will not* be stored in the support building and (2) that the mirror must be stripped and cleaned in order to use the vacuum lifting fixture, so it will be necessary to recoat M1 at the end of the process. As before in §9.3.2, the M1 transport box is outfitted with its wheels and is driven along the rails using the M1 transport cart as a tug. §9.3.2 also outlines the precautions to be taken with the vacuum lifting system.

The process is a combination of the procedures involved in coating M1 and installing it in its cell:

- All instruments and accessories are removed from the M1 cell and stored.
- The mirror cart is lowered from the upper part of the coating chamber. If need be, the cart and coating chamber are cleaned.
- The mirror cart travels over the rails to the telescope enclosure and is raised to support the M1 cell, which is then disconnected from the telescope.
- The mirror cart lowers the M1 cell from the telescope and transports it over the rails to the mirror wash area in the support building.

- The M1 cell is sealed and the mirror is stripped of aluminium and washed in its cell.
- The mirror cart moves under the coating chamber.
- A crane loads the M1 transport box onto the bridge.
- The M1 transport box moves into the vestibule in the support building.
- In the mirror washing area, the bridge crane is fitted with the M1 vacuum lifting fixture.
- The lifting fixture is lifted into position.
- The mirror cart with M1 in its cell moves to the mirror washing area.
- The lifting fixture is attached to M1 and M1 is lifted out of its cell.
- The mirror cart returns to its previous position under the coating chamber.
- The M1 transport box moves to the mirror washing area.
- M1 is lowered into its transport box and the lifting fixture is detached.
- The transport box is sealed.
- The M1 transport box returns to the vestibule.
- The mirror transport cart returns to the mirror washing area where the M1 cell can be repaired.
- Once repaired, the mirror transport cart transports the M1 cell under the coating chamber.
- In the mirror washing area, the bridge crane is fitted with the M1 vacuum lifting fixture.
- The lifting fixture is lifted into position.
- The M1 transport box brings M1 into the mirror washing area.
- The lifting fixture is attached to M1 and M1 is lifted out of its transport box.
- The M1 transport box returns to the vestibule.
- The mirror transport cart transports the M1 cell from under the coating chamber to the washing area.
- M1 is lowered into its cell and the lifting fixture is detached.
- The mirror cart moves under the coating chamber.
- The lifting fixture is removed from the bridge crane and stored.
- The M1 transport box returns to the bridge, from which it is lifted onto a transport truck that will take it to its storage location.
- If need be, the mirror cart moves to the mirror washing area and the mirror is cleaned once more.
- The coating chamber is charged with aluminium filaments.
- The mirror cart travels to the coating chamber and is raised into place, sealing the coating chamber.
- The chamber is evacuated, the filaments are fired, and the mirror is coated.
- The mirror cart lowers from the coating chamber and transports the M1 in its cell to the telescope enclosure.
- The mirror cart lowers transports the M1 in its cell to the telescope enclosure.
- The mirror cart raises the M1 cell to mate with the lower end of the telescope’s optical support structure.
- The M1 cell is attached to the telescope.
- The mirror cart lowers and returns to its position below the coating chamber.
- The mirror cart is raised into position, sealing off the coating chamber.

9.3.7 M2 exchange

The TSPM optical design contemplates that multiple secondary mirrors will be in use after Day 1. We base the following schematic procedure on the documented procedure that exists to exchange the Cassegrain f/5 secondary at the Magellan II/Clay telescope (R.39; EXT/SAO/010 in DOCMA). At a later date, this procedure will be modified appropriately for use at the TSPM.

- The M2 cart and the M2 baffle handling fixture are loaded upon CartZilla.
- CartZilla is driven to the telescope enclosure, just inside the doors to the bridge.
- The telescope is pointed to the horizon, towards the doors to the bridge.
- The M2 baffle is secured with the dome crane and dismounted from the M2 support structure, lowering it to its handling fixture.
- The M2 in its cell is secured with the dome crane and dismounted from the M2 support structure, lowering it and securing it on its cart.
- CartZilla proceeds to the support building. The M2 cart and the M2 baffle handling fixture are removed and stored.
- The cart with the M2 to be put into service as well as its baffle handling fixture are loaded onto CartZilla.
- CartZilla returns to the telescope enclosure.
- The M2 in its cell is attached to the dome crane and dismounted from its cart.
- The M2 is raised into position and attached to the M2 support structure.
- The crane raises the baffle, which is attached to the M2 support structure.
- CartZilla returns to the support building and the M2 cart and baffle handling fixture are stored.
- Human access is achieved using a people lifter with a vertical height of at least 7m and a horizontal displacement of 4m.

9.3.8 Access to the M2 mechanisms

Access will be required to the different parts of the M2 support structure and its mechanisms. To facilitate this, it is envisioned that a platform be installed on the fixed part of the enclosure which would give access to the back (sky-pointing) end of the M2 support structure. For access to the sides and front of the M2 support structure, a people lifter with a vertical height of at least 7m and a horizontal displacement of at least 4m would be required. If access to elements inside the M2 cell is necessary, M2 and its baffle would have to be removed (see §9.3.7) and the M2 cell transported to the clean room in the support building. Personnel access would be via the same people lifter.

9.3.9 M2/M3 coating

It is planned to coat M2 and M3 in the same coating chamber as M1. They could also be coated in the coating plant at the 2.1m telescope (1 km away), but it is not clear that this would offer any advantage. It should be possible to coat M3 without removing it from its cell. If possible, M2 will also be coated in its cell.

The procedure would be as follows:

- The M1 transport cart is lowered from the upper section of the coating chamber.
- If necessary, the mirror transport cart and coating chamber are cleaned.
- The coating chamber is charged with aluminium filaments.
- If necessary, M2 or M3 are removed from the telescope as explained in §9.3.7 and §9.3.14, respectively, and brought to the mirror washing area.
- M2/M3 in its cell is secured to the bridge crane and detached from its cart.
- The M2/M3 transport cart travels to the vestibule.
- The M1 transport cart travels to the mirror washing area.
- M2/M3 is lowered and secured to the M1 transport cart.
- M2/M3 is stripped and washed.
- The M1 transport cart moves to the coating chamber and is raised to seal M2/M3 in the coating chamber.
- The chamber is evacuated, the filaments are fired, and the mirror is coated.
- The mirror cart lowers from the coating chamber and transports M2/M3 to the mirror washing area.
- M2/M3 in its cell is secured to the bridge crane and lifted off the M1 transport cart.
- The M2/M3 cart is moved to the mirror washing area.
- M2/M3 is lowered and secured to its cart.
- If necessary, the M2/M3 transport cart to the telescope enclosure.
- If necessary, M2 or M3 are installed on the telescope as explained in §9.3.7 and §9.3.14, respectively.

9.3.10 Installing the M1 shroud

We base the following schematic procedure upon a preliminary study developed by CIDESI to install M3. The M1 shroud is used regardless of the focal station in use, as its purpose is to protect the inner edge of M1. The M1 shroud is installed before any other optical elements.

- The mirror shroud is brought to the telescope enclosure on its storage cart.
- The telescope is pointed to zenith and the elevation locking pin is inserted.
- The M1 shroud storage cart is centred below the M1 cell.
- The M1 shroud storage cart is raised to mate the M1 shroud with the front plate of the M1 cell.
- The M1 shroud is attached to its flange on the front plate of the M1 cell and detached from its storage cart.
- The M1 shroud storage cart is lowered and moved clear of the area.

To remove the M1 shroud, the foregoing should be reversed.

The foregoing should be modified to explicitly note that the shroud is attached to the bottom surface (away from the M1) of the front plate of the M1 cell. The Cassegrain WFC is also fixed to this surface. As a result, the M1 shroud is attached between the M1 cell and the WFC. Given the tight alignment tolerances required by the Cassegrain WFC, the M1 shrould will have to (1) incorporate the holes required to install the Cassegrain WFC, (2) allow its bolts to remain recessed so as not to affect the Cassegrain WFC interface, and (3) by sized (in thickness) to adjust the distance along the optical axis so that the Cassegrain WFC is where it should be with respect to M1. If need be, it could presumably include any other alignment adjustment required to put the Cassegrain WFC where it should be with respect to M1. Explicitly noting this will avoid any confusion regarding the interface for the Cassegrain WFC.

9.3.11 Installing the Cassegrain f/5 baffles (lower and middle sections)

At the TSPM, the Cassegrain f/5 baffle design follows the Magellan example and is divided into three sections. The bottom section is attached to the primary mirror cell via an interface on the M1 shroud. The middle section is suspended above M1 by cables, while the top section is attached to M2 and discussed earlier (§9.3.7). The bottom section of the Cassegrain f/5 baffle attaches to the M1 shroud and so requires very careful positional control near the front surface of M1. In order to achieve this, an extensible mount is used to install it.

The following is based partly upon the procedure documented at Magellan (R.39) and partly upon the CIDESI's study on the installation of the M3 structure (R.42; §9.3.14). Since the TSPM's M1 cover cannot support the weight of personnel, the mid-baffle will be installed following the example from the MMT.

- The bottom portion of the Cassegrain f/5 baffle is brought to the telescope enclosure on its storage cart.
- The extensible mount on its stand is placed on a scissor lift.
- The telescope is pointed to zenith and the elevation locking pin is inserted.
- The extensible mount is raised into position behind M1, extended through the M1 cell into the M1 shroud, and bolted to the M1 shroud.
- The scissor lift lowers the stand for the extensible mount and is moved clear of the area.
- The telescope is balanced, pointed to 5° elevation, and the elevation locking pin is inserted.
- The M1 mirror covers are opened.
- The storage cart with the lower part of the Cassegrain f/5 baffle is placed below the telescope tube.
- The extensible mount is extended to receive the bottom portion of the baffle.
- The dome crane is lowered through the telescope structure to attach it to the bottom part of the Cassegrain f/5 baffle.
- The dome crane raises the bottom portion of the baffle to allow it to be attached to the extended mount.
- The dome crane is detached and raised.
- The mount is retracted to bring the bottom portion of the baffle into contact with the flange on the M1 shroud.
- The bottom portion of the baffle is attached to the M1 shroud.
- The M1 mirror covers are closed.
- The mid-baffle is placed below the telescope tube.
- The dome crane is lowered through the telescope structure to attach it to the mid-baffle.

- The mid-baffle is raised into position and its supporting cables are connected and tensioned by personnel using ladders or a person-lift.
- The dome crane is disconnected from the mid-baffle and raised.
- The telescope is balanced, pointed to the zenith, and the elevation locking pin is inserted.
- The scissor lift is centred below the M1 cell and raises the stand for the extensible mount.
- The extensible mount is mated to its stand, detached from the baffle, retracted, unbolted from the M1 shroud, and extracted from the M1 cell.
- The scissor lift with the extensible mount is lowered and stowed.
- The baffles storage cart is returned to the instrument storage bay.

Removing the Cassegrain f/5 lower and mid-baffles is the reverse of the previous procedure.

9.3.12 Installing and removing the Cassegrain f/5 Wide Field Corrector (WFC)

We base the following schematic procedure on the documented procedure that exists to install the Cassegrain f/5 WFC at the MMT (R.40; not yet in DOCMA) in its imaging mode (Day 1 configuration at the TSPM). In this mode, the WFC requires no electrical or other connections. This (much simplified) procedure supposes that there is no instrument installed at the Cassegrain focus, but that the f/5 Cassegrain baffles are installed.

- The telescope is pointed at the zenith.
- Verify that the Cassegrain f/5 WFC shroud is installed (§9.3.10).
- The Cassegrain f/5 WFC on its storage cart is loaded onto CartZilla.
- Cartzilla transports the Cassegrain f/5 WFC on its storage cart to the Cassegrain focal station.
- Remove the WFC's front cover and store in a clean location.
- Raise the WFC into position at the M1 cell's front plate until it is possible to insert the jack screws to attach the WFC to the M1 cell flange. Attach security bolts.
- Disengage (unbolt) the WFC from its storage cart.
- Tighten the jack screws to raise the WFC to mate with the M1 cell flange.
- Insert and tighten the mounting bolts. Remove jack screws and security bolts, replacing them with additional mounting bolts.
- Carefully lower the WFC cart.
- Remove the WFC rear cover and store in a clean location.
- CartZilla transports the WFC storage cart to the instrument storage bay.

The removal of the Cassegrain f/5 WFC is approximately the reverse of the above procedure and documented in R.39.

9.3.13 Cassegrain instrument installation

The instruments used at the Cassegrain focal station will be handled as at the Magellan II telescope. Detailed installation procedures exist (R.39, R.41). What follows is purely schematic.

- The instrument cart is loaded on CartZilla.

- CartZilla is positioned below the instrument in the telescope enclosure.
- CartZilla raises the instrument cart is raised into position and the instrument is secured to its cart.
- The instrument is disconnected from the telescope and CartZilla is lowered to its minimum height.
- CartZilla returns to the support building and the instrument on its cart is stored.
- The instrument to be installed and its cart are loaded onto CartZilla and brought to the telescope enclosure.
- CartZilla raises the instrument into position and the instrument is attached to the telescope.
- The instrument is disconnected from its cart and the cart is lowered.
- CartZilla returns to the support building and the instrument's cart is stored.

The foregoing applies specifically to the Megacam and MMIRS instruments. Should other Cassegrain instruments be used (e.g., Binospec), they will require carts functionally equivalent to Cartzilla. Future instruments built specifically for the TSPM project should ideally be compatible with Cartzilla. If not, their handling/installation carts should have a wheel base width identical to that of Cartzilla.

Personnel access will be provided by ladders or a people lifting device.

9.3.14 M3 installation and removal (including baffle)

The tertiary mirror (M3) structure will be attached to the front plate of the primary mirror cell. For the purposes of the following, the M3 structure can be divided into 3 parts: the M3 baffle, the M3 assembly (M3 itself, cell, support structure, and rotary mechanism), and the M3 tower (order top to bottom). The M3 tower is installed from behind M1 and attaches to the front plate of the M1 cell. However, the M3 assembly and M3 baffle will have to be installed and removed from in front of M1, since they are much too large to be taken through the aperture in M1. Precautions must be taken to protect M1 in this process and to prevent screws and the like from falling into the M1 cell. At present, CIDESI is developing a procedure to install and remove the M3 structure (R.42). To provide precise motion in front of M1, an extensible mount is used to attach the M3 assembly to the M3 tower (see also §9.3.11). It is attached to the M3 tower (from behind M1). This procedure involves a scissor lift and a personnel lift on a boom. The capabilities of the personnel lift will not exceed those required for exchanging M2 or maintaining its mechanisms (§9.3.7 and §9.3.8). Note that the M1 shroud remains in place when the M3 structure is installed. M3 will not exist at Day 1.

The CIDESI procedure for removing M3 can be summarized as follows:

- The telescope is pointed at zenith and the elevation locking pin is inserted.
- The scissor lift with the extensible mount on its stand is centred below the M1 cell.
- The extensible mount is raised to mate with the M3 tower, to which it is bolted.
- The extensible mount is detached from its stand.
- The extensible mount is extended and bolted to the base of the M3 assembly.
- The scissor lift lowers the stand for the extensible mount and is moved clear of the area.

- The telescope is balanced, pointed to 5º above the horizon, towards the doors to the bridge, and the elevation locking pin inserted.
- All power, control, and air connections to the M3 assembly are disconnected.
- The M3 assembly is unbolted from the M3 tower.
- The extensible mount is extended to allow clearing M3 of the elevation ring.
- The dome crane is lowered and attached to the M3 assembly (with the M3 baffle).
- The M3 assembly is unbolted from the extensible mount.
- The M3 transport cart is brought below the dome crane.
- The M3 assembly is lowered and secured on its cart.
- The extensible mount is retracted.
- The telescope is balanced, pointed to the zenith, and the elevation locking pin inserted.
- The M3 storage cart returns to the support building and M3 is stored.
- The scissor lift with the stand for the extensible mount is centred below the M1 cell.
- The stand is raised to mate with the extensible mount, to which it is bolted.
- The scissor lift is lowered and moved clear of the area.
- The extensible mount is secured to the M3 storage cart.
- The M3 tower storage cart is centred below the M1 cell and extended to mate with the bottom flange of the M3 tower.
- The M3 tower is secured to its storage cart and detached from the front plate of the M1 cell.
- The M3 tower storage cart is lowered and returns to the support building for storage in the instrument storage bay.

Installing M3 and its baffle would reverse the previous procedure. In order to install M3 and its baffle, it is necessary to remove the Cassegrain WFC. Presumably, the removal of M3 is necessary for some other maintenance work, such as aluminizing the primary mirror or configuring the telescope to use its Cassegrain focal station.

9.3.15 Nasmyth instrument exchange

At present, this procedure is merely conceptual and supposes that each instrument has a cart on which it can be stored and transported. This may require special tracks to be laid over the floor, as is done for the f/5 instruments at Magellan. The instruments that will be used at the Nasmyth focal stations will be handled as follows:

- The telescope is rotated such that the Nasmyth platforms do not point to the bridge.
- The instrument cart travels to the telescope enclosure.
- The instrument cart is lifted with the dome crane and raised into position (above the envelope that will be occupied by the instrument in the second step below).
- The telescope is rotated so that the Nasmyth platform points to the bridge.
- The instrument cart is lowered to the Nasmyth platform and secured to the instrument.
- The instrument is detached from the telescope.
- The dome crane lifts the instrument on its cart off the Nasmyth platform to a position that permits clearance for the next step.
- The telescope is rotated such that the Nasmyth platforms do not point to the bridge.

- The instrument on its cart is lowered to the enclosure floor.
- The instrument cart proceeds to the support building where the instrument is stored.
- The instrument to be installed is brought to the telescope enclosure.
- The instrument cart is lifted with the dome crane and raised into position (above the envelope that will be occupied by the instrument in the second step below).
- The telescope is rotated so that the Nasmyth platform points towards the bridge.
- The instrument on its cart is lowered onto the Nasmyth platform and the instrument is secured to the instrument.
- The cart is detached from the instrument.
- The dome crane lifts the instrument cart off the Nasmyth platform to a position that permits clearance for the next step.
- The telescope is rotated such that the Nasmyth platforms do not point towards the bridge.
- The instrument cart is lowered to the enclosure floor.
- The instrument cart proceeds to the support building where the instrument cart is stored.

These instruments, built specifically for the TSPM project, will use carts whose wheel base width is identical to that of Cartzilla.

Personnel access will be provided by the Nasmyth platform itself or ladders positioned on the Nasmyth platform.

9.3.16 Folded Cassegrain instrument installation

The instruments that will be used at the folded Cassegrain focal stations will be handled as follows:

- The telescope is rotated such that the focal station points towards the bridge.
- The instrument cart travels to the telescope enclosure.
- The instrument cart is lifted with the dome crane and raised to mate with the instrument.
- The instrument cart is attached to the instrument and the instrument detached from the telescope.
- The instrument on its cart is lowered to the floor.
- The instrument cart proceeds to the support building where the instrument is stored.
- The instrument to be installed is brought to the telescope enclosure.
- The instrument on its cart is lifted with the dome crane and raised into position to mate with the focal station.
- The instrument is attached to the telescope and the cart is detached from the instrument.
- The instrument cart is lowered to the floor.
- The instrument cart proceeds to the support building where the instrument cart is stored.

These instruments, built specifically for the TSPM project, will use carts whose wheel base width is identical to that of Cartzilla.

Personnel access will be provided by people lifters with a vertical reach of at least 6m and a horizontal displacement of 4m.

9.3.17 Access to the telescope mechanisms

Access to the telescope mechanisms will be via the Nasmyth platforms (elevation) or the platforms between the inner and outer piers (azimuth).

9.3.18 Access to the dome mechanisms

Access to all mechanisms will be provided either using stairs, ladders and platforms incorporated into the telescope enclosure's structure or via a people lifting device. The latter will need a vertical reach of at least 10m.

9.3.19 Handling of liquid nitrogen

The two first light instruments, Megacam and MMIRS, will require liquid nitrogen for their operation. Future instruments may require liquid nitrogen as well. Consequently, a liquid nitrogen tank shall be installed outside the support building, adjacent to the wall of the TSPM equipment room (#209, see Figure 14). A fill line from this tank shall be brought into the TSPM equipment room to facilitate the filling of the dewars used to fill instruments. All rooms in which liquid nitrogen is handled shall be equipped with oxygen sensors to warn users in the case of leaks. Having the main holding tank outside is a safety precaution in the case of a major leak, which would vent to the atmosphere rather than an enclosed space.

Although the principal mode of filling the dewars to supply instruments is via the fill line in the TSPM equipment room, there will also be access to the main holding tank outside the building via walkways with minimal inclination in the event that it is not possible to use the fill line in the TSPM equipment room.

9.3.20 Shipping and receiving instruments

Since all instrument maintenance and movement occurs on the upper levels of the support building and telescope enclosure, it is useful if instruments may arrive (and leave) at that level. As Figure 14 indicates, there is an access door at the eastern end of the support building whose dimensions are large enough to allow the entry or exit of any instrument envelope that fits in a standard commercial shipping container (3m width, 4m height). The instruments could be unloaded and brought into the support building using a forklift or other suitable device.

9.3.21 Instrument commissioning

Instrument commissioning is likely to take place in several stages, starting in the cleanroom (#210, Figure 14) and finishing at the telescope.

9.3.22 Instrument repair

Instrument repair will occur primarily in the cleanroom (#210, Figure 14). The cleanliness level of this entire space is specified as ISO 7 (Class 10,000 in the FED STD 209E scheme). The instrument access door to this space is 2.75m wide by 3.5m high, which is large enough to accommodate even the Binospec simulator. The floor space in the clean room is 6.65 x 5.62 m^2. The clean room is equipped with an overhead crane with a clear hook height of 3.5m. There is also a vestibule (#211, Figure 14) where personnel may don the appropriate apparel. The apparel required for instrument installation (e.g., face masks, etc.) may also be stored in the cleanroom vestibule.

Given the expected TSPM organizational structure (§7.5.1), the personnel who actually undertake a given instrument repair will depend upon the nature and extent of the repair as well as the agreements drawn up by the TSPM Board. Normally, this will be primarily personnel from the partners who have contributed the instrument in question.

9.3.23 Access to the space between inner and outer piers

Do we need access to this space for anything, e.g., cryotigers or the like that might like to ride around on the azimuth disc?

9.4 Facility Operating procedures

The following sections will have to be developed in collaboration with the Enclosure designer and the head of the control system.

9.4.1 TSPM Facility Start-up

9.4.2 TSPM Facility Shut-down

9.4.3 Facility Environmental Control

9.5 Emergency situations

The following sections outline operational procedures to confront emergency situations at the TSPM. What follows is partly a description of how these situations are handled presently at the OAN-SPM. As a result, the following could change as a result of the needs of the TSPM partner institutions. In particular, the TSPMO will not be subject to the same collective bargaining agreement as UNAM, and so could perhaps negotiate greater flexibility.

9.5.1 Electrical Power Outages

Electrical power outages should be the most common emergency at the TSPM. Presently, the OAN-SPM generates its own energy using diesel generators because the Mexican national electricity grid does not reach it. Power outages are planned every two weeks, during the morning, when the generators are rotated in and out of service. In addition, there are occasional power outages with a frequency of order 3-6 per year due to anomalies with the generators. When this happens, a 235 kW emergency generator on the telescope ridge (see Figure 4, its effective capacity is about half that) comes online and provides power to the telescopes in less than 30 seconds. In the past, there were additional power outages during storms, both in summer and in winter, due to branches or trees falling on the aerial power lines. However, all of the power lines within the OAN-SPM were buried in 2009 and there have been no outages during storms since then.

Uninterruptible power supplies (UPSs) provide all of the clean power used at the telescopes at the OAN-SPM. These UPSs can power the equipment connected to them for tens of minutes and so are able to provide power during the planned power cuts or the unplanned power cuts when the emergency generator comes online. Since all planned cuts happen during the day, maintenance activities are not affected. On the other hand, motors are generally not connected to clean power. Thus, telescope operations are affected by unplanned cuts during the night in clear weather if the emergency generator fails to come online (which is usually the result of operator error during a previous planned power outage). On the few occasions when this happens, the maintenance staff is usually able to restore power within an hour.

Figure 15: *This map shows the path of the electricity line that will connect the OAN-SPM to the national electricity grid. The part shown in green will be an aerial line that will branch from an existing power line. The part shown with black diamonds will be a buried line and follows the south side of the road to the OAN-SPM, shown as the black line that connects to the transpeninsular highway ("MEXICO 1", yellow line). (Do not be fooled by the airplane symbol. It corresponds to a very, very rudimentary airstrip!)*

Currently, through an agreement with the Comisión Federal de Electricidad (the national electricity company), the OAN-SPM is installing a connection to the national electricity grid (see Figure 15). This line will connect the observatory to the town of Camalú, south of the junction between the transpeninsular highway and the road to the OAN-SPM. The first section will be an aerial line, but the last 20+ km that traverses the high altitude terrain where trees are found will be buried. This line will connect to the OAN-SPM's main electricity line where the main generators are located. Once this electricity line is in operation, it is likely that the OAN-SPM will maintain both the emergency generator on the telescope ridge and another generator in the dormitory area (see Figure 4). In addition to electrical power, this line will also provide a fibre optics connection from the OAN-SPM to Ensenada.

Therefore, the electrical power "landscape" facing the TSPM will be a direct electricity line that connects to the national electricity grid. The generators at the OAN-SPM will provide backup power. In this scenario, the planned power cuts should disappear, or at least be much less frequent than they are now. The frequency of unplanned power cuts is of course unknown, but, by the time the TSPM enters its commissioning phase, the OAN-SPM will have had several years of experience operating with the new power line, so it will be feasible for the TSPM to plan for these. The OAN-SPM's current emergency generator has considerable excess capacity for the existing complement of telescopes (25 kW). However, in the next few years, the COATLI, DDOTI, TAOS II, SAINT-EX and Colibrí projects will all come online, requiring an additional 25 kW for a total of 50 kW, and leaving of order 60 kW available to close the dome of the TSPM. In such a situation, it would not be necessary to return the telescope to its park position until normal power is restored. Also, not all of these facilities need operate on emergency power simultaneously. If a power cut occurs during a clear night, the different installations may be closed in sequence, leaving enough power for everyone.

While regular power for motors and the like can still come directly from the grid, it would be wise to retain clean power provided/conditioned by UPSs for more sensitive equipment. As is currently the case, the suite of UPSs at the TSPM should be sized to cover the needs of the connected equipment during outages lasting tens of minutes.

9.5.2 Severe Winter Storms

As noted in §5.7, severe winter storms occur once to twice per decade. Historically, these storms have occurred in 1978, 1979, 1987, 1988, 1993, 1998 (twice), and 2010. The total is thus 8 events in 45 years of operation. In the most recent cases, in 1998 and 2010, the weather predictions were good enough from several days to a week before the storms hit to know that an unusually heavy snowfall (or precipitation) was imminent and that some action must be taken.

Once it is clear that the OAN-SPM is in the storm's path, plans are made to evacuate personnel and snow removal equipment before the storm arrives. Prior to evacuation, the telescopes and instruments are taken out of operation and allowed to warm to ambient temperature. Finally, all power generation is stopped before the personnel are evacuated. Previously, when weather predictions were not so accurate, the personnel were trapped for some time on different occasions. Although all involved were eventually able to return to Ensenada, these experiences indicate that evacuation is much safer for the personnel and much better for their morale. Once the storm passes, the personnel and equipment then open the road and restore operations. The road is usually opened in less than a week (it is harder to remove snow going uphill rather than down, as is normally done). However, on several occasions, the rain from these storms that falls at lower altitudes has caused bridges or sections of the road to wash out, occasionally on the transpeninsular highway. In these cases, there are further delays in opening the road to the OAN-SPM.

The OAN-SPM also closes for approximately three weeks in December-January (as do almost all UNAM installations). During this end of year closure, no observations are made and the OAN-SPM and instruments are taken out of operation. However, a skeleton crew remains on site. Power is maintained to the dormitory compound and the telescopes, though heaters and other important energy sinks in the telescopes are disconnected. This is feasible because the great majority of the plumbing at the OAN-SPM's three telescopes uses rubber tubing rather than rigid pipes. As a result, the risk of plumbing damage from freezing is greatly reduced. All of the instruments and detectors are brought to ambient temperature during these closures. The TSPM would not necessarily have to close during these periods, but there would be reduced support staff at the OAN-SPM. This could be relevant if the TSPM personnel take their meals or accommodation in the OAN-SPM facilities and would have to be taken into account.

Given the foregoing, it is prudent to consider that severe winter storms may close the TSPM for two-week periods 1-2 times per decade. Severe winter storms have two implications for the TSPM project. First, the installations must be built to survive these conditions. The survival conditions detailed in §5.7 include appropriate snow, ice, and wind loads. Thus, the design specifications are such that survival of the structures should be assured and, in principle, this risk should be minimal.

The second implication of severe winter storms is operational. The most pressing issues in this regard are plumbing and the instruments at the TSPM that must be warmed slowly to ambient temperatures. MMIRS, for instance, takes approximately 3 days to warm up to ambient temperature because its optics section must be protected from sudden thermal changes (McLeod et al. 2012). There are two ways of confronting this situation. One option is to start warming such instruments once a severe winter storm that could affect the OAN-SPM is identified. This will normally provide more than a day of lead time before the personnel is evacuated. The second option is to provide the TSPM with power from an autonomous backup generator that can supply power to the instruments and maintain the installations above the freezing point. This backup generator could either be part of the TSPM or provided by the OAN-SPM. The obvious worry with an autonomous generator is the possibility of fires in a wooded area when no one is present.

As regards personnel survival, the OAN-SPM maintains sufficient food and fuel supplies so that both will be available.

9.5.3 Earthquakes

The northern part of the state of Baja California is a seismically-active zone, as noted in §5.7. Most of the activity takes place in the Mexicali valley, but earthquakes are possible at the OAN-

SPM. Figure 16 and Table 1 present the spectral acceleration design spectrum recommended for the TSPM project in a detailed study undertaken by the Gerencia de Ingeniería Civil, an specialized branch of the Comisión Federal de Electricidad (CFE, national electricity company). This design spectrum has been taken into account in the designs of the enclosure and support building, the telescope, the M1 cell, and the M3 cell.

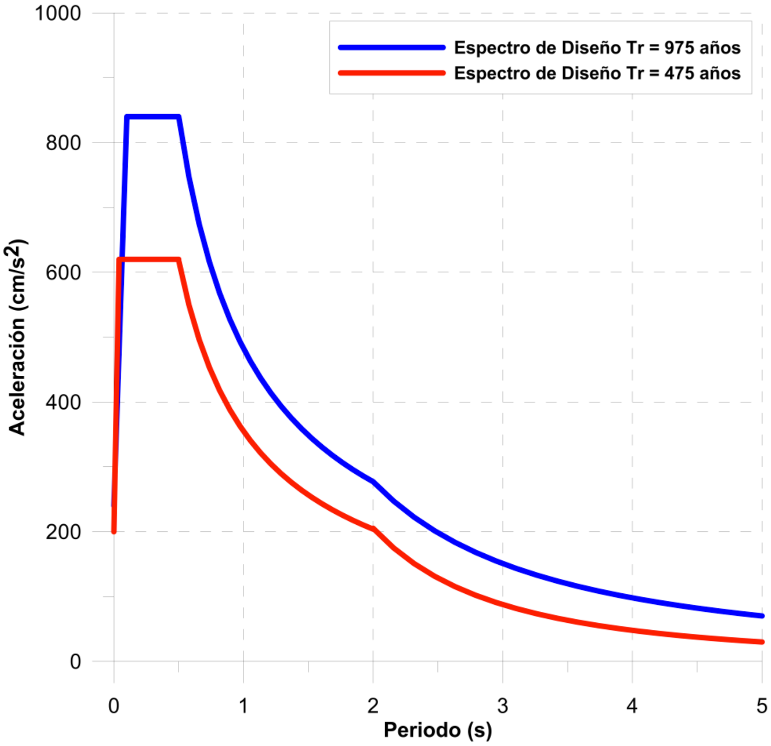

Figure 16: *Design spectrum with 5% damping. The units of the spectral acceleration are gals. In the gravitational system, 1g = 980 gal. (This figure and Table 1 is from the report delivered by CFE on 14 July 2017.) The TSPM project adopts the design spectrum for a 975 year return period.*

Table 1: *Seismic design spectrum for the TSPM project.*

Acceleration (1 g = 980 gal)		**Period (s)**
(gal)	(*g*)	
6000T + 240	**6.1T + 0.245**	**0<T<0.04 s**
840	**0.857**	**0.04<T<0.5 s**
$480T^{-0.8}$	$0.490T^{-0.8}$	**0.5<T<2 s**
$785T^{-1.5}$	$0.801T^{-1.5}$	**T>2.0 s**

9.5.4 Forest fires

The OAN-SPM is located in a wooded area and forest fires are a natural part of its environment. Fortunately, the limited rainfall and the limited resources with which forest fires are suppressed have maintained the forest a low-density forest, with mature pine trees separated by 5-10 m. However, forest fires do occur, though none have threatened the OAN-SPM. At present, it is personnel from the Comisión Nacional Forestal (CONAFOR; forest service) and the Mexican army that fight forest fires with helicopter (water bombing) support from the Mexican navy.

For many years, the OAN-SPM was the only agency of any kind in the area, but over the past two decades the park service has developed a permanent presence and access has been greatly improved. Each year, the OAN-SPM participates with personnel from various government agencies in preparing to face forest fires within or near the PNSSPM. In particular, it is the OAN-SPM's responsibility to maintain a contingency reservoir of 100,000 liters at the ready should it be necessary to combat forest fires.

At the OAN-SPM, steps are being taken to develop some local fire-fighting capacity. At present, only the main dormitory is equipped with an autonomous fire hydrant system. There is also a program underway to equip one or both of the observatory's tanker trucks as a fire truck and to train the personnel in its use. A longer-term goal, that would require cooperation between Protección Civil (civil protection), CONAFOR, and the Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT; environmental protection agency), would be to clear out the underbrush in the vicinity of all buildings (100 to 200 meters) and to cut firebreaks around the observatory compound. This would significantly reduce the risks to the OAN-SPM associated with forest fires, but the SEMARNAT would have to authorize such a plan.

A particular worry concerning forest fires is that there is only one "escape" route from the OAN-SPM in the immediate environs of the OAN-SPM. Once outside the park, various secondary access roads become available, though their transit is not always easy for all vehicles. Furthermore, unlike winter storms, the development of forest fires is much less predictable, so it is conceivable that access to the escape route(s) cannot always be assured or predicted with confidence. Should access be cut off, the OAN-SPM maintains sufficient food and fuel supplies so that both will be available. Hence, a temporary blockage of the access road would not imperil the lives of personnel at the OAN-SPM, provided that the fire does not reach it.

9.5.5 Medical Emergencies

Medical emergencies are a very important problem for the TSPM project due to the OAN-SPM's distance from hospitals. The OAN-SPM has a doctor present at all times (as of 1 February 2017) and a basic infirmary, but it is intended and equipped to confront minor injuries only, not life-threatening medical emergencies. The OAN-SPM is three hours by car from the nearest clinic (in San Quintín) and four-to-five hours from the nearest hospital (in Ensenada). Even if a helicopter were available, the time to the nearest hospital is reduced to only two hours.

This reality underpins the conclusion of §7.2 that defines personnel safety as the TSPM's highest priority.

In addition to having someone onsite at all times in charge of personnel safety (7.2), more should be done, both by the TSPM and the OAN-SPM. More complete medical attention should be available, particularly during the construction and commissioning phases. Emergency evacuation procedures should be established with the military or any others with access to helicopters that can land and take off at 2800m altitude. Once established, these procedures should be maintained.

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11. APPENDIX A

Item	length (m)	width (m)	footprint (m^2)	may enter cleanroom	location
M1 transport box	7	7	49	no	off-site
M1 lifting fixture	5	5	25	no	off-site
M1 dummy mirror	7	7	49	no	off-site
rigging for M1 lifting fixture			0		instrument bay
f/5 Cassegrain M2 baffle	3	3	9	yes	instrument bay
f/5 Cassegrain mid baffle	3	3	9	yes	instrument bay
f/5 Cassegrain M2 cart	2.2	1.7	3.74	yes	instrument bay
f/5 Cassegrain M2 lifting fixture, rigging			0	yes	instrument bay
f/5 instrument storage	4.6	4.6	21.16	yes	instrument bay
Binospec handling cart	2.9	2.9	8.41	yes	instrument bay
Megacam shipping stand	2	2	4	yes	off-site
MMIRS shipping stand	2	2	4	yes	off-site
Binospec simulator	5.5	2.2	12.1	yes	off-site
Binospec shipping stand	3	3	9	yes	off-site
f/5 Nasmyth M2 baffle	3	3	9	yes	instrument bay
f/5 Nasmyth mid baffle	0	0	0	yes	instrument bay
f/5 Nasmyth M2 cart	2.5	2	5	yes	instrument bay
f/5 Nasmyth visible corrector cart	2	2	4	yes	instrument bay
f/5 Nasmyth NIR corrector cart	2	2	4	yes	instrument bay
Nasmyth corrector insertion fixture			0	yes	instrument bay
f/5 Nasmyth lifting fixtures, rigging			0	yes	instrument bay
M3 cart	2.2	1.7	3.74	yes	instrument bay
M3 lifting fixtures, rigging			0	yes	instrument bay
M3 turret			0	yes	
M3 turret insertion fixture			0	yes	
Nasmyth instrument #1 shipping stand	3	3	9	yes	off-site
Nasmyth instrument #1 handling cart	3	3	9	yes	instrument bay
Nasmyth instrument #2 shipping stand	3	3	9	yes	off-site
Nasmyth instrument #2 handling cart	3	3	9	yes	instrument bay
Nasmyth instrument lifting fixtures, rigging			0	yes	instrument bay
f/11 Nasmyth baffles	3	3	9	yes	instrument bay
f/11 Nasmyth M2 cart	2.5	2	5	yes	instrument bay
f/11 Nasmyth corrector	2	2	4	yes	instrument bay

Item	**length (m)**	**width (m)**	**footprint (m^2)**	**may enter cleanroom**	**location**
f/11 Nasmyth NIR corrector	2	2	4	yes	instrument bay
Nasmyth instrument #1 shipping stand	3	3	9	yes	off-site
Nasmyth instrument #1 handling cart	3	3	9	yes	instrument bay
Nasmyth instrument #2 shipping stand	3	3	9	yes	off-site
Nasmyth instrument #2 handling cart	3	3	9	yes	instrument bay
Nasmyth instrument lifting fixtures, rigging			0	yes	instrument bay
folded Cassegrain inst. #1 handling cart	2	2	4	yes	instrument bay
folded Cassegrain inst. #1 shipping stand	2	2	4	yes	off-site
folded Cassegrain inst. #2 handling cart	2	2	4	yes	instrument bay
folded Cassegrain inst. #2 shipping stand	2	2	4	yes	off-site
folded Cassegrain inst. #3 handling cart	2	2	4	yes	off-site
folded Cassegrain inst. #3 shipping stand	2	2	4	yes	off-site
folded Cassegrain inst. #4 handling cart	2	2	4	yes	off-site
folded Cassegrain inst. #4 shipping stand	2	2	4	yes	off-site
instrument packing materials			0		off-site
CartZilla	3.3	2.5	8.25	N/A	vestibule
total footprint			**143.05**		instrument bay
			8.25		vestibule
			212.1		off-site
available space in the instrument bay	10.045	9.235	**92.77**		instrument bay
focal station footprints					
f/5 Cassegrain			51.31		instrument bay
			20.1		off-site
f/5 Nasmyth			43.74		instrument bay
			18		off-site
f/11 Nasmyth			40		instrument bay
			18		off-site
folded Cassegrain			8		instrument bay
			24		off-site