TSPM OPTICAL CONFIGURATIONS

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INSTITUTO DE ASTRONOMIA – UNIVERSIDAD NACIONAL AUTONOMA DE MEXICO
Apartado Postal 70-264 Cd. Universitaria 04510 MEXICO D.F. – Phone: 525556223907 – Fax: 525556160653
URL : http ://www.astro.unam.mx E-mail : beatriz@astro.unam.mx

Approval control

Prepared by	J. Jesús González	
Revised by	Alan Watson William Lee Beatriz Sánchez David Urdaibay	
Approved by	Beatriz Sánchez	
Authorized by	William Lee Alberto Carramiñana	Date: xx-xx-xx

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	TSPM High Level Requirements	TSPM/HLREQ-001	1.0c
R.2	f/5 Wide Field Corrector Manual	D. Fabricant 2003	
R.3	Optical Specifications for the MMT Conversion	D. Fabricant 1999	
R.4	Support and Actuation of Six Secondaries for the 6.5 m MMT and 8.4 m LBT Telescopes. SPIE, 2871,	P.M Gray 1997	

Change history

Date	Document title	Author	Issue
September 2015	Changed design since TSPM adopted: • Modified LMC M1 • M2 & WFC from Magellan	JJGG	6.0

List of acronyms and abbreviations

ADC	**Atmospheric Dispersion Corrector**
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
M2	
MMT	Multi Mirror Telescope
OAN	Observatorio Astronómico Nacional
RMS	Root-Mean-Square
SAO	Smithsonian Astrophysical Observatory
TSPM	Telescopio de San Pedro Mártir
SPM	San Pedro Mártir
TBC	To be confirmed
TBD	To be determined
UA	University of Arizona
WFC	Wide-Field Corrector

CONTENTS

SCOPE

This document summarizes the main characteristics of the Optical Configurations of the 6.5 m telescope for the San Pedro Mártir Observatory (TSPM project). Namely:

- Base design: f/5-cassegrain identical to MMT/Magellan, since M2, WFC and f/5 science instruments are imported from these facilities. Both, MMT and Magellan have nominally identical primaries and f/5 secondaries and WFCs, in optical terms.

- Other secondaries and focal stations are only schematic in this document, and are still broadly open since they are to be refined after definition of specific science programs.

- To limit the mechanical design and the dimensions of the tertiary mirror (M3), two extreme nasmyth configurations are defined:
  - An f/5 Classical Nasmyth configuration with a 1° diameter field of view (FoV).
  - An f/11 Gregorian Nasmyth configuration with a 0.5° diameter FoV.
  - It is important to realize that in TSPM the Cassegrain and Nasmyth stations require different secondaries, since these stations have very different back-focal distances.
  - These particular f/11 Gregorian and f/5 Classical Nasmyth configurations are not expected to be constructed at this point, and do not represent conceptual designs subjected for deeper revisions (PDR, CDR, etc.). They are meant to be indicative designs to limit the telescope structure and enclosure and as a tool for the error budget of the telescope structure.

- Here we also consider folded-Cassegrain stations fed by the Nasmyth secondaries, but with a smaller field of view.

- The day-one configuration of TSPM will be the f/5 Cassegrain and is the only one that is fully defined (actually all, except for the primary mirror, fully constructed and in operation). The other configurations are here studied as possible upgrade paths mainly to ensure the mechanical design of the telescope permits future implementation of this sort.

- In particular, if the design is compatible with the above extreme configurations, it should also be compatible with f/9 and f/15 classical configurations. Therefore we do not consider them further.

Relevant High-Level REQUIREMENTS

This section summarizes the requirements in the document "TSPM High Level Requirements" (R1) that apply to the Optical Design of the TSPM telescope (those that do not apply are omitted or simply marked as NA).

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.

Req ID	
3	**GENERAL REQUIREMETS RELATED TO OPTICAL DESIGN**
3.1	Project Development
3.1.1	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
3.1.2	TSPM should be operational on a short time scale.
3.1.3	TSPM shall minimize risks by following existing and proven reference designs (e.g., the MMT and Magellan) where appropriate and possible
3.1.4	The TSPM primary mirror shall be manufactured and polished to the same optical specifications as the MMT and Magellan primaries.
3.1.5	The TSPM design and development shall explicitly consider operations and operation costs.
3.2	**Wavelength range, image quality and background**
3.2.1	TSPM shall be optimized from the near ultraviolet to the near infrared (0.35 - 2.5 μm).
3.2.2	TSPM shall not exclude astronomical observations up to 26 μm albeit reduced performance.
3.2.3	The delivered image quality of TSPM shall be dominated by the natural seeing.
3.2.4	The background from 0.35 μm to 2.5 μm shall be dominated by the atmospheric and astronomical backgrounds (TBC).
3.3	**Plate Scales and Focal Stations**
3.3.1	TSPM shall start operations with an f/5 secondary and a wide-field corrector at a Cassegrain station
3.3.2	TSPM shall use the existing secondary and wide-field corrector now in operation at Magellan
3.3.3	TSPM shall not exclude focal stations other than Cassegrain

3.3.4	TSPM shall not exclude other focal ratios that are compatible with those presently at Magellan and MMT, namely classical f/9 and f/15 and Gregorian f/11.
3.3.5	TSPM shall not exclude a Nasmyth f/5 configuration with a 1-degree field of view
3.3.6	TSPM shall not exclude at least 4 folded Cassegrain focal stations with minimal unobscured aperture of TBD cm and capable of supporting a weight of 1 TBD kg with torque TBD
3.4	**Science Instruments**
3.4.1	TSPM shall not exclude the use of the f/5 science instruments presently in use at or under construction for the f/5 Cassegrain stations of MMT and Magellan (MEGACAM, MMIRS, HECTOSPEC, HECTOCHELLE, BINOSPEC, SWIRC and MAESTRO)
3.4.2	TSPM shall be commissioned and initially operate with f/5 Cassegrain instruments TBD
3.4.3	NA
3.4.4	TSPM shall not exclude future instruments that maintain it at the frontier of competitive astronomical research.
3.4.5	TSPM shall not exclude the future development of the capacity to use multiple instruments in one night
3.5	NA (TSPM Enclosure & Services)
3.6	NA (TSPM Lifespan
4	**NA (SURVIVAL LIMITS)**
5	**OPERATIONS AND SUPPORT REQUIREMENTS**
5.1	**NA (Observing Modes)**
5.2	**General Operation Requirements**
5.2.1	TSPM should, where appropriate, minimize engineering, down and set up times, and ensure clear and simple operations
5.2.2	NA
5.2.3	TSPM shall provide adequate training, simulators and documentation for support and user astronomers and operations and maintenance staff
5.2.4	NA
5.2.5	NA
5.2.6	NA
5.3	**NA (Pointing & Tracking)**
5.4	**NA (Target acquisition)**
5.5	**Active Optics Control**
5.5.1	TSPM shall have an active control system to maintain image quality under the nominal operation conditions
5.6	**NA (Instrument Control)**
5.7	**Dome Control**
5.7.5	The design of the TSPM enclosure should minimize the stray light reaching

	the focal stations.
5.8	**NA (Observatory Monitoring)**
5.9	**NA (Control System Architecture)**
5.10	**Operational limits (Environmental Conditions)**
5.10.1	Sustained wind speed limits (TBD): <45 km/h (98% of the time) 60 km/h (max)
5.10.2	Wind gusts (TBD): < 65 km/h (95% of the time) 80 km/h (max)
5.10.3	Sustained wind speed limit for dome closure (TBD): 60 km/h (max)
5.10.4	Humidity limits for shutdown (TBD): < 90%, or at condensation point
5.10.5	Operational temperature range (TBD): -15°C to +30°C
5.10.6	The atmospheric pressure range for nominal operation shall be TBD
5.10.7	The atmospheric pressure range for nominal operation shall be TBD
5.10.8	NA
6	**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 f/5 Cassegrain configuration

In its initial (base) configuration, TSPM is to:

1) Use an existing 6.5 meters honeycomb primary mirror (M1) cast by the UA Mirror Lab and polished to the same prescription and specifications as the primaries of the MMT and the Magellan telescopes.
2) Adopt the existing F/5 secondary from the Magellan telescope, together with its wide-field corrector (WFC).
3) Start operations at least with a set of f/5 instruments either in use or already under construction for the MMT or the Magellan observatories. The precise instruments are TBD.

Therefore, the optical design of the f/5 Cassegrain configuration is already fixed, and although the TSPM M1 is yet to be polished, it has to be figured within the same optical specifications as the MMT and Magellan primaries. The TSPM f/5 Cassegrain optical configuration, being an exact copy of Magellan, is a fully proven design.

1.3 Primary mirror main characteristics

The following table summarizes the optical parameters of the TSPM primary mirror

	TSPM	MMT	Magellan I & II
Diameter	6512.56 +/- 0.5 mm (6500 optical)	6512 Overall 6502 Optical	6502.4
Outer Clear Ap	6478	6435	6478
Focal Length	8128 mm	8127.75 +/- 0.15	
Conic Constant	-1.0000	-1.0000 (+0.0001,-0.0004)	
Central Aperture Diameter [mm]	889 +/- 0.5 (top) 940 +/- 0.5 (bot)		970
Inner Clear Ap	967-923	967	923
Thickness	711 +/- 2 mm (max) 391 +/- 2 mm (min)	711	710
Faceplate thickness	27.9 +/- 1 mm	32.4+/-0.7 mm	
Bottom plate thickness	25.4 +/- 1 mm		
Wall thickness	15 +/- 2 mm		
Cast Figure	F/1.25 parabola		
Material	E6 borosilicate (O'Hara)		
Structure	Honeycomb about 20% solid density (1020 cells)		
Casting date	2002	1992	1994
		2% heavier	
Weight [kg] w/loadspreaders hardpoint blocks	9364	7735 (glass) 9318	9670 & 9005
Polished	2015-2017		
Surf Err Spec r_o Image FWHM	118 cm 0.086 arcsec	109 cm 0.093 arcsec	118 cm 0.086 arcsec
Polished precision [nm] RMS		35[3)] 26[4)]	14 & 19 (polish) 24 & 22 (support)
Thermal control across mirror		< 0.1 C	< 0.1 C
M1-Air Gradient		0.2 – 0.4 C (0.15 spec)	0.25
Image Quality Active Optics			<0.3"
1) 2) 3) Excluding 3er-ordes astigmatism (actively controlled)			

4) Also excluding trefoil, quarterfoil and 5th-order astigmatism (actively controlled)

1.4 F/5 Secondary

TSPM will adopt either the existing secondary at MMT or at Magellan. Both were constructed under the same optical design and specifications but have slightly different after-construction characteristics. TSPM needs the as-constructed characteristics of the secondary to be installed, in order to characterize the actual system and for future developments.

1.4.1 f/5 Secondary as design

TSPM will adopt the actual f/5 secondary (M2) of either MMT or the Magellan telescopes (TBD), which were fabricated under the same specifications. According to the Optical Specifications for the MMT Conversion (Fabricant, McLeod & West, 1999), the optical characteristics of the MMT secondary are:

Secondary Vertex Radius	Secondary Conic	Secondary Clear Aperture
–5150.974 mm	–2.6946	1692 mm
–202.7943 in		66.61 in

Material: Zerour (Schott)
Edge thickness: 133 mm
Central thickness: 206 mm
Glass weight: 288 kg (R.4 for MMT), 316 kg,

1.5 Wide Field Corrector

TSPM will adopt either the existing WFC at MMT or at Magellan. Both were constructed under the same optical design and specifications but have slightly different after-construction characteristics. TSPM needs the as-constructed characteristics of the WFC to be installed, in order to characterize the actual system and for future developments.

The f/5 wide field corrector greatly reduces the off-axis aberrations of the primary and secondary. The bare telescope optics is of classical Cassegrain design, and coma quickly dominates the images off-axis. Thus, wide-field instruments must either use this WFC or incorporate their own field corrector.

The f/5 corrector has two configurations: (1) the spectroscopic mode offers a telocentric 1° diameter field of view with a curved focal surface, (2) the imaging mode

offers a flat 0.5° diameter field of view. The spectroscopic mode was optimized for use with optical fibers, and includes Atmospheric Dispersion Compensation (ADC) prisms to efficiently feed optical fibers or narrow spectroscopic slits. To change from imaging to spectroscopic mode a field-flattener is removed and an ADC is inserted.

TSPM will adopt the actual f/5 secondary (M2) of either MMT or the Magellan telescopes (TBD), which were fabricated under the same specifications. The characteristics of the different configurations are next summarized from the Optical Specications for the MMT Conversion (Fabricant, McLeod & West, 1999).

1.5.1 Imaging and Spectroscopic Plate scales

The plate scale and, more importantly, the corrected field of view are different in the imaging and spectroscopic configurations of the WFS, as summarized in the following table. A field-flattener in imaging mode permits a flat focal surface for direct imaging while in spectroscopic mode, the focal surface is curved and well characterized by a conic.

The Wide-Field Cassegrain Foci
(with refractive corrector)

f/	Purpose	ADC?	Scale (mm/arcsec)	Distortion	Focal Surface Radius (mm)	Focal Surface Conic
5.29	Spectroscopy, 1° FOV	Yes	0.167	1.8%	3404	–665
5.36	Imaging, 0.5° FOV	No	0.169	1%	Flat	

1.5.2 Imaging Mode Prescription

The whole optical prescription (including telescope) in the imaging mode of the WFC is given in the following table. In this mode, there is no ADC but a field-flattener is inserted after the main first three lenses of the corrector and a filter glass is also included in the optimized prescription.

SURFACE DATA SUMMARY:

Surf	Type	Radius	Thickness	Glass	Diameter	Conic
OBJ	STANDARD	Infinity	Infinity		0	0
STO	STANDARD	-16255.300	-6184.110	MIRROR	6502.400	-1
2	STANDARD	-5150.890	6184.110	MIRROR	1714.500	-2.6947
3	STANDARD	Infinity	29.382		621.755	0
4	STANDARD	604.737	73.288	SIL5C	831.440	0
5	STANDARD	694.826	80.085		831.440	0
6	STANDARD	1012.496	46.741	SIL5C	797.030	0
7	STANDARD	577.816	325.001		797.030	0
8	STANDARD	-8055.300	66.097	SIL5C	523.950	0
9	STANDARD	-2020.770	1044.671		523.950	0
10	STANDARD	Infinity	8.467	S-TIL1	365.153	0
11	STANDARD	Infinity	38.100		364.341	0
12	STANDARD	-1134.801	48.260	SIL5C	360.848	0
13	STANDARD	-4097.612	52.445		360.794	0
IMA	STANDARD	Infinity			358.573	0

1.5.3 Spectroscopic Mode Prescription

The whole optical prescription (including telescope) in the spectroscopic mode of the WFC is given in the following table. In this mode, the pair of double prisms of the ADC replaces the field flattener of the imaging mode.

SURFACE DATA SUMMARY:

Surf	Type	Radius	Thickness	Glass	Diameter	Conic
OBJ	STANDARD	Infinity	Infinity		0	0
STO	STANDARD	-16255.300	-6184.652	MIRROR	6502.400	-1
2	STANDARD	-5150.890	6184.652	MIRROR	1683.535	-2.6947
3	STANDARD	Infinity	29.382		818.368	0
4	STANDARD	604.737	73.288	SIL5C	831.440	0
5	STANDARD	694.826	80.085		831.440	0
6	STANDARD	1012.496	46.741	SIL5C	797.030	0
7	STANDARD	577.816	171.250		797.030	0
8	STANDARD	-5983.100	49.108	SIL5C	767.410	0
9	STANDARD	-2104.290	53.828		767.410	0
10	COORDBRK	***tilt about z***	***90°***			
11	FZERNSAG	Infinity	25.400	SFSL5Y_5C	748.920	0
12	FZERNSAG	Infinity	0.127	CAF2P20	748.920	0
13	FZERNSAG	Infinity	15.240	PBL6Y_5C	748.920	0
14	STANDARD	Infinity	25.705		748.920	0
15	COORDBRK	***tilt about z***	***-180°***			
16	FZERNSAG	Infinity	15.240	PBL6Y_5C	748.920	0
17	FZERNSAG	Infinity	0.127	CAF2P20	748.920	0
18	FZERNSAG	Infinity	25.400	SFSL5Y_5C	748.920	0
19	STANDARD	Infinity	699.754		748.920	0
20	COORDBRK	***tilt about z***	***90°***			
21	STANDARD	Infinity	12.700	SIL5C	648.479	0
22	STANDARD	Infinity	471.551		647.780	0
IMA	STANDARD	-3404			611.131	-665

1.5.4 ADC Prisms

Atmospheric dispersion is a significant issue for spectroscopy with optical fibers. The differential dispersion between 0.37 and 0.76 μm is about 1.4" at a zenith distance of 45° (1.4 airmasses) and about 2.5" at a zenith distance of 60° (2 airmasses). This would cause significant light loss with 1.5" diameter fibers if it were not corrected with the Atmospheric Dispersion Compensation (ADC) prisms built into the wide-field corrector.

The angles of the ADC prims are specified as single Zernike term as follow:

```
SURFACE DATA DETAIL (Prism Angles):

Surface  11     : FZERNSAG
Number of terms:                3
 Maximum rad ap :             2540
 Zernike Term  1:                0
 Zernike Term  2:                0
 Zernike Term  3:        4.0744902

Surface  12     : FZERNSAG
 Number of terms:               3
 Maximum rad ap :             2540
 Zernike Term  1:                0
 Zernike Term  2:                0
 Zernike Term  3:       -44.694627

Surface  13     : FZERNSAG
 Number of terms:               3
 Maximum rad ap :             2540
 Zernike Term  1:                0
 Zernike Term  2:                0
 Zernike Term  3:       -44.694615

Surface  16     : FZERNSAG

 Number of terms:               3
 Maximum rad ap :             2540
 Zernike Term  1:                0
 Zernike Term  2:                0
 Zernike Term  3:        4.2296588

Surface  17     : FZERNSAG
 Number of terms:               3
 Maximum rad ap :             2540
 Zernike Term  1:                0
 Zernike Term  2:                0
 Zernike Term  3:        50.624257

Surface  18     : FZERNSAG
 Number of terms:               3
 Maximum rad ap :             2540
 Zernike Term  1:                0
 Zernike Term  2:                0
 Zernike Term  3:        50.624252
```

1.5.5 WFC Element Dimensions

Element	Drawing Number	Clear Diameter (mm)	Overall Diameter (mm)	Center Thick (mm)	Weight (kg)
Lens 1	SAO MMTC-1000	806 mm	831 mm	73	73
Lens 2	SAO MMTC-1001	772 mm	797 mm	47	93
Lens 3	SAO MMTC-1002	728 mm	767 mm	49	39
Lens 4	SAO MMTC-1003	484 mm	524 mm	66	28
Top ADC Assembly	SAO MMTC-500	724 mm	749 mm	41	45
Bottom ADC Assembly	SAO MMTC-501	724 mm	749 mm	41	45
Element	Drawing Number	Clear Diameter (mm)	Overall Diameter (mm)	Min. Thick. (mm)	Max. Thick (mm)
ADC Prism 1	SAO MMTC-1004	724 mm	749 mm	18.2	32.6
ADC Prism 2	SAO MMTC-1005	724 mm	749 mm	8.7	21.8
ADC Prism 3	SAO MMTC-1006	724 mm	749 mm	8.4	22.1
ADC Prism 4	SAO MMTC-1007	724 mm	749 mm	17.9	32.9

1.6 TSPM f/5 Cassegrain Configuration

The following figure shows the f/5 optical layout (imaging mode).

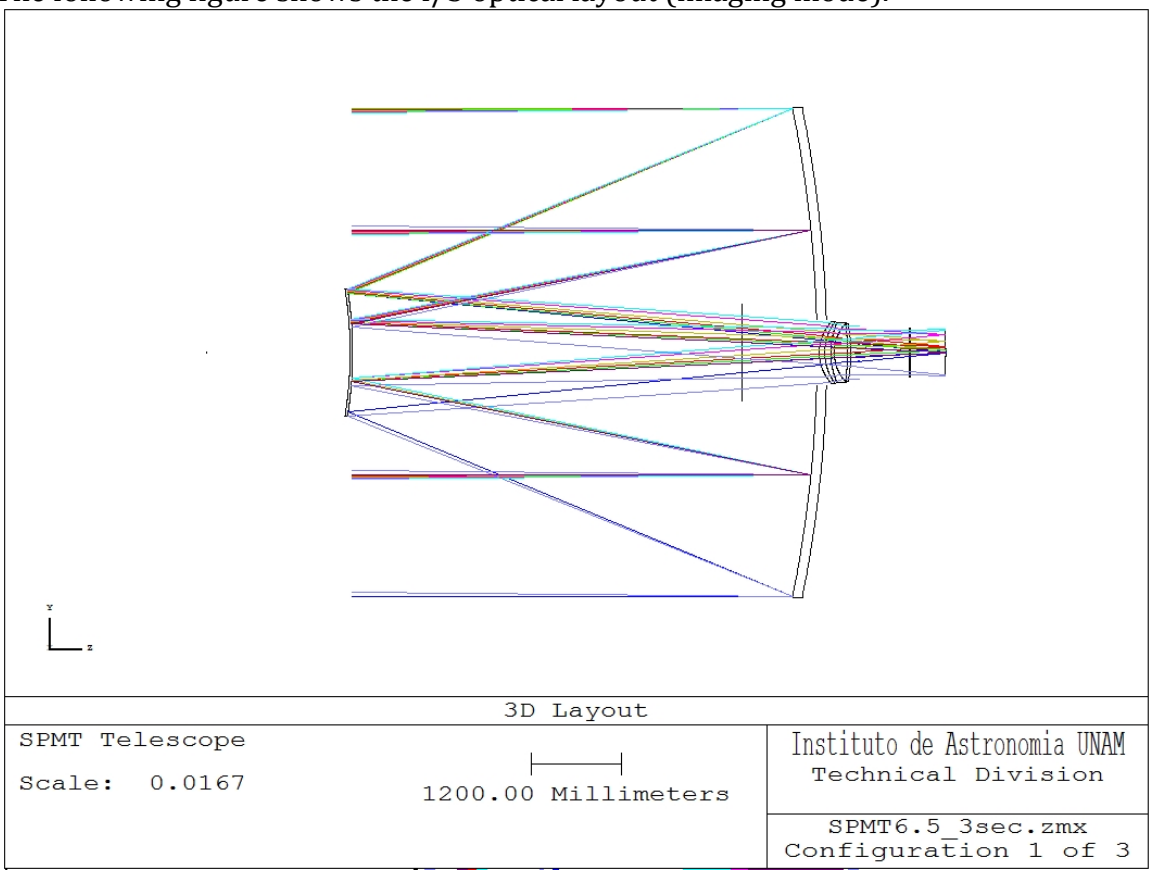

Figure 0-1 TSMP optical layout of the base f/5 Cassegrain configuration (only the imaging mode configuration of the WFC is shown).

1.6.1 GENERAL LENS DATA (IMAGING MODE):

Design Temperature & Pressure: 20°C and 1 atm.

Entrance Pupil Diameter: 6502 mm
Effective Focal Length : 34372.47 mm
Effective Focal Length : 34372.47 mm (in image space)
Back Focal Length : 525.3352 mm
Total Track : 109841 mm

Image Space F/# : 5.286446
Paraxial Working F/# : 5.286446
Working F/# : 5.286794
Image Space NA : 0.09416126
Object Space NA : 3.250965e-07
Stop Radius : 3251 mm
Paraxial Image Height : 299.964 mm
Entrance Pupil Position : 108127.7 mm
Exit Pupil Diameter : 1333.065 mm
Exit Pupil Position : -6993.394 mm
Maximum Radial Field : 0.5 Degrees
Primary Wavelength : 0.55 μm
Angular Magnification : 4.877229

1.7 MMT Telescope Error Budget

Purely for the purpose of information, in this section we summarize the error-budget of the MMT f/5 Cassegrain station. This information is taken from D. Fabricant document "MMT Conversion Specifications" that, together with "f/5 Wide Field Corrector Manual" summarizes the design and performance of the MMT f/5 system.

1.7.1 Bare Telescope Error Budget at Cassegrain

Error Source	Image FWHM (arcseconds)	Equivalent r_0 (cm)
Tracking and Drives	0.070	∼144
Secondary Alignment and Focus	0.090	∼112
Primary Mirror Surface	0.170	∼59
Primary Conic/Radius	0.056	∼180
Secondary Mirror Surface	0.040	∼253
Secondary Conic/Radius	0.028	∼361
Telescope Seeing (5%)	0.060	∼168
Best Atmospheric Seeing	0.225	∼45
Best Final Image (total)	0.319	∼32

1.7.2 f/5 Wide-Field Error-Budget

Error Budget for Wide Field Imaging

Error Source	50% EE Dia. (arcseconds)	Equivalent r_0 (cm)	90% EE μm
Tracking and Drives	0.070	~144	21
Secondary Alignment and Focus	0.090	~112	28
Primary Mirror Surface	0.170	~59	52
Primary Conic/Radius	0.075	~135	23
Secondary Mirror Surface	0.040	~253	12
Secondary Conic/Radius	0.028	~361	9
Telescope Seeing (5%)	0.060	~168	18
Best Atmospheric Seeing	0.225	~45	68
Corrector Optical Design	0.065	~156	20
Corrector Fabrication	0.065	~156	20
Primary Alignment	0.036	~280	11
Corrector Alignment	0.018	~560	5
Best Final Image* (total)	0.338	~30	103

*Averaged over field angle and color.

Error Budget for Wide Field Spectroscopy

Error Source	50% EE Dia. (arcseconds)	Equivalent r_0 (cm)	90% EE μm
Tracking and Drives	0.070	~144	21
Secondary Alignment and Focus	0.090	~112	28
Primary Mirror Surface	0.170	~59	52
Primary Conic/Radius	0.075	~135	23
Secondary Mirror Surface	0.040	~253	12
Secondary Conic/Radius	0.028	~361	9
Telescope Seeing (5%)	0.060	~168	18
Best Atmospheric Seeing	0.225	~45	68
Corrector Optical Design	0.235	~43	72
Corrector Fabrication	0.220	~46	67
Primary Alignment	0.070	~144	21
Corrector Alignment	0.070	~144	21
Best Final Image* (total)	0.467	~22	143

*Averaged over field angle and color.

Wide Field Differential Distortion Error Budget

Differential Distortion Source	Offset (μm)
Primary Collimation	5
Primary Mechanical/Optical Fab.	4
Secondary Collimation	1
Corrector Collimation	35
Corrector Fabrication	35
Total	50

TSPM Nasmith extreme configurations

1.8 F/11 Gregorian

The design of the TSMP f/11 Configuration is based on the Magellan Gregorian system. The main differences from Magellan are:

- TSPM has a higher elevation axis (1 m form M1 vertex)
- TSPM requires Wider FoV in Nasmyth, about 0.5° (f/11) or 1° (f/5) in diameter. This implies a slightly larger M2
- This also implies a much larger M3 (f/5 1° FoV at Nasmyth)
- Given the bigger tertiary mirror, it would inconvenient to mount the WFC close to M3 fore mechanical and operational reasons. Therefore, a similar WFC-ADC system is designed for TSPM, but placed closer to the focal plane, inside the Nasmyth rotator.
- A disadvantage of this choice of WFC position is that each port needs its own corrector. On the other hand, an advantage is that the WFC can be optimized for each instrument.

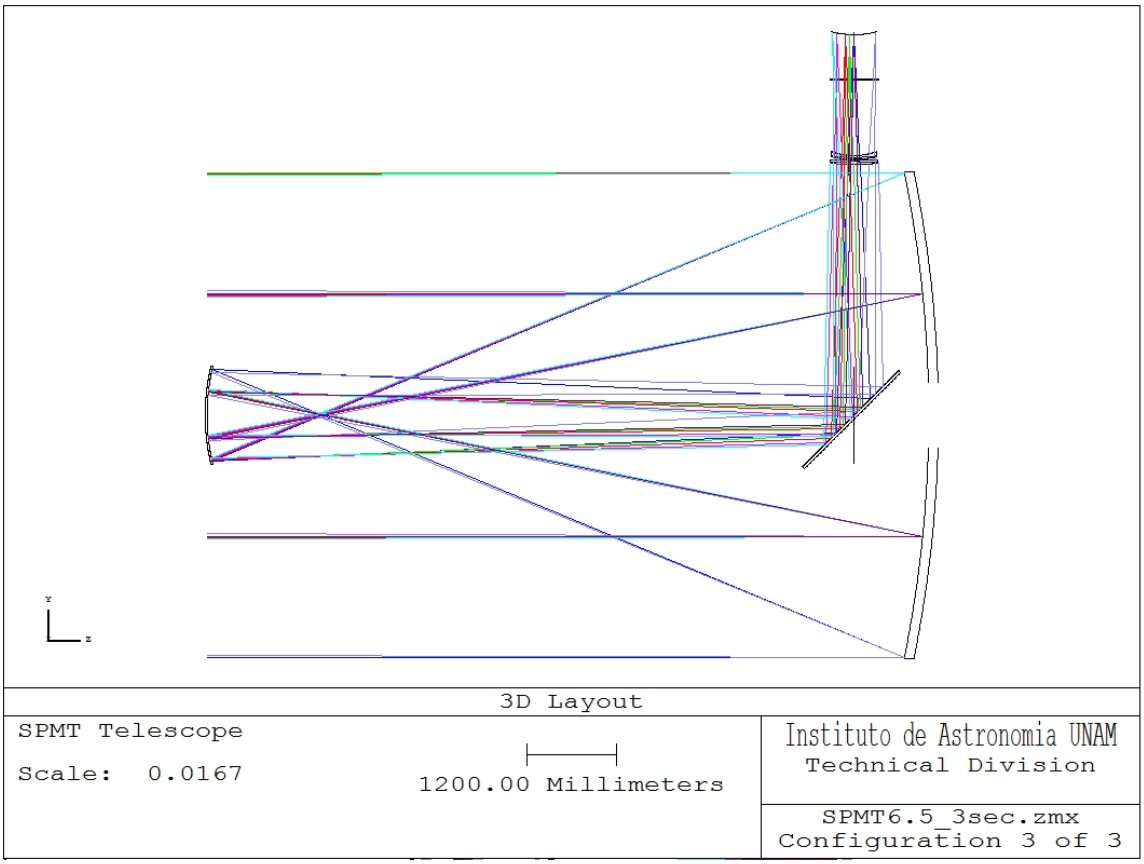

Figure 0-1 Extreme f/11 configuration of TSPM. The size of M2 is a bit larger than in Magellan, to accommodate the same physical field as the f/5 configuration that, given the 2.08 factor given by the ratio of the effective lengths, is close to 0.5 degrees in diameter.

1.8.1 Nasmyth f/11 System General Optical Data

Temperature	5.0 °C
Pressure	1.0 ATM
Entrance Pupil Diam.	6502 mm
Effective Focal Length	-71524.11 mm(in air at design T and pressure)
Effective Focal Length	-71524.11 mm(in image space)
Back Focal Length	1620.486 mm
Total Track	108127.6 mm
Image Space F/#	11.00032
Paraxial Working F/#	11.00032
Working F/#	11.00025
Image Space NA	0.04540633
Object Space NA	3.250965e-007

Stop Radius	3251 mm
Paraxial Image Height	280.876 mm
Entrance Pupil Position	108127.7 mm
Exit Pupil Diameter	991.6851 mm
Exit Pupil Position	10908.89 mm
Maximum Radial Field	0.225 degrees
Primary Wavelength	0.55 µm
Angular Magnification	6 .555377

1.8.2 f/11 Optical Prescription

Surf	Type	Radius	Thickness	Glass	Diameter	Conic	Comment
OBJ	STANDARD	Infinity	Infinity		0	0	
1	ATMOSPHR	Infinity	100000		8389.231	0	ATM_Refraction
2	STANDARD	Infinity	8127.65		6800	0	Spider_FocM1
3	STANDARD	Infinity	-9671.613		6502	0	M1-M2_sep
4	STANDARD	Infinity	9671.613		6502	0	M2-Shadow
STO	STANDARD	-16255.3	-9671.613	MIRROR	6502.4	-1	PRIMARY
6	STANDARD	2777.355	9671.613	MIRROR	1308.207	-0.6388845	M2
7	STANDARD	Infinity	-1000		1137.959	0	M1-Elevation
8	STANDARD	Infinity	0		1278.148	0	Elevation_Axis
9	COORDBRK	-	0	-	-		
10	STANDARD	Infinity	0	MIRROR	1819.936	0	M3
11	COORDBRK	-	-	-	-		
12	STANDARD	Infinity	0		1137.959	0	
13	STANDARD	Infinity	-2360		817.6152	0	
14	STANDARD	-2657.677	-40	N-PK52A	640	0	CORR1
15	STANDARD	3465.898	-24.88	K10	640	0	CORR2
16	STANDARD	Infinity	-5		640	0	
17	STANDARD	-1413.836	-25.04	K10	600	0	CORR3
18	STANDARD	-2179.47	-25.04	N-PK52A	600	0	CORR4
19	STANDARD	-892.3095	-1015.84		600	0	
20	COORDBRK	-	0				
21	FZERNSAG	Infinity	0		748.92	0	
22	FZERNSAG	Infinity	0		748.92	0	
23	FZERNSAG	Infinity	0		748.92	0	
24	STANDARD	Infinity	0		748.92	0	
25	COORDBRK	-	0		.		
26	FZERNSAG	Infinity	0		748.92	0	
27	FZERNSAG	Infinity	0		748.92	0	
28	FZERNSAG	Infinity	0		748.92	0	
29	STANDARD	Infinity	0		704.8809	0	

30	COORDBRK	-	0	-	-	
31	STANDARD	Infinity	-12.7	649.1717	0	
32	STANDARD	Infinity	-591.9124	648.4748	0	
IMA	STANDARD	-1213.932	611.3333			0.9916101

M2 approximated glass weight : 154 kg
M3 approximated glass weight : 200 kg

LENS	**Vol (cc)**	**g/cc**	**Mass (g)**
CORR1	7382.14	3.747	27660.9
CORR2	10383.41	2.520	26166.2
CORR3	5474.14	2.520	13794.8
CORR4	11421.53	3.747	42796.5

1.9 Nasmyth f/5 configuration

The extreme f/5 Nasmyth configuration of TSPM is defined to be equivalent to the f/5 Cassegrain. The schematic design has a similar corrector, yielding the same plate scale and field of view. The f/5 WFC is more complex and massive than the f/11 Nasmyth WFC so, unlike Magellan it is not located close to M3, but much closer to the focal plane within the Nasmyth rotator.

As the case of the f/11 Nasmyth configuration, this configuration will not necessarily will be constructed, but is presented to limit the size of the tertiary as well as the mechanical design. In particular, this extreme Nasmyth configuration drives the size of M3. The indicative f/11 Gregorian and f/5 classical configurations at Nasmyth define the largest M1-M2 separation and of the larger secondary respectively, as set the physical limits of any final configuration TSPM decides to construct: from an f/5 classical configuration and slower systems up to a prime focus and Gregorian systems slower than about f/11.

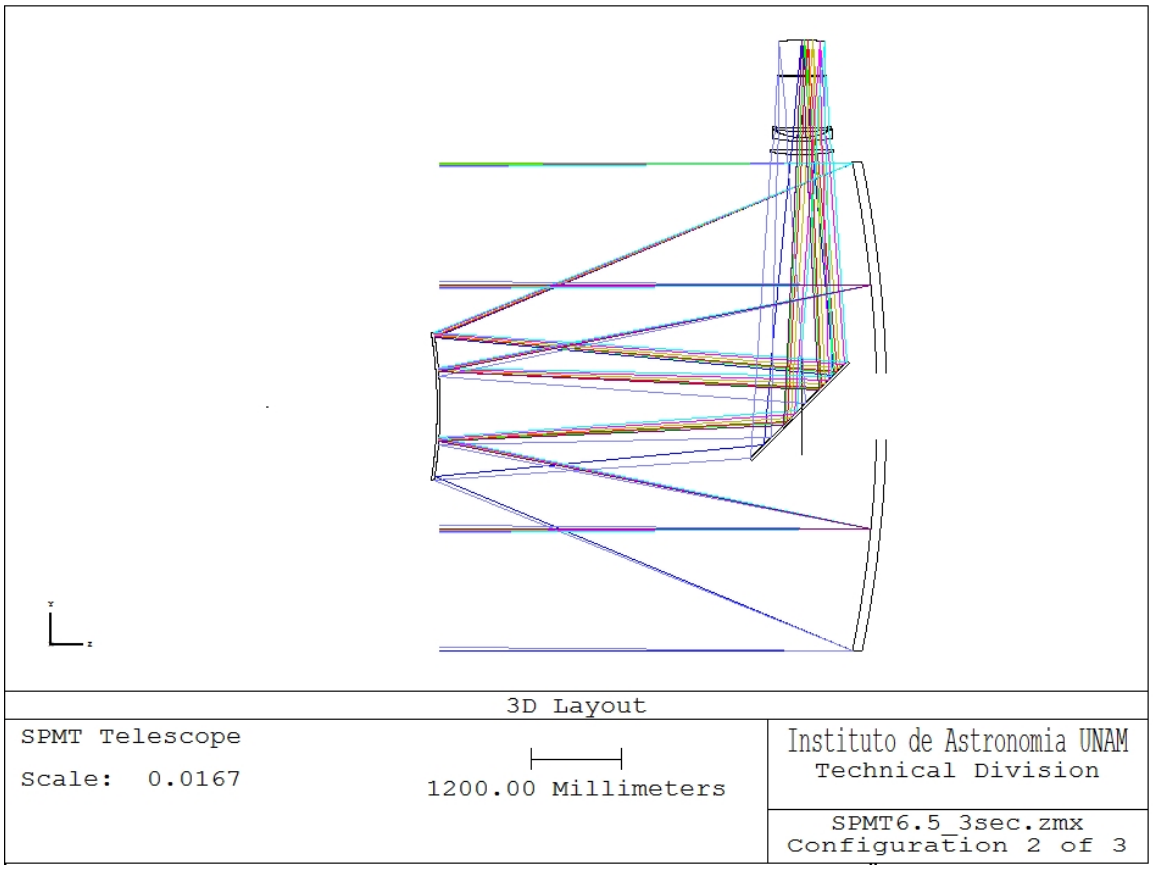

Figure 0-2 Optical layout of the TSPM extreme f/5 Nasmyth configuration. The indicative system has the same field of view and plate scale than for the base f/5 Cassegrain system, setting important limits for the actual configurations TSPM decides to actually construct like the size of M3, the widest un-obstructed aperture and the largest M2, among others.

1.9.1 Nasmyth f/5 System General Optical Data

Entrance Pupil Diameter = 6502 mm

Temperature	5.0 °C
Pressure	1.0 ATM
Entrance Pupil Diameter	6502 mm
Effective Focal Length	34358.79 mm (in air at system T and pressure)
Effective Focal Length	34358.79 mm (in image space)
Back Focal Length	471.7552 mm
Total Track	108127.6 mm
Image Space F/#	5.284341
Paraxial Working F/#	5.284341

Working F/#	5.284522
Image Space NA	0.09419845
Object Space NA	3.250965e-007
Stop Radius	3251 mm
Paraxial Image Height	299.8446 mm
Entrance Pupil Diameter	6502 mm
Entrance Pupil Position	108127.7 mm
Exit Pupil Diameter	1566.436 mm
Exit Pupil Position	8277.784 mm
Maximum Radial Field	0.5 degrees
Primary Wavelength	0.55 µm
Angular Magnification	-4.150527

M2 Approximated Weight

LENS	Vol (cc)	g/cc	Mass (g)
CORR1	29011.2	2.20	63824.544328
CORR2	41431.7	2.20	91149.793376
CORR3	18040.3	2.20	39688.558804
ADC1	11192.2	2.46	27532.695737
ADC2	6715.3	2.79	18735.663684
ADC3	6715.3	2.79	18735.663684
ADC4	10543.7	2.46	25937.477879
FILTER	4203.5	2.20	9247.736888

1.9.2 f/5 Nasmyth Optical Prescription

Surf	Type	Radius	Thickness	Glass	Diameter	Conic	Comment
OBJ	STANDARD	Infinity	Infinity		0	0	
1	ATMOSPHR	Infinity	100000		8389.231	0	ATM_Refraction
2	STANDARD	Infinity	8127.65		6800	0	Spider_FocM1
3	STANDARD	Infinity	-5824.393		6502	0	M1-M2_sep
4	STANDARD	Infinity	5824.393		6502	0	M2-Shadow
STO	STANDARD	-16255.3	-5824.393	MIRROR	6502.4	-1	PRIMARY
6	STANDARD	-6045.714	5824.393	MIRROR	1965.556	-2.615194	M2
7	STANDARD	Infinity	-1000		1137.959	0	M1-Elevation
8	STANDARD	Infinity	0		1278.148	0	Elevation_Axis
9	COORDBRK	-	0		-	-	
10	STANDARD	Infinity	0	MIRROR	1819.936	0	M3
11	COORDBRK	-	-1000			-	-
12	STANDARD	Infinity	0		1137.959	0	
13	STANDARD	Infinity	-2360		817.6152	0	

14 STANDARD	-2388.479	-73.288	SILICA	831.44	0 CORR1
15 STANDARD	25827.91	-107.5751		831.44	0
16 STANDARD	-2011.661	-46.741	SILICA	797.03	0 CORR2
17 STANDARD	-744.8416	-80		797.03	0
18 STANDARD	-2186.196	-49.108	SILICA	767.41	0 CORR3
19 STANDARD	-5402.545	-53		767.41	0
20 COORDBRK	-	0		-	-
21 FZERNSAG	Infinity	-25.4	S-FSL5Y	748.92	0
22 FZERNSAG	Infinity	-0.127	CAF2	748.92	0
23 FZERNSAG	Infinity	-15.24	PBL6Y	748.92	0
24 STANDARD	Infinity	-25.705		748.92	0
25 COORDBRK	-	0		-	-
26 FZERNSAG	Infinity	-15.24	PBL6Y	748.92	0
27 FZERNSAG	Infinity	-0.127	CAF2	748.92	0
28 FZERNSAG	Infinity	-25.4	S-FSL5Y	748.92	0
29 STANDARD	Infinity	-699.754		704.8809	0
30 COORDBRK	-	175.9561		-	-
31 STANDARD	Infinity	-12.7	SILICA	649.1717	0
32 STANDARD	Infinity	-471.551		648.4748	0
IMA STANDARD	5278.013			611.3333	-388.6368

TSMP OPTICAL CONFIGURATIONS SUMMARY

The following figures presents all three TSPM optical configurations discussed. The base f/5 Cassegrain configuration is the only one that will be constructed initially. The other two configurations are indicative designs to limit the size of the building, the top-end of the telescope dimensions and rigidity, the size of the tertiary mirror, the clear apertures and overall dimensions of the Nasmyth rotators and platforms. In particular, the f/5 Nasmyth drives the size of M3 and the telescope rigidity necessary to support its M2 while the f/11 Gregorian drives the height of the dome.

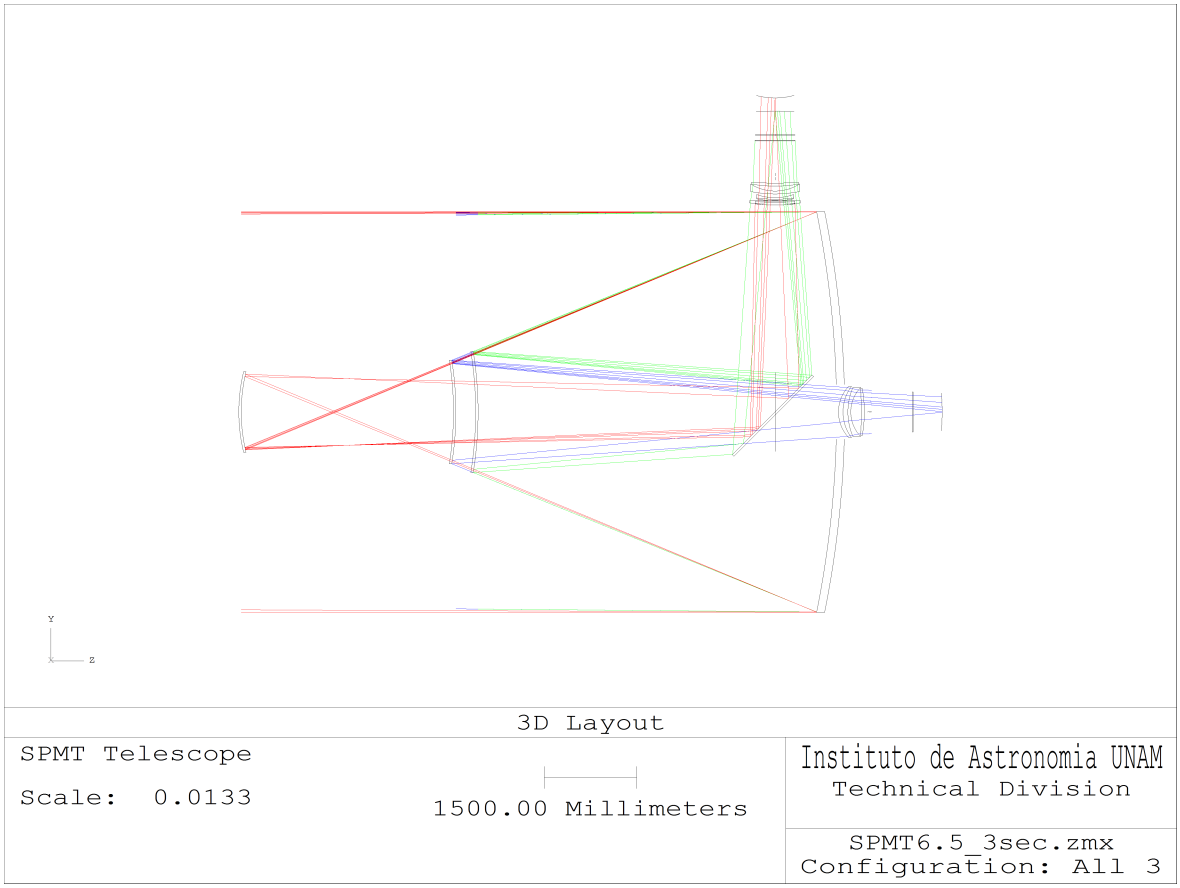

Figure 0-1 All the TSPM optical configurations. Beyond the base f/5 Cassegrain configuration, which TSPM will certainly have, the other two Nasmyth layouts represent indicative designs to limit the maximal design criteria for the building and telescope structure.

The following table summarizes the main characteristics of the reference TSPM optical configurations discussed in this document.

	F/5 Cas	F/5 Nas**	F/11 Nas**
Primary Mirror (M1)	Diameter=6502mm, Rc=16255.3 mm, Conic=-1.0000		
Elevation Axis	1,000 mm above M1		
Eff. focal length [mm]	34372.5	34358.8	71524
FoV [degrees]	1.0	1.0	0.45
M1-M2 distance [mm]	6184.65	5,824.4	9671.6
M2 Diameter/Rc [mm]	1682 / 5150.9	1966 / 6045.7	1308 / 2777.4
M2 conic	-2.69470	-2.61519	-0.63888
M3 Location* [mm]		0, -46.23, -46.23 (65.38 mm disp)	

M3 Aperture [mm]		1830x1300 ellipse	
WFC concept	3-elements +2-doublet ADC		2-doublet ADC system
WFC 1st-surf Loc* [mm]	0, 0, 1029.4	0, 3360, 0	0, 3360, 0
WFC 1st-surf D/Rc [mm]	831.4 / 604.7	831.4 / 2,388.5	640 / 2,657.7
ADC last-surf Loc* [mm]	0, 0, 1529.4	0, 3,877, 0	0, 3,480, 0
ADC last-surf D/Rc [mm]	704.9 / flat	704.9 / flat	600 / -892.3
Focal Surface Loc* [mm]	0, 0, 2713.4	0, 4885, 0	0, 5100, 0
Focal Surface D/Rc [mm]	611.3 / -3404	611.3 / 5278	611.3 / -1214

* Locations are relative to the coordinate-system center defined by the intersection of the telescope optical axis and the elevation axis (1.0 mts above the primary vertex).
** These optical prescriptions are schematic, to define the extremes of the mechanical design. They will be refined after definition of future science cases and instrumentation.