





TSPM High Level Requirements

Project Code: TSPM/HLREQ-001
Issue: 1.F
Date: March 8, 2016

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Approval control

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Applicable documents

Nº	Document title	Code	Issue
A.1			
A.2			
A.3			
A.4			
A.5			

Reference documents

Nº	Document title	Code	Issue
R.1	Reporte Encuesta sobre Iniciativa TSPM		
R.2	Letter of Intent UNAM, INAOE, UA, SAO		
R.3			

Changes control


Nº	Page	Section	Description
1.A			First issue
1.E	All	All	Requirement codes added
1.F		4	012 - Modified and changed to guideline 013 - Modified to quantify seeing at TSPM and accepted degradation 014 - Rephrased and TBD removed 022 - Magellan is confirmed and TBD removed 024 - Modified 025 - Modified 026 - Added 031 - TBC removed 032 - TBC removed, BINOSPEC is not yet confirmed but it is not excluded at the previous requirement 035 - Clarification added about focal stations availability in one night. 061 - Survival limits reviewed and TBCs/TBDs



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			<p>removed.</p> <p>073 - TBC removed</p> <p>074 - TBC removed</p> <p>087 - Non-availability percentage added</p> <p>093 - Defined</p> <p>094 - Updated (from 1" to 5") and rephrased</p> <p>096 - Larger offsets are included here as pointing movements.</p> <p>097 - Quantity for the azimuth offset modified. Larger offset are changed as pointing movements.</p> <p>098 - Rephrased</p> <p>099 - Rephrased</p> <p>100 - TBC removed</p> <p>122 - TBD removed</p> <p>161 - Operational limits reviewed and TBCs/TBDs removed</p> <p>162 - Operational limits with degraded performance added</p> <p>163 - Nominal conditions added</p> <p>179 - TBD removed</p>
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List of acronyms and abbreviations

CIDESI	Centro de Ingeniería y Desarrollo Industrial
EMC	Electromagnetic Compliance
IA-UNAM	Instituto de Astronomía – Universidad Nacional Autónoma de México
INAOE	Instituto Nacional de Astrofísica, Óptica y Electrónica
MMT	Multi Mirror Telescope
MTBF	Mean Time Before Failure
MTTR	Mean Time To Recovery
OAN	Observatorio Astronómico Nacional
RMS	Root-Mean-Square
SAO	Smithsonian Astrophysical Observatory
TSPM	San Pedro Mártir Telescope
SPM	San Pedro Mártir
TBC	To be confirmed
TBD	To be determined
UA	University of Arizona
WFC	Wide-Field Corrector

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SCOPE

This document presents the high level requirements for the TSPM telescope project.

Definitions

1.1 Use of shall and should

In this document “shall” is to be taken as indicating a requirement and “should” as indicating a guideline. Requirements are mandatory and guidelines are not mandatory, although their fulfillment should be pursued.

1.2 Stable and unstable requirements

A “TBC” or a “TBD” identifies unstable or undefined requirements respectively.

General Requirements

1.3 Project development

3.1.1. [RQ/TSPM/001] The TSPM project shall construct a new 6.5-m telescope at SPM. TSPM shall be suitable for general science projects. TSPM shall use the existing 6.5-m primary mirror owned by INAOE and UA.

Rationale: By “suitable for general science projects” it is understood that TSPM should have comparable flexibility to facilities such as MMT, Magellan, Keck, Gemini, VLT, and GTC, and not be a single-purpose facility such as LSST, Pan STARRS, and VISTA.

3.1.2. [RQ/TSPM/002] Under the assumption of the securing of approximately 70 million USD (2014) optimally distributed in time, TSPM should be operational 6 years after PDR.

3.1.3. [RQ/TSPM/003] TSPM shall minimize risks by following existing and proven reference designs (e.g., the MMT and Magellan) where appropriate and possible.

3.1.4. [RQ/TSPM/004] The TSPM primary mirror shall be manufactured and polished to the same optical specifications as the MMT and Magellan primaries.

Rationale: This is to exchange secondaries, field-correctors and science instruments with these facilities as well as to facilitate its polishing and to minimize fabrication and testing risks.

3.1.5. [RQ/TSPM/005] The TSPM design and development shall explicitly consider operations and operation costs. The annual operation cost should not exceed 11.5 (goal 5.75) million USD (2014).

Rationale: We estimate the capital cost of TSPM to be about \$115M including \$15M for M1 and its cell, \$5M for M2 and its support, and \$15M for operational science instruments. These figures represent 5% and 10% of this cost.

3.1.6. [RQ/TSPM/006] The development of TSPM shall take place in Mexico, by Mexican institutions and companies, where appropriate and possible.

3.1.7. [RQ/TSPM/007] TSPM shall comply with applicable national environmental regulations.

1.4 Wavelength range, image quality and background

3.2.1. [RQ/TSPM/011] TSPM shall be optimized from the near ultraviolet to the near infrared (0.35 -2.5 μm).

3.2.2. [RQ/TSPM/012] The effective thermal emissivity of the telescope at the Cassegrain focus shall be less than 10% of that from a blackbody at the ambient temperature and should be less than 7%.

3.2.3. [RQ/TSPM/013] The delivered image quality of TSPM shall allow a 10% degradation of the 10th-percentile seeing reported by Skidmore et al. (2009, PASP, 121, 1151). The reported 10th-percentile seeing is 0.5" at 5000Å.

3.2.4. [RQ/TSPM/014] The telescope background shall be at most 5% of the expected minimum atmospheric and astronomical backgrounds given in the table below.

Band	Wavelength (μm)	BB	IL
u	0.33-0.39	22.9	
g	0.41-0.53	21.9	
r	0.55-0.70	21.1	22.0
i	0.70-0.82	19.9	21.7
Z	0.83-0.93	19.0	22.1
Y	0.97-1.07	18.0	22.5
J	1.17-1.33	17.4	23.1
H	1.49-1.78	15.4	23.6
K	1.90-2.40	14.5	


Table 1. Minimum atmospheric and astronomical backgrounds (AB magnitudes) at TSPM (BB stand for broadband and IL stands for inter-line).

Note: It is being considered that the instruments backgrounds would be also at most 5% of the expected minimum atmospheric and astronomical backgrounds given above.

1.5 Plate scales and Focal Stations

3.3.1. [RQ/TSPM/021] TSPM shall start operations with an f/5 secondary and a wide-field corrector at a Cassegrain station.


3.3.2. [RQ/TSPM/022] TSPM shall start operations with the existing secondary and wide-field corrector now in operation at Magellan.

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- 3.3.3. [RQ/TSPM/023] TSPM shall permit upgrades to provide other focal ratios that are compatible with those presently at Magellan and MMT, namely classical f/9 and f/15 and Gregorian f/11, as described in the document “TSPM Optical Configurations”.
- 3.3.4. [RQ/TSPM/024] TSPM shall permit upgrades to provide at least two Nasmyth focal stations compatible the f/11 and f/5 Nasmyth configurations described in the document “TSPM Optical Configurations”, and each with a mechanical de-rotator, guide sensor and WFS similar to the existing sensors in the existing f/5 Cassegrain corrector, and a science instrument with a minimal unobscured focal surface at least 0.60 m in diameter. The Nasmyth focal stations weight and envelope limits shall be as follows:
- The load capacity of the Nasmyth rotator shall be at least 4 Tn at 1.5 m.
 - The Nasmyth static instruments weight shall be less than 4 Tn
 - The maximum total envelope of Nasmyth rotating modules (including AG and instrument) shall be less than 3 m diameter and 2.7 m length.
 - The maximum total envelope of Nasmyth static modules shall be less than 2.7 m x 3 m (area) x 3 m height.
- 3.3.5. [RQ/TSPM/025] TSPM shall permit upgrades to provide at least four folded Cassegrain focal stations compatible the f/11 and f/5 Nasmyth configurations described in the document “TSPM Optical Configurations”, and each with a mechanical de-rotator, guide sensor and WFS similar to the existing sensors in the existing f/5 Cassegrain corrector, and a science instrument with a minimal unobscured focal surface at least 0.30 m in diameter. The Folded Cassegrain focal stations weight and envelope limits shall be as follows:
- The total weight of the FC modules (including rotator, AG and instrument) shall be at least 1.5 Tn at 0.75 m.
 - The maximum total envelope of FC modules (including rotator, AG and instrument) shall be less than 1 m diameter and 1.5 m length.
- 3.3.6. [RQ/TSPM/026] The Cassegrain focal station weight and envelope limits shall be as follows:
- The load capacity of the Cassegrain rotator shall be 2.7 Tns with a CoG at 0.76 m, or 1.36 Tn when the CoG is at 1.26 m.
 - The maximum total envelope of Cassegrain instruments shall be less than 3 m diameter and 2.7 m length.

1.6 Science Instruments

- 3.4.1. [RQ/TSPM/031] The TSPM f/5 Cassegrain station shall permit the use of at least the following science instruments presently in use at or under construction for the f/5 Cassegrain stations of MMT and Magellan: MEGACAM, MMIRS, BINOSPEC, SWIRC and MAESTRO.
- 3.4.2. [RQ/TSPM/032] TSPM shall be commissioned and initially operate with the following f/5 Cassegrain instruments: MEGACAM and MMIRS.

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- 3.4.3. [RQ/TSPM/033] After initial operations with the existing f/5 Cassegrain instruments, TSPM should not preclude future dedicated or long-term projects, other specialized or general instrumentation, or other observing modes such as classical, queued, remote or robotic modes.
- 3.4.4. [RQ/TSPM/034] TSPM shall not exclude future instruments that maintain it at the frontier of competitive astronomical research.
- 3.4.5. [RQ/TSPM/035] TSPM shall not exclude the future development of the capacity to use multiple Nasmyth and Folded-Cassegrain stations in one night. Note that Cassegrain focal station shall not be available the same nights that the Nasmyth and Folded Cassegrain stations (i.e., daytime actions are required for changing between Cassegrain and the other focal stations).

1.7 TSPM Enclosure & Services

- 3.5.1. [RQ/TSPM/041] TSPM shall include provision of all necessary services for the observatory operations including aluminizing, power supplies, gases, fluids, telecommunications, building maintenance, janitorial, snow clearing, storage and accommodations, possibly making use of existing site facilities.
- 3.5.2. [RQ/TSPM/042] The TSPM design shall include space for an observing room, a control room and instrument storage area and an instrument laboratory with environmental control.
- 3.5.3. [RQ/TSPM/043] TSPM shall conform to all applicable environmental, safety and engineering regulations and codes.


1.8 TSPM LIFESPAN

- 3.6.1. [RQ/TSPM/051] The scientific lifespan of TSPM shall be at least 40 years, counted from the start of science operations.
- 3.6.2. [RQ/TSPM/052] After its life TSPM shall be decommissioned.

survival LIMITS

[RQ/TSPM/061] TSPM shall survive the following external natural conditions:

- Relative humidity range: 0% to 100%
- Temperature range: -25° to +35° 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/m²
- Ice height: 100 mm (density 917 kg/m³)
- Earthquake accelerations: horizontal 0.4g, vertical 0.2g (use SDC-C), Ss=0.492g, Sds=0.39g, S1=0.1414g, Sd1=0.15g, Site Class C
- Electrical storms
- Winter storm evacuation period: 2 weeks maximum

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Rationale: The winter storm evacuation period will require preparatory work. Water pipes must be drained and instruments must be put on backup power in order for them to warm up safely to ambient temperature and allow for their coolant supply to be consumed (of order 60 hours). At that point, backup power could be switched off. The temperature range must span more than 100% of the recorded values. At these extreme temperatures, it may not be feasible to rotate the dome or operate the telescope, see operational limits. The seismic data will have to be updated using CFE's study.

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.

Operations and support requirements

1.9 Observing Modes

[RQ/TSPM/071] We consider five observing modes: engineering, queued, classical, remote and robotic modes.

Definitions:

- 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.

5.1.1. [RQ/TSPM/072] TSPM shall implement engineering mode and queue mode.

5.1.2. [RQ/TSPM/073] TSPM shall permit upgrades to classical and remote modes.

5.1.3. [RQ/TSPM/074] TSPM should permit upgrades to robotic mode.


5.1.4. [RQ/TSPM/075] TSPM shall provide routine calibration of the instruments.

1.10 General Operation Requirements

5.2.1. [RQ/TSPM/081] TSPM should, where appropriate, minimize engineering time, down time and set up time, and ensure clear and simple operations.

5.2.2. [RQ/TSPM/082] TSPM shall be maintained and operated by specialized and dedicated support and operation staff.


5.2.3. [RQ/TSPM/083] TSPM shall provide adequate training, simulators and documentation for support and user astronomers and operations and maintenance staff.

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- 5.2.4. [RQ/TSPM/084] TSPM shall provide appropriate tools and systems to plan and carry out observations efficiently in the implemented observing modes.
- 5.2.5. [RQ/TSPM/085] TSPM shall provide the appropriate tools and systems for quality control of the observations.
- 5.2.6. [RQ/TSPM/086] TSPM equipment shall conform to applicable EMC requirements for proper operation.
- 5.2.7. [RQ/TSPM/087] 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 MTTF 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%.

1.11 Pointing & Tracking

- 5.3.1. [RQ/TSPM/091] The nominal pointing and tracking region of TSPM shall be between elevation angles of 18 and 89.5 degrees.
- 5.3.2. [RQ/TSPM/092] For servicing, TSPM shall point to the horizon at least at one azimuth.
- 5.3.3. [RQ/TSPM/093] It shall be possible to select any PA of the rotator over the nominal pointing and tracking region
- 5.3.4. [RQ/TSPM/094] TSPM shall track any object moving at up to 5 arcsec per second relative to sidereal rate, over its nominal tracking range.
- 5.3.5. [RQ/TSPM/095] TSPM shall point and track and maintain field rotation from when an object first enters the nominal tracking region until it leaves the nominal tracking region.
- 5.3.6. [RQ/TSPM/096] Open-loop pointing accuracy:
 - For zenith angles between 5 and 60 degrees: 10 arcsec (goal < 2 arcsec)
 - For zenith angles less 5 degrees or more than 60 degrees: 20 arcsec (goal < 4 arcsec)
 - Offsets up to 1 degree in elevation and 3 degrees in azimuth: 1.0 arcsec.
Rationale: To come back to the guider
- 5.3.7. [RQ/TSPM/097] Open-loop offset accuracy:
 - Offsets up to 10 arcmin in elevation and 20 arcmin (goal: 30 arcmin) in azimuth: 0.1 arcsec.
Rationale: in order to come back into slit
- 5.3.8. [RQ/TSPM/098] Open-loop offset total time overhead:
 - Offsets up to 5 arcsec in elevation and 15 arcsec in azimuth: 1 sec
 - Offsets up to 10 arcmin in elevation and 30 arcmin in azimuth: 10 sec
 - Offsets up to 1 degree in elevation and 3 degrees in azimuth: 30 sec
- 5.3.9. [RQ/TSPM/099] Open-loop pointing total time overhead:
 - Telescope pointing movements up to 10 degrees in elevation and 30 degrees in azimuth: 30 sec (goal 20 sec)
 - Larger telescope pointing movements: 5 minutes (goal 3 minutes).
- 5.3.10. [RQ/TSPM/100] Open-loop tracking accuracy at sidereal rate:

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- In 10 minutes: 0.1 arcsec
- In 1 hour: 0.5 arcsec

5.3.11. [RQ/TSPM/101] Closed-loop jitter over 1000 s under steady wind (considering a perfect guiding signal at 1 Hz): 0.03 arcsec RMS
Rationale: This is likely to be the longest exposure times we commonly use.

1.12 Target acquisition

- 5.4.1. [RQ/TSPM/111] Each instrument or its adapter shall provide appropriate means to acquire targets.
- 5.4.2. [RQ/TSPM/112] TSPM shall provide the means to instruments to execute offsets programmatically.

1.13 Instrument Control


- 5.5.1. [RQ/TSPM/121] The control systems of future TSPM instruments shall have interfaces that are compatible with the control system of the telescope.
- 5.5.2. [RQ/TSPM/122] TSPM shall adapt the control systems of existing or under-construction instruments to the TSPM control system.
Rationale: The control systems of existing instruments such as MEGACAM, MMIRS, and BINOSPEC are almost certainly not completely compatible with the future TSPM control system. Therefore, TSPM will need to provide a “glue layer” between the instrument control system and the TSPM control system.
- 5.5.3. [RQ/TSPM/123] The control systems of future new instruments should follow the requirements and guidelines of the TSPM control system architecture.
- 5.5.4. [RQ/TSPM/124] Each instrument shall provide appropriate hardware (e.g., lamps) for its routine calibration.

1.14 Dome Control

- 5.6.1. [RQ/TSPM/131] The TSPM dome shall provide a clear aperture on sky for elevation angles between 18° and 90°. The dome shall allow continuous observation of an unvignetted field at least 1° in diameter while tracking in the nominal tracking region.

1.15 Observatory Monitoring

- 5.7.1. [RQ/TSPM/141] The TSPM state and services shall be continuously monitored.
- 5.7.2. [RQ/TSPM/142] A long-term data base of TSPM calibration and state shall be implemented for fault and performance analysis.
- 5.7.3. [RQ/TSPM/143] The relevant aspects of TSPM monitoring for operations shall be displayed and proper fault and diagnostic alarms implemented.
- 5.7.4. [RQ/TSPM/144] TSPM observing (meteorological and atmospheric) conditions shall be an integral part of the control system.

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1.16 Control System Architecture

The architecture of the TSPM control system shall consider:

- 5.8.1. [RQ/TSPM/151] TSPM should adopt recognized standards and best practices of reference observatories.
- 5.8.2. [RQ/TSPM/152] TSPM should use commercial products where appropriate and possible.
- 5.8.3. [RQ/TSPM/153] The control system architecture of TSPM shall adopt a modular design in which each subsystem has standalone capabilities.
 - o *Rationale: So that hardware/software modifications can be performed in parallel with minimal interference with the observatory operations.*
- 5.8.4. [RQ/TSPM/154] TSPM software should be independent of hardware and the operating system where appropriate and possible.
- 5.8.5. [RQ/TSPM/155] TSPM shall implement self-diagnostics, which should run continuously while operating.
- 5.8.6. [RQ/TSPM/156] The TCS architecture of TSPM shall provide automatic calibration, set-up and diagnostic procedures.

1.17 Observing limits

[RQ/TSPM/161] Operational limits

- All the survival limits except
- 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: -2°C to +18°C (goal: -5°C to +18°C)

Rationale: The temperature range spans almost 90% of all recorded values. The temperature range indicated as the goal spans almost 95% of all recorded values. The particulate specification allows the telescope operator or other human to judge whether observations can be carried out safely.


[RQ/TSPM/162] Operational limits with degraded performance

- All of the operational limits except
- Temperature range: -18°C to +30°C

Rationale: This temperature range spans 100% of the recorded values. In this extended range, the hydrostatic oil will not track the ambient temperature but will be limited to the extreme values for the operational limits.

[RQ/TSPM/163] Nominal conditions:

- Daytime median temperature: 10.4 C
- Night time median temperature: 6.8 C
- Mean atmospheric pressure: 730 mbar

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- Mean relative humidity: 54%
- Median wind speed: 13 km/h
- Dominant wind direction: southwest to northeast (and vice versa)
- Photometric nights: 57%
- Spectroscopic nights: 80%
- Sky brightness (dark sky): B=22 mag/arcsec²
- Optical turbulence (seeing): 0.5 arcsec at 15m
- Atmospheric water vapor: 2.5 mm H₂O
- Atmospheric inversion layer (over sea level): 1000 m

1.18 Safety

- 5.10.1. [RQ/TSPM/171] TSPM shall be as safe as similar international facilities.
- 5.10.2. [RQ/TSPM/172] The safety priorities of TSPM shall be (in order of importance):
1. Human integrity and protection
 2. TSPM facility safeguarding and integrity
 3. Science data protection

Safety criteria:

- 5.10.3. [RQ/TSPM/173] TSPM shall comply with applicable national and international safety regulations.
- 5.10.4. [RQ/TSPM/174] TSPM operation and maintenance procedures shall be documented and validated.
- 5.10.5. [RQ/TSPM/175] The TSPM operation plan shall explicitly address the safety implications of human factors.
- 5.10.6. [RQ/TSPM/176] All acquired equipment or any services subcontracted shall comply with TSPM safety standards.
- 5.10.7. [RQ/TSPM/177] TSPM shall implement hardware and software limits for the operation of all relevant systems.
- 5.10.8. [RQ/TSPM/178] The TSPM shall not be operated beyond its defined operational limits.
- 5.10.9. [RQ/TSPM/179] For safety reasons, it shall be possible to shut the dome in under 2 minutes.
- 5.10.10. [RQ/TSPM/180] The TSPM premises should be protected from the access of unauthorized persons.
- 5.10.11. [RQ/TSPM/181] 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.
- 5.10.12. [RQ/TSPM/182] TSPM operation and maintenance procedures should provide protection against accidental loss of scientific data.

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Verification

The fulfillment of the high level requirements of the TSPM will be verified along the Project on a distributed basis. It will be performed mainly by means of:

- Validation of the TSPM subsystems, through design reviews and inspection and testing of products. Every subsystem must include a verification section describing the plan to verify the requirements.
- TSPM integration, testing and commissioning. The Integration and Test Plan of TSPM will describe the validation of the TSPM to be performed during the final integration of the subsystems and during TSPM testing and commissioning.

This document contains the high level requirements for all TSPM subsystems. Specifications for each subsystem shall be derived considering the contribution of all subsystems to the compliance of these high level requirements. Therefore, the subsystems validation through design reviews and inspection and testing of products will partially perform the verification of these TSPM high-level requirements. The identification of the parent requirements for the subsystems requirements will help to identify which part of the high level requirements TSPM is violated when any subsystem did not match any of its requirements. However, in order to validate the TSPM as a whole, the verification of high-level requirements of TSPM shall be completed during the TSPM integration, test, and commissioning.