HERSCHEL TELESCOPE SPECIFICATION

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ESA Herschel/Planck Project

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DOCUMENT CHANGE RECORD

Issue / Rev. Date	Pages affected / Brief description of change
November 1997	F. Felici, FIRST/Planck Project Manager (Acting) ESA/ESTEC, Noordwijk
1/A January 1998	All changes on pages listed below are indicated by bold vertical lines in the left hand margins. i, iii, 1-1, 2-1, 2-2, 2-3, 3-3, 3-4, 4-1, 4-3, 4-5, 4-6, 5-1, 5-2, 5-6, 5-7, 5-9, 5-10, 5-11, B-2, B-3, B-4, B-5, B-6, B-7
2/0 July 1999	New issue of document. All changes on pages listed below are indicated by bold vertical lines in the left-hand margins. Changes after FIRST telescope workshop held at ESTEC on 21-22 July 1999.
3/0 May 2000	All changes on pages listed below are indicated by a vertical line in the left margin. i, v, 7, 10, 12, 15, 19, 33
4/0 11 May 2001	New issue of document for start of the Herschel telescope contract based on SiC technology. All changes on pages listed below are indicated by vertical lines in the left-hand margins. Par 6.4 Deliverables has been deleted (i.e. part of SoW).
5/0 5 April 2002	Update of document following start of the Herschel telescope contract followed by the Mid Term Review (MTR) in view of the Critical Design Review (CDR). All changes are indicated by vertical lines in the left-hand margins.
6/0 22 October 2002	Update of document following successful Critical Design Review (CDR) and following negotiation meeting on Herschel telescope contract in September 2002. The following requirements TEFU-010, TEFU-015, TEFU-070, TEFU-080, TEPE-065, TEPE-075, TEPE-090, TEEN-090, TEVE-050, TEVE-055, TEEN-030, section 3.3, the figure 4.3.1 and the annex-B have been modified. Requirement TEFU-095 on protective cover has been added for clarification.
7/0 26 July 2004	Update of document following ➢ electrical interface modification in Nov 02 and July 03 and ➢ negotiation meeting on telescope contract in October 2003 and July 04. Document list has been updated with addition of ICDs as reference documents. The requirements TEFU-030 up to 045 and TEEN-140 and sections 3.5.4, 4.2.2 have been slightly corrected (drawing or document reference corrected). **Requirement on thermal environment during launch phase (TEFU-057) has been added for clarification.** **The requirements TEFU-070 up to 085 concerning electrical requirements have been modified following electrical interface modification agreement.** **TEFU-095 modification has been implemented as coming from H/P prime contractor.** **TEPE-065 and TEPE-075 requirements have been modified following as-built data of M1 (radius of curvature).** **TEPE-135 and TEEN-100 requirements have been updated following telescope mass increase from 300 to 315 kg.**

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TABLE OF CONTENTS

1 INTRODUCTION

ESA's Horizon 2000 Science Programme has two important missions for performing astronomical investigations in the far-infrared, sub-millimetre and millimetre wavelength range:

- **Herschel** (previously called FIRST, the Far Infrared and Sub-millimetre Telescope), an observatory type mission;
- Planck (previously named COBRAS/SAMBA), a survey mission.

Herschel is the fourth "cornerstone" (CS4) mission in the European Space Agency (ESA) long term space science plan "Horizons 2000". **Herschel** is a multi-user (observatory type) mission, which targets the far-infrared and sub-millimetre part of the spectrum. **Herschel** will address key scientific topics such as deep broadband extra-galactic surveys, follow-up spectroscopy of especially interesting program objects discovered in the survey, detailed studies of the physics and chemistry of the interstellar medium in galaxies, including star formation, observational astro chemistry of gas and dust and detailed high-resolution spectroscopy of a number of comets.

Herschel will operate in the spectral range between 80 and 670 µm wavelength. The operational orbit shall be assumed to be an orbit around the second Libration point (L_2) in the Earth/Moon - Sun system at an average distance of 1.5 million kilometres from the Earth.

The concept for the **Herschel** telescope is based on an axisymmetric, 3.5-m-diameter Cassegrain design. The telescope is protected by a sunshield in order to avoid direct solar radiation to the primary and secondary reflectors and their structures and to provide a stable thermal environment, which minimises temperature variations across the telescope.

Due to the science requirements, high initial accuracy and in-orbit thermal stability are required by the telescope to enable spectroscopy and photometry in the far infrared and submillimetre frequency range.

2 SCOPE

This specification establishes the performances, design, development and qualification test requirements for the Herschel telescope.

2.1 Terms and Acronyms

AD	Applicable Document
AIV	Assembly, Integration & Verification
BOL	Begin of Life
CFRP	Carbon Fibre Reinforced Resin
CTE	Coefficient of Thermal Expansion
EOL	End of Life
EP	Entrance Pupil
FIRST	Far Infrared and Submillimetre Telescope
FOV	Field-of-view
LOS	Line Of Sight
MGSE	Mechanical Ground Support Equipment
MOS	Margin of Safety
N/A	Not applicable
NDI	Non Destructive Inspection
OGSE	Optical Ground Support Equipment
PA	Product Assurance
PLM	Payload Module
PSF	Point-Spread-Function
RD	Reference Document
RH	Relative Humidity
RMS	Root Mean Square
S/C	Spacecraft
TBC	To be confirmed
TBD	To be determined
WFE	Wave Front Error

2.2 Abbreviation List for Requirements

The requirements in this specification have been systematically numbered. The code applied consists of four letters and three digits. The four letters start for the telescope with TE, continued with an abbreviation of the area concerned. The numbering convention is illustrated in the table below.

Requirement Type	*Abbreviation*	*Specification paragraph*
Functional and General Requirements	*TEFU-xxx*	*3.*
Mission and Performance	*TEPE-xxx*	*4.*
Environmental, Design and Construction	*TEEN-xxx*	*5.*
Verification	*TEVE-xxx*	*6.*

2.3 Documents

The following documents of the exact issue shown form a part of this specification. In the event of conflict between documents referenced herein and the content of the specification, the content of this specification shall be considered a superseding requirement.

2.3.1 Applicable Documents (AD)

The following documents form a part of this specification.

Ref	Reference	Issue - date	Title
1.	ESTEC/WMA/he/ FIRST/3	4 - Mar 97	FIRST L_2 Radiation Environment
2.	ECSS-Q-70-01A - Draft	18 June 99	Cleanliness and contamination control
3.	ECSS-Q-70A	Apr 96	Materials, Mechanical Parts and Processes
4.	ESA PSS-01-702	2 - Oct 94	A thermal vacuum test for the screening of space materials
5.	SCI-PT-RS-04683	2-rev1 20 Sep 00	Product Assurance Requirements for FIRST/Planck Satellite
6.	ECSS-Q-70-36A	20 Jan 98	Material selection for controlling stress corrosion cracking
7.	PT-RQ-09060, Is 1	10/05/01	Durability requirement for Herschel optical coating
8.	ARIANESPACE	3/0 - March 00	ARIANE 5 Users Manual
9.	ESA PSS-01-301	2 - Apr 92	Derating requirements applicable to electronic, electrical and electro-mechanical equipment
10.	SCI-PT-RS-05991	Is 3, Oct 2002	System Requirements Specification

2.3.2 Reference Documents (RD)

The Telescope Provider is invited to refer to the following documents for guidance.

Nb	Reference	Issue - date	Title
1.	PSS-03-203	1 - Feb. 94	Structural Materials Handbook Vol. 1 and 2
2.	CSG-RS-10A-CN & 22A-CN	Latest issue	CSG Safety Regulations, Vol 1 & Vol 2, Part 2
3.	HP-2-ASED-TN-002	Draft July 01	Herschel Alignment Concept
4.	HER.NT.0052.T.ASTR	Latest issue	Mechanical Interface Control Document (ICD)
5.	HER.NT.0058.T.ASTR	Latest issue	Thermal Interface Control Document (ICD)
6.	HER.NT.0187.T.ASTR	Latest issue	Electrical Interface Control Document (ICD)
7	HER.NT.0167.T.ASTR	Latest issue	Optical Interface Control Document (ICD)

3 GENERAL REQUIREMENTS

3.1 Description of Herschel Telescope

The Telescope is composed of:

- a primary reflector (M1) and a secondary reflector (M2),
- a secondary reflector support structure (tripods, bipods, hexapod or else)
- a telescope support structure (3 bipods)
- baffles as necessary
- thermal hardware (MLI or thermal screens; heaters; harness, thermistors..) for in-orbit contamination release from optical surfaces and for bake-out of the telescope
- telescope adjustment shims
- Alignment devices (cubes, pin balls).

The telescope interfaces with the PLM interface frame , which is part of the Payload Module (PLM). The telescope and the PLM shall be thermally decoupled to the maximum extent.

3.2 General Functional Requirements of the Telescope

TEFU-005 *The telescope primary reflector shall collect the electromagnetic radiation and shall deliver the collected power via the secondary reflector to the focal plane units.*

The sunshield of the spacecraft will provide a stable thermal environment to the telescope and will therefore protect the telescope from direct Sun irradiation during all operation phases and modes and will provide for overall straylight reduction.

3.3 Axis System of the Telescope

The following axis system shall be used for the telescope: the basic coordinate system shall be a right handed Cartesian system with its origin located within the plane defined by the mean plane passing through the center of the 3 bipods interface zones (including telescope adjustment shims foreseen to be between 2 and 12 mm thick), at the centre of the triangle defined by the three interface zones.
The X-axis is perpendicular to this interface plane, positive towards the target source.
The Z-axis is in the plane normal to the X-axis such that nominally the Sun will lie in the XZ-plane (zero roll axis with respect to the Sun), positive towards the Sun.
The Y- axis completes the right-handed orthogonal reference frame.

3.4 Optical Axis System of the Telescope

TEFU-007 *The telescope optical axis is by definition the axis going through the vertices of the Primary and Secondary mirrors. The optical axis shall coincide with the axis normal to the telescope interface plane (defined in par 3.5.1) and shall pass through the geometrical centre of this plane. The coincidence between the 2 axes shall be within a halfcone angle of 3 mrad. The deviation shall be verified with an accuracy better than 2 mrad at ambient (measurement) and in vacuum (measurement and analysis).*

3.5 General Interface Requirements

The figure 3.5-1 summarises the different interfaces with the telescope.
All dimensional parameters are defined w.r.t. a reference plane at the height of the instrument optical bench.

3.5.1 Mechanical

TEFU-010 *The telescope interfaces mechanically with the PLM frame via three interface areas (defined in TEEN-130), which shall allow alignment and mounting of the complete telescope to the PLM. The telescope includes axial adjustment shims under their bipods. The thickness of the shims under the bipod is between 2 and 12 mm.*

TEFU-015 *One interface point shall be located on the -Z-axis, at a distance of 875 mm from the X-axis. The other interface points shall be within the Y/Z Plane and be at +/- 120 degree rotated around the X-axis..*

TEFU-020 *The structural interface of the telescope and its accessibility shall allow an easy and reproducible assembly and alignment of the complete telescope to the PLM.*

TEFU-025 *The surface planarity across the three telescope flight mounting areas shall be better than 20 µm) peak to valley when considering* *the mean plane through the mountings as reference. The roughness of each mounting area shall be better than 3.2 µm (rms). The Flight mounting areas of the telescope shall be protected during transportation and AIV activities when not integrated.*

3.5.2 Thermal

3.5.2.1 Thermal Interface with Sunshield/Sunshade

The thermal interface between the telescope and the sunshield/sunshade is a radiative coupling.

TEFU-030 *The sunshield/sunshade interface temperatures to be considered for the thermal interface with the telescope are given in figures 3.5-4-d.*

TEFU-035 *The sunshield/sunshade surface properties shall be used as defined in figures 3-5.4-c.*

3.5.2.2 Thermal Interface with PLM

The thermal interface between the telescope and the PLM is a radiative and conductive coupling.

TEFU-040 *The PLM interface temperatures to be considered for the thermal interface with the telescope are given in figure 3.5-4-d.*

TEFU-045 *The PLM surface properties shall be used as in figure 3-5-4-c.*

TEFU-050 *The telescope is conductively coupled to the PLM via the PLM interface frame. This conductively coupled interface shall be considered for the telescope design with a total conductance value of 9 mW/K at 75K, and 44 mW/K at 300K.*

3.5.2.3 Thermal Gradients

TEFU-055 *The maximum values for the thermal gradients across the primary reflector of telescope are the following:*

- *Gradient in Z-direction:* *10 K*
- *Gradient in Y-direction:* *1 K*
- *Gradient change in Z-direction:* *13 mK/min*
- *Gradient change in Y-direction:* *1.3 mK/min.*

3.5.2.4 Thermal environment during launch phase

The requirements below are explicit requirements derived from AD-08 for the specific Herschel/Planck scenario,

TEFU-057 The telescope shall be compatible of the following thermal environment.

<u>Sun illumination:</u>
During the complete launch phase, the telescope shall be compliant with a roll angle included in –26 and + 26 deg.

In addition, two transient illuminations by Sun may occur (see figure 3.5.2.4.a below):
1) *between t0 (fairing separation) and t0+ 160 sec for a roll angle up to +/- 180 deg and an a pitch angle between 20 and 50 deg (angle between Sun direction and X axis)*
2) *between t0+350 sec and t0+ 420 sec for a roll angle up to +/- 180 deg and an a pitch angle between 60 and 90 deg (angle between Sun direction and X axis).*

During these two transient phases the roll rate is higher than 0.5 °/sec. It can be less than 0.5°/sec for duration of no more than 5 sec with a duty cycle of 10% (5ec low/ 45 sec high).

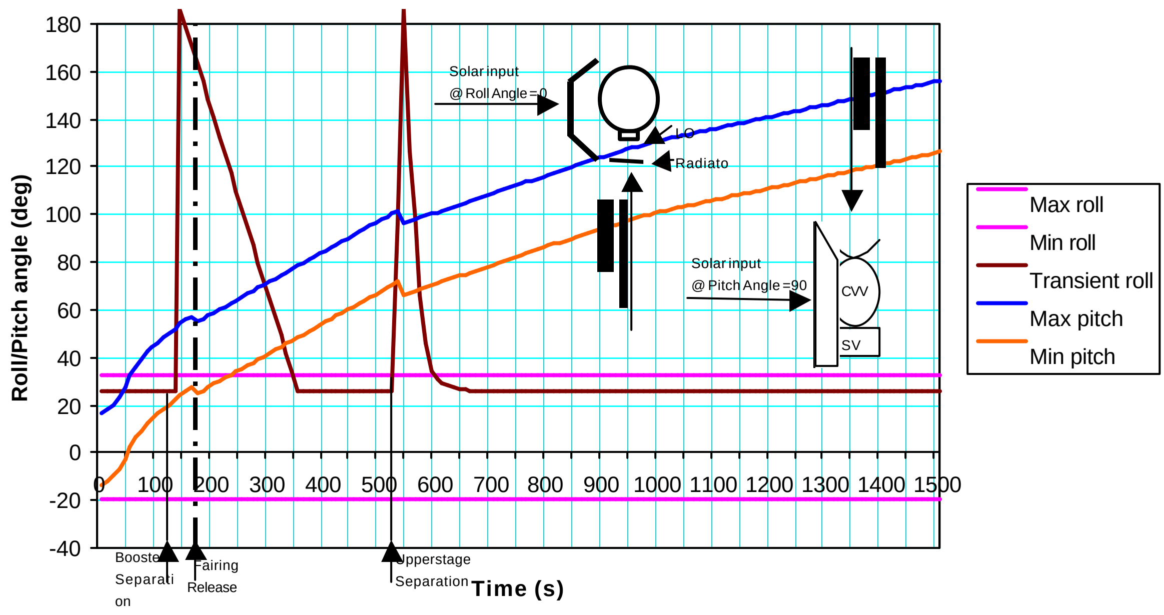


Figure 3.5.2.4.a: Pitch/roll angle during launch phase

Following and in-between these transient illuminations, the Secondary Mirror (M2) will remain shadowed by the Sunshade during the launch phase.

Outside the two transients identified above,
From t0+160 sec to t0+500 sec, the telescope shall be compliant with a Primary Mirror (M1) illumination by Sun close to the telescope axis perpendicular: pitch angle

(angle between Sun direction and X axis) is between 20 deg and 90 deg, and roll angle is between +/- 26 deg. Pitch angle shall be assumed to increase linearly during these 340 seconds, as indicated in the figure 3.5.2.4.a below.

From t0+500 sec to t0+1400 sec, the telescope shall be compliant with a Primary Mirror (M1) illumination by Sun by a shallow angle from below: pitch angle (angle between Sun direction and X axis) is between 90 deg and 150 deg, and roll angle is between +/- 26 deg. Pitch angle shall be assumed to increase linearly during these 900 sec, as indicated in the figure 3.5.2.4.a below.

Aerothermal flux:
After fairing jettisoning (at t0), the telescope shall withstand without damage two aerothermal fluxes (see figure 3.5.2.4.b. below).
The first aerothermal flux occurs between t0 and t0+~60 sec with a maximal flux of 1135 W/m2.
The second aerothermal flux occurs between t0+~300 sec and t0+~1000 sec with a maximal flux of 500 W/m2.

In the absence of roll motion, the aerothermal flux direction can be between 0 and 20 deg from X axis, in the (X,Z) plane but only in the (+X,+Z) quadrant. This has to be combined with the roll motion of the launcher during the phase.

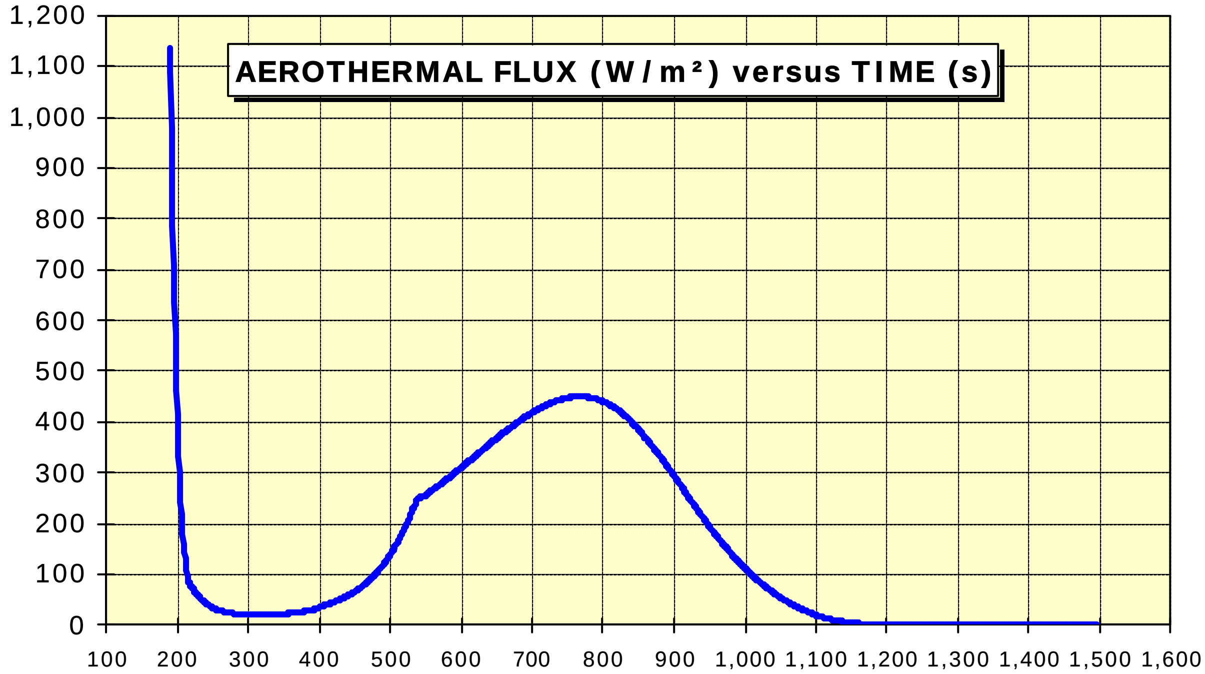


Figure 3.5.2.4.b: Aerothermal flux during launch phase

The Herschel telescope is also subjected to albedo and Earth fluxes during all these phases.

The compatibility of the telescope design with the Sun illumination and aerothermal flux during launch as defined in the above shall be demonstrated by test.

3.5.3 Electrical

TEFU-060 *All telescope conductive surfaces, as well as the mirror coatings shall be grounded. All thermal blankets larger than 100 cm2 shall be grounded on the telescope.*

TEFU-065 *The electrical resistance between any grounding point of the telescope and the telescope grounding system (on S/C side) shall be less than 1W.*

TEFU-070 *Provision shall be made for heaters and thermal sensors on the telescope (reflectors; tripod; thermal H/W; etc..).*

The following configuration shall be implemented for the heater lines of the telescope:

- *6 lines of 87 W nominal power with a total (heater + harness from telescope connector to heater) resistor nominal value of 6.4 Ohms, maximum power of 99 W with minimum total resistor of 6.4 Ohms -7%, minimum power of 82 W with maximum total resistor of 6.4 Ohms +7%, located on M1*
- *1 line of 59 W nominal power with a total (heater + harness from telescope connector to heater) resistor nominal value of 10.4 Ohms, maximum power of 68 W with minimum total resistor of 10.4 Ohms -7%, minimum power of 55 W with maximum total resistor of 10.4 Ohms +7%, located on M1*
- *2 lines of 18.5 W nominal power with a total (heater + harness from telescope connector to heater) resistor nominal value of 36 Ohms, maximum power of 22 W with minimum total resistor of 36 Ohms -7%, minimum power of 17 W with maximum total resistor of 36 Ohms +7%, located on M2.*

For all the lines, maximum resistor variation shall be less than +/- 7% w.r.t. nominal.

In case of failure of one nominal line, the other lines should be able to maintain the temperature as defined in TEPE-040. The lines on M1 and M2 will be independently controlled using the median temperature of 3 selected thermistors and by an ON/OFF switching of all lines with high/low thresholds.

A maximum of 12 thermistor lines (9 on M1 and 3 on M2) are foreseen for the telescope temperature during decontamination and during orbital life.

TEFU-075 *The telescope shall provide:*

- *fixation points for the Herschel S/C heater and thermal sensor harnesses and*
- *connectors for interfacing with the Herschel S/C thermal control system*
- *dedicated points for the thermal blanket grounding (i.e. M5 threaded holes for instance).*

Type and location of fixation points and connectors are defined in RD-6. Connectors shall be redundant for the power lines and the thermistor lines as indicated in RD-6.

TEFU-080 *For decontamination release, the thermal design of the telescope shall permit to achieve in-orbit temperature as defined in TEPE-040 when a maximum power of 600 W is dissipated in the telescope heaters.*

3.5.4 Interface with Spacecraft Sunshield

The figures 3.5-4-a and b give the interface dimensions with a typical sunshield sunshade and with the PLM.

Note: *The sunshield protects the telescope against direct sun illumination. In agreement with document AD-10 the sun is kept at 90º - 30º / + 30º from the X-axis and from the 90º ± 5º from the Y-axis.*
Figure 3.5-4-a gives dimensions of the sunshield/sunshade for the telescope.

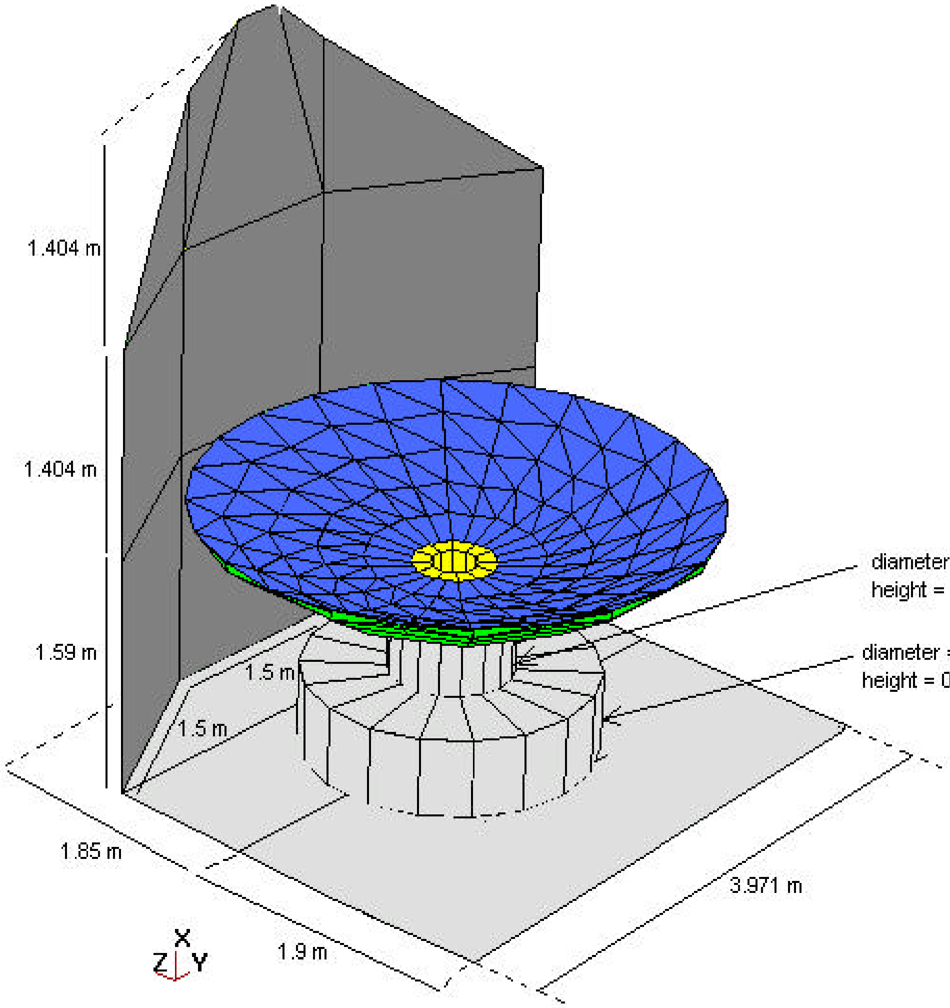


Figure 3.5-4-a: Thermal Interface Telescope/Sunshield/Sunshade/PLM

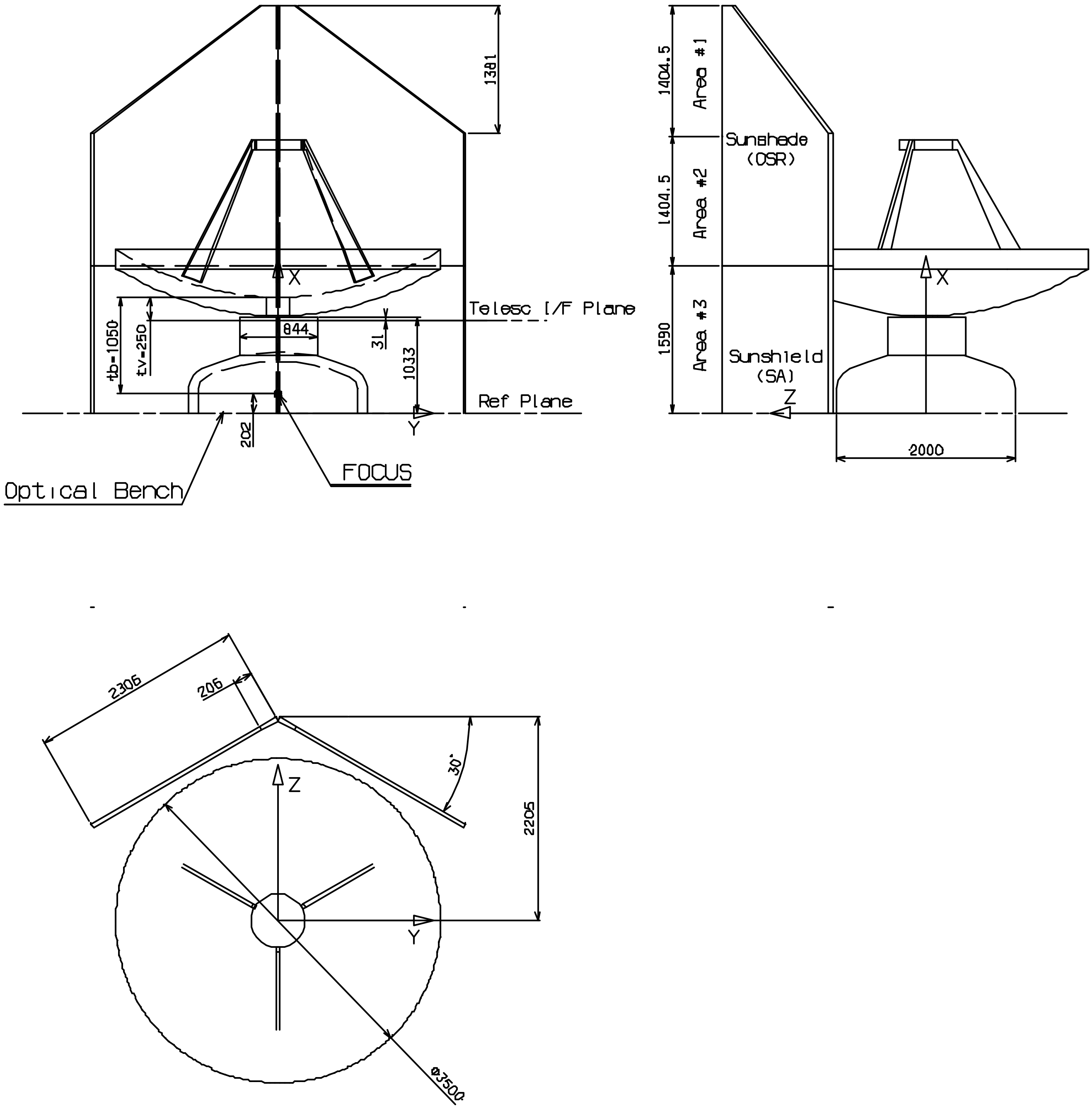


Figure 3.5-4-b: Mechanical Interface Telescope/PLM
(dimensions of sunshield/sunshade not correct – see fig 3-5-4-a)

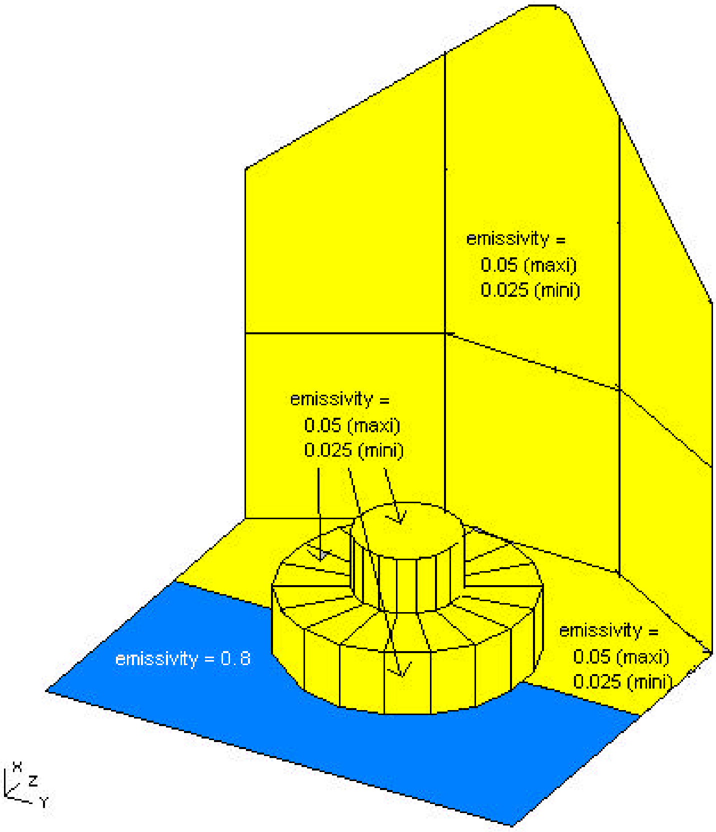


Figure 3.5-4-c: Thermal Interfaces (emissivities)

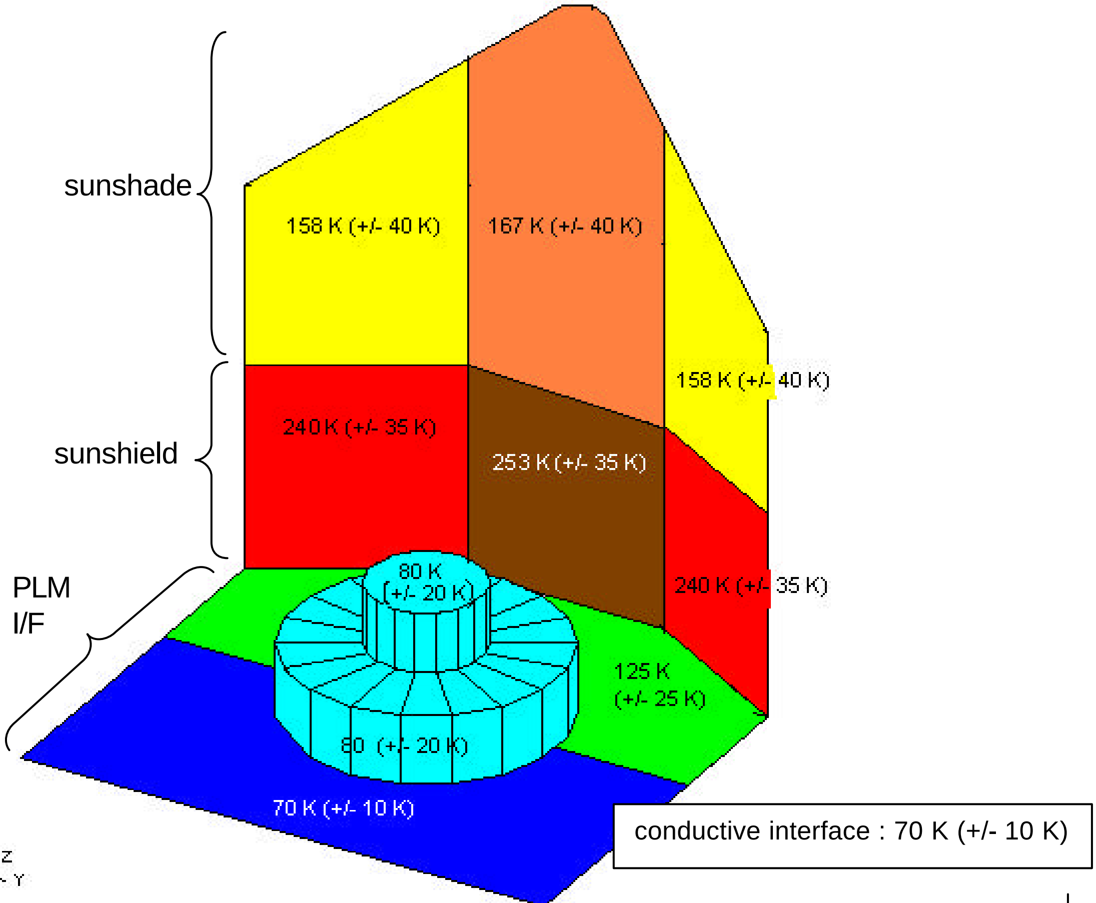


Figure 3.5-4.d: Thermal Interfaces (temperatures)

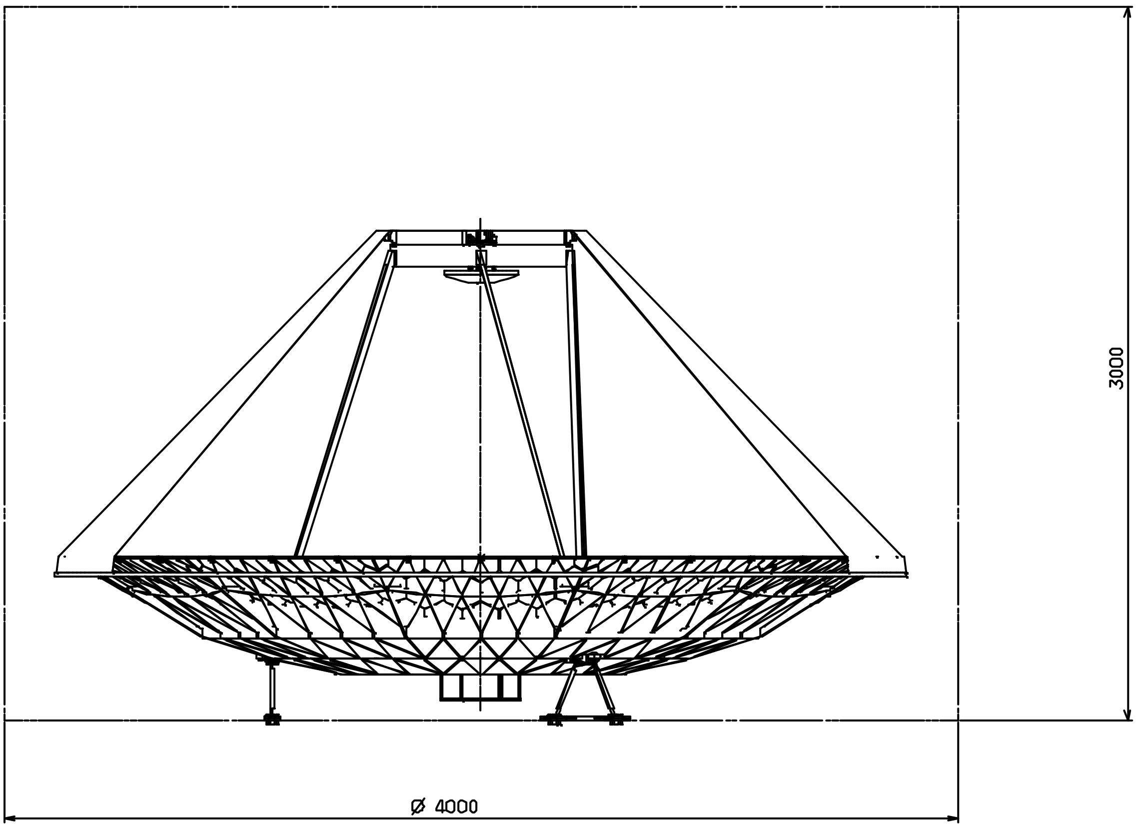


Figure 3.5-5: telescope hoisting device envelope (*delimited by a cylinder Ø4000, height 3000)*

3.5.5 GSE Interfaces

TEFU-085 *The max. height for hoisting device shall not exceed 3 meter (from bottom telescope I/F to crane hook) with a volume not exceeding that given in fig 3.5-5.*

TEFU-090 *The telescope and especially the Primary Mirror shall be equipped with handling interface points for hoisting in all AIT sequences from manufacturing until integration on Herschel S/C (assumed to be in vertical position).*

TEFU-095 *The telescope shall be equipped with a protective cover having the function to protect the telescope from particulate contamination in all AIT activities (incl vibration and acoustic tests with the exception of the thermal vacuum tests) until launcher fairing installation. The height necessary to remove the cover shall not exceed 4.1 meter (from telescope I/F to crane hook).*

4 MISSION AND PERFORMANCE REQUIREMENTS of the TELESCOPE

4.1 General Specifications for the Telescope

4.1.1 Telescope

The general configuration of the telescope is shown in Figure 4.1-1.
The telescope shall comply with the following specifications:

TEPE-005 *The average telescope temperature shall be within a temperature range of 70 K or lower (*) up to 90 K.*
This is called the ***Performance Temperature Range****.*
(*) the telescope design shall withstand with margins a temperature above 55K (ref TEEN.075)

TEPE-010 *The telescope shall be designed to meet its performance within the Performance Temperature Range.*

TEPE-015 *The optical free diameter of the Primary Reflector shall be 3,500 mm +2mm, - 0 mm.*

TEPE-020 *The f-number of the Primary Reflector shall be 0.5*

TEPE-025 *The area obscuration ratio including:*
- secondary reflector structure (tripod; hexapod or else) with secondary reflector and its shadowing
- “cone in secondary”
shall be: £ 0.077 (with respect to the paraxial entrance pupil).

TEPE-030 *The nominal distance of the primary reflector vertex-best on axis focus shall be*
- *by construction value* t_b *= 1,050 mm*
- *this value shall be measured with the accuracy defined in TEPE-0150.*

TEPE-035 *The nominal distance of the best focus to the telescope fixation plane (including telescope shims and excluding PLM possible shims) shall be:* t_f*:=800mm with the accuracy defined in TEPE-0150 (see Figure 4.1-1).*

4.1.2 Heaters

The telescope shall be designed to allow the decontamination/ contamination prevention of the optical surfaces in the early orbital phase by means of heaters.

TEPE-040 *The heaters shall allow an increase of the orbital average temperature of the telescope to a contamination release temperature, of at least 313 K and shall be able to maintain this temperature for a minimum duration of 3 weeks in a row.*

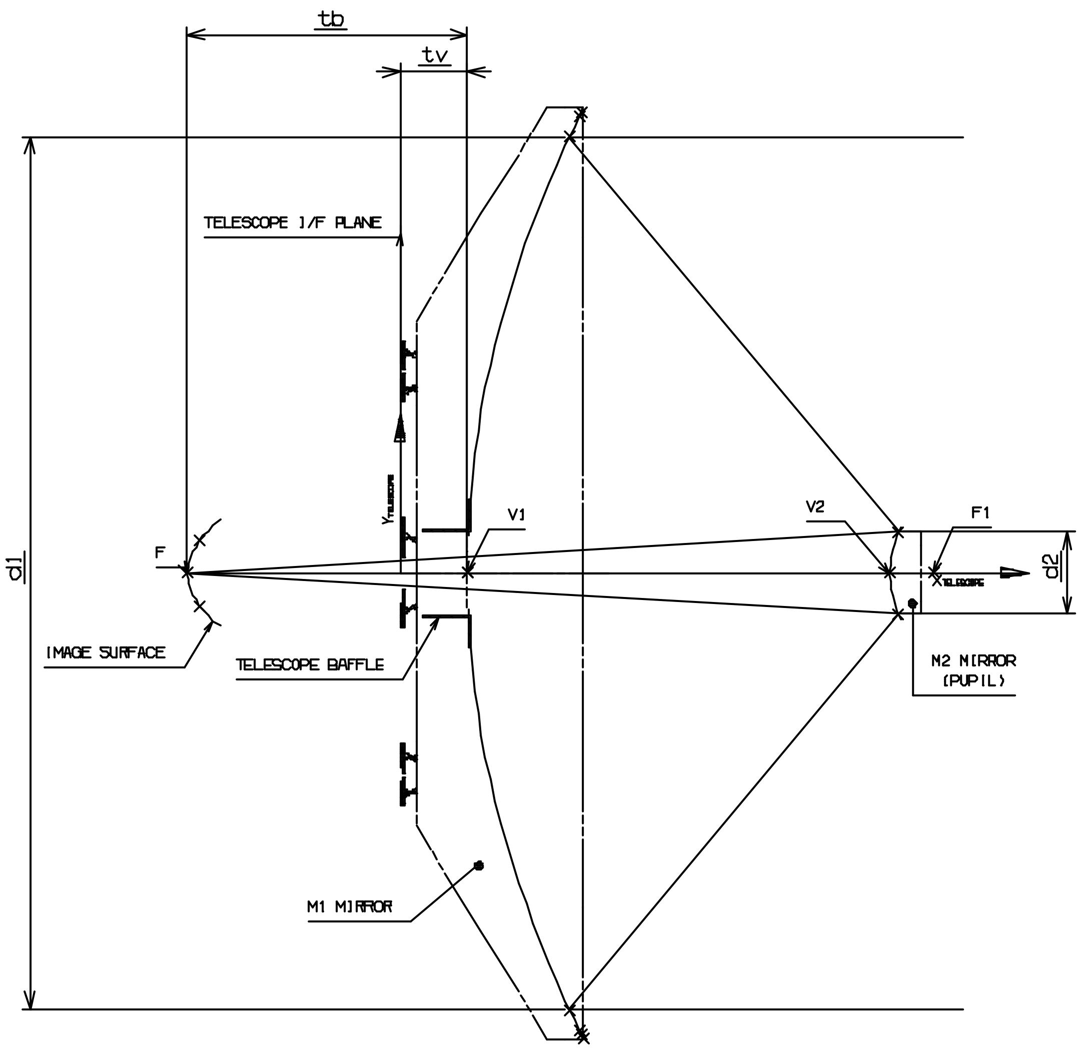


Figure 4.1-1 **TELESCOPE CONFIGURATION**

4.2 Optical Requirements

4.2.1 Telescope Performances

The telescope shall comply with the following optical performance requirements until the end of its life when in temperature performance range:

TEPE-045	*Operating wavelength range*	*80 mm to 670 mm.*
TEPE-050	*Telescope total WFE Budget at nominal focus*	*£ 6.0 mm rms*

These performances shall be met within the performance temperature range for the complete FOV.

TEPE 055 *Encircled Energy*

The encircled energy shall be better than the values given in table 4.2.1-1 , respectively at 85 µm and 150 µm.

Performance at 85 µm		
Encircled energy	50%	0,52 mm
	60%	0,72 mm
	70%	1,24 mm
	80%	2,17 mm
Spot radius (mm)	4	85,8% of energy
	7	90,4% of energy
	11	93,2% of energy
	15	95,2% of energy
Performance at 150 µm		
Encircled energy	50%	0,80 mm
	60%	0,97 mm
	70%	1,75 mm
	80%	2,44 mm
Spot radius (mm)	7	89,0% of energy
	12	92,3% of energy
	19	94,3% of energy
	26	95,7% of energy

Table 4.2.1-1 encircled energy performance (tbc)
Nota: modelization accuracy on encircled energy is estimated to be ±0,3%

TEPE-060 *The aperture stop location shall be implemented at the secondary reflector.*

TEPE-065 *The system focal length shall be 28.5 m ± 0,15 m and the f-number of the telescope shall be f/D = 8.68 (precision ± 0.02) where D is the diameter of the effective aperture (i.e. entrance pupil).*
The focal length at operational temperature shall be known at telescope delivery with an accuracy better than ± 0,09 m. This accuracy includes the characterisation of the focal length under ambient conditions at ± 0,065 m and the in-flight uncertainties.

TEPE-070 *The Field-of-view (FOV) shall be ± 0.25º, free of vignetting.*

TEPE-075 *The optical characteristics of the Primary and Secondary reflectors with their tolerances are given in the table below:*

Primary reflector		
Radius of curvature	*3500 mm*	*± 2 mm (*)*
Conic constant	*-1*	
f-number	*f/0.5*	
(Free) diameter	*3500 mm*	*0, +2 mm (*)*
Secondary reflector		
Radius of curvature	*345.2 mm*	*± 0.4 mm (*)*
Conic constant	*-1.279*	
Optical Diameter (**)	*308.1 mm*	*± 0.5 mm*
Image surface		
Radius of curvature	*- 165 mm*	
Conic constant	*-1*	
Diameter	*246 mm*	

(*) Tolerances given as indications: Compensation between some parameters is assumed allowed if requested, provided that the telescope optical parameters are preserved (f-number, focal length, focus position). The as-built values of the FM telescope combination at 70K are defined in the telescope OICD (RD-07).
(**) The mechanical diameter shall be in accordance with occultation requirements and the self-emission requirements TEPE-110.

TEPE-080 *The telescope shall maintain the specified performance over its lifetime without the need for a refocusing mechanism.*

TEPE-085 *The telescope design shall be such as to avoid narcissus effect.*

TEPE-090 *Relative spectral transmission* [a] *^{3}0.975 BOL* [b]
^{3} 0.98 BOL (goal) [b]
The in-orbit degradation shall be less than 0.005.
This shall be demonstrated

- *at any wavelength l within the operating range measured on witness samples over a sampling interval of Dl/l = 1/100*
- *and by analysis over the entire FOV.*

TEPE-095 *Non-uniformity of relative spectral transmission* ^{d} *£ ± 0.01.*

Notes and definitions for TEPE-090 and 095:

a. *The relative spectral transmission t(l) of the telescope is defined by*

$$t\,(l) = f\,(l)\,/\,f_{0}\,(l)$$

with

$f\,(l)$ *integrated flux [W] leaving the telescope in image space*

$f_{0}\,(l)$ *integrated flux [W] entering the telescope through its entrance pupil within the unobstructed areas.*

b. *At acceptance and delivery of the telescope.*

c. *The design life is specified in paragraph 5.1*

d. *The non-uniformity of the relative spectral transmission is defined as the maximum deviation between the relative spectral transmission values for any 100 mm diameter area within the entrance pupil (EP) and the average relative spectral transmission determined for the full EP area of the telescope, excluding the gaps between the segments.*

4.2.2 Straylight

The Straylight requirement for the telescope including the sunshield, is defined w.r.t. the straylight level obtained at a specified detector element location. The definition of the optical components and properties between the Primary reflector and the detector element, as far as relevant for the straylight verification will be provided by ESA.

The following straylight requirements apply over the full operational wavelength range:

- Scattered light

TEPE-100 *Sources outside telescope FOV:*
Taking into account the worst combination of the Moon and the Earth positions w.r.t. the LOS of the telescope with maximal:
- *Sun - S/C - Earth angle of 37º*
- *Sun - S/C - Moon angle of 47º*
- *Sun - S/C - LOS angle of 60º to 120º,*

the straylight shall be: < 1.0% of background radiation induced by self-emission of the telescope.

TEPE-105 *Sources inside FOV:*
over the entire FOV at angular distances ³ 3' from the peak of the point-spread-function (PSF), the straylight shall be:

< 1 x 10^{-4} of PSF peak irradiance (in addition to level given by diffraction).

- Self-emission

TEPE-110 *The straylight level, received at the defined detector element location of the PLM/Focal Plane Unit Straylight model by self emission (with "cold" stops in front of PACS and SPIRE instrument detectors), not including the self emission of the telescope reflectors alone, shall be £ 10 % (tbc) of the background induced by self-emission of the telescope reflectors.*

4.2.3 Coating

The optical coating of the telescope reflectors shall be designed for the operating wavelength defined in 4.2.1.

TEPE-115 *The coating shall comply with the durability requirements defined in AD-7.*

TEPE-120 *The durability requirements of the optical coating shall be verified with representative samples from the same coating batch/material as the reflectors.*

TEPE-125 *The optical coating shall be grounded via the telescope grounding system.*

4.3 Physical Requirements

4.3.1 Dimensions of the Telescope

TEPE-130 *The telescope and its interfaces shall not exceed the size of the dynamic envelope defined in Figure 4.3-1.*

4.3.2 Mass properties

TEPE-135 *The total mass of the Telescope (including the thermal H/W and the alignment cubes) shall not exceed 315 kg.*

TEPE-140 *The knowledge accuracy of the position of the centre of gravity (CoG) shall be better than ±3 mm: it shall be verified by test (Y and Z axes) and by analysis (X axis). The knowledge accuracy of the moments of inertia wrt CoG shall be better than ± 5% (analysis).*

4.3.3 Alignment

TEPE-145 *The telescope shall be equipped with optical alignment references (cube and pinball) for the purpose of PLM-telescope alignment. These alignment references shall represent an orthogonal telescope reference frame.*

TEPE-150 *The actual on-axis point of the best focus shall be positioned and located within a cylindrical tolerance volume perpendicular and centred on the X-axis of the telescope. The volume of the cylinder shall be ± 5 mm (with a goal of 3 mm) in cylinder-axis (X-direction) and ± 5 mm (with a goal of 3 mm) in diameter.*

TEPE-155 *The centre of the telescope field of view in the focal plane shall be known with respect to this reference frame with an accuracy of ± 3.5 mm in lateral direction and ± 3 mm (defocus) in axial direction (with a goal of ± 2 mm).*

TEPE-160 *The secondary reflector shall be positioned with a lateral accuracy of ± 3 mm (with a goal of 2 mm) with respect to this reference frame and its position shall be known with an accuracy of ± 1mm (with a goal of 0.5 mm).*

TEPE-165 *The alignment references shall be visible also after completion of integration of the telescope with the PLM.*

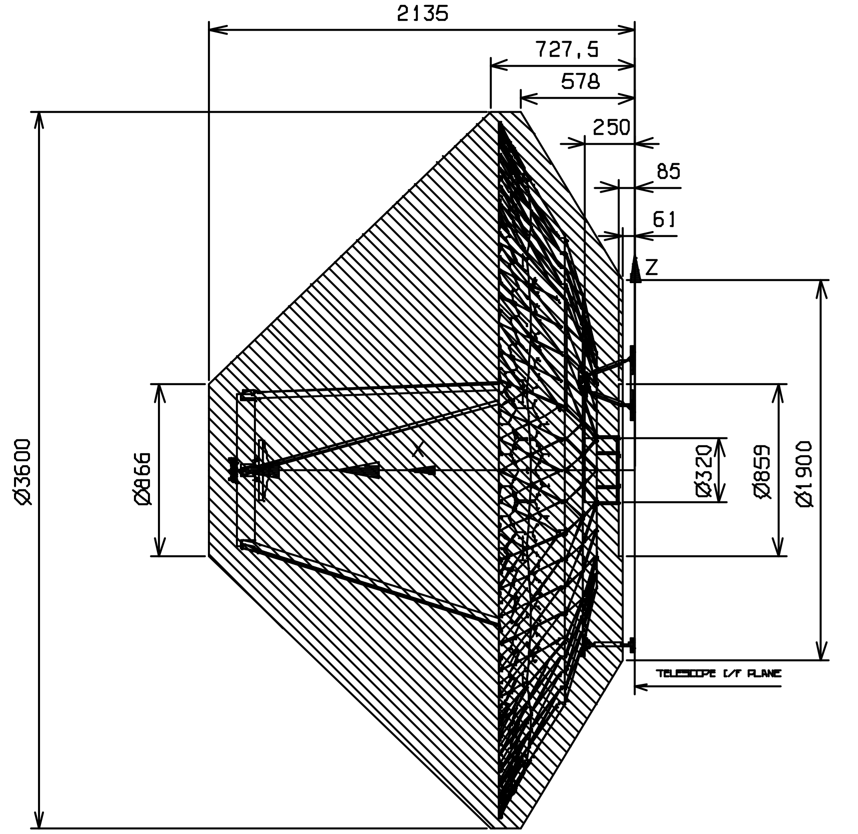


Fig. 4.3-1 TELESCOPE DYNAMIC ENVELOPE (with cover)
Dimension of 85 mm to be corrected to 120 mm

5 ENVIRONMENTAL, LIFETIME, DESIGN and CONSTRUCTION REQUIREMENTS

5.1 Lifetime, Storage and Transport

5.1.1 Lifetime

TEEN-005 *The design life of the Herschel telescope shall be at least 4 years of on-ground operations (testing, transport and launch preparation including the storage conditions) followed by 4.5 years of in-orbit operations with no performance degradation to a level inferior to that given in this specification*.

5.1.2 Storage Environment

TEEN-010 *The storage conditions and storage environment (container, clean room ...) shall not degrade the performances of the telescope as defined in section 5.2.*

5.1.3 Transportability and Handling

TEEN-015 *The telescope shall be able to be transported fully assembled in any angular position between vertical and horizontal in an adequate transportation container, using the interface defined in section 3.5.1. The design of the telescope shall allow its handling in and out of the transport container and its handling during the tests and when integrated to the spacecraft.*

TEEN-020 *The container shall be compatible with class 1000 operations and equipped with shock recording. The containers shall be compatible with clean dry nitrogen or air purging.*

TEEN-025 *The design of the container for the telescope shall be compatible with all ground operations for a transport to and within Europe and in French Guyana and for a shipment from Europe to French Guyana, by boat and by road.*

TEEN-030 *The container shall ensure and shall record that the transportation environment (loads, temperatures, humidity,...) does not exceed the design specifications of the telescope given in the chapter 5 of this specification.*

5.2 Pressure - Humidity

5.2.1 Pressure

TEEN-035 *The Telescope shall withstand any external air pressure between ambient (0.115 MPa) to vacuum.*

TEEN-040 *The Telescope shall provide adequate means of venting and shall be able to cope with the depressurisation profile as defined in the ARIANE 5 Users Manual AD-8.*

5.2.2 Humidity

TEEN-045 *The Telescope shall be designed to withstand without degradation of its performance during storage a relative humidity (RH) of 0% RH to 95% RH, non-condensing.*

5.3 Radiation

TEEN-050 *All materials of the telescope shall be able to withstand the radiation environment (type, total dose and dose rate) as defined in the applicable document AD-1 with a safety factor of 2.*

5.4 Cleanliness/Cleanability

TEEN-055 *All non optical parts of the telescope shall be designed and manufactured such that they can be cleaned in order to remove accidental contamination deposited during on-ground operations.*

TEEN-060 *The cleanliness to be maintained during the on-ground operations and the in-orbit lifetime of the telescope shall be such that the telescope transmission does not degrade beyond the limits specified in Section 4.2.1. The exposure of the optical surfaces to the ambient has to be minimised. The telescope optical surfaces shall be covered and protected as much as possible during on-ground operations to prevent contamination.*

TEEN-065 *The optical surfaces of the telescope with their reflective surfaces shall be designed to withstand possible and exceptional (physical) cleaning operations without degradation of the performance of the telescope beyond specified values.*

TEEN-070 *The maximum molecular contamination for the telescope shall not exceed* $2.10^{-7} g/cm^2$ *at delivery including the ground storage. Obscuration ratio due to particulate contamination shall be smaller than 300 ppm at delivery to spacecraft contractor.*

5.5 Thermal environment

5.5.1 Temperatures of the Telescope

TEEN-075 *The telescope shall be designed to withstand with margins a temperature range from 55K to 358K in vacuum without performance degradation within the Temperature Performance range defined in TEPE-005.*

TEEN-080 *Furthermore, the telescope shall be able to withstand the temperatures defined in the table here below.*
The performance of the telescope specified in 4.2.1 shall not be degraded when it is tested in the temperature range here below.

Range Type	***Min Temperature***	***Max Temperature (bake-out & contamination release)***
Acceptance Temperatures of the Telescope	*65 K**	*318 K*
Qualification Temperatures of the Telescope	*60 K**	*323 K*

**Note:* *Depending on the temperature performance range defined in TEPE-005, the minimum temperature could be lowered. Gluing qualification temperature shall be performed down to 55K.*
It is not required that the above ranges are verified by test at telescope level but they shall, however, be verified on sample basis for a better evaluation of the performance of the telescope during its life in orbit.

5.5.2 Thermal Shock/Thermal Cycling - Bake-Out

<u>Thermal Shock</u>

TEEN-085 *The telescope with its optical coating shall be able to withstand a cooldown induced by a radiative temperature change of the thermal vacuum facility from room temperature to 90K under vacuum within 5 hours.*

<u>Thermal Cycling</u>

TEEN-090 *The telescope shall withstand without degradation in vacuum three (3) cycles of temperature variations between 70K* and 318K for acceptance or five (5) cycles of temperature variations between 70 K* and 323K for qualification. Each cycle shall include a soak time*

long enough to achieve thermal equilibrium of the telescope (the equilibrium condition is reached when any temperature rate-of-change is lower than 1°C/hour).
(*)(TBC, depending on LHe facility)

5.6 Design and Construction Requirements

5.6.1 Mechanical Stiffness Requirements

The telescope shall be designed to satisfy the following structural stiffness requirements:

TEEN-095 - Longitudinal eigenfrequency > 60 Hz

TEEN-100 - Lateral eigenfrequency > 43.5 Hz

TEEN-105 - Local modes (i.e. with an effective mass or effective inertia w.r.t. the same reference frame less than 10% of the total mass or of the total corresponding inertia) shall be > 6 Hz in lateral direction and > 31 Hz in longitudinal direction.

- Torsion modes shall be > 45 Hz.

5.6.2 Design Limit loads

TEEN-110 The design limit loads shall be applied for the structural design considering in addition the safety factors defined in paragraph 5.6.3:

For Primary Reflector and its support

Case	Longitudinal	Lateral
1	12 g	4,6 g
2	3,2 g	10 g

For Secondary Reflector and its support (hexapod or else)

Case	Longitudinal	Lateral
1	12 g	35 g

Longitudinal loads can have any sign.
Lateral loads can have any direction.

NB: Design loads for the Secondary Reflector are valid up to the interface between the secondary reflector support and the Primary Reflector. The attachments are to be sized against these loads.

Secondary reflector design loads are additive to Primary reflector design loads.

5.6.3 Mechanical Strength Requirements

5.6.3.1 Safety Factors

TEEN-115 *The telescope shall withstand the worst combinations of mechanical and thermal loads without degradation.*

TEEN-120 *Following Safety Factors (SF) are defined for the dimensioning and verification of the equipment to cover uncertainties of load factor evaluation, material data and analysis as well as to avoid undesirable influences of manufacturing tolerances.*

The Safety Factors shall be applied to the design limit loads, yield against permanent deformation, ultimate against rupture and loss of functionality.

Item	***Yield SF***	***Ultimate SF***	***Buckling SF***
Conventional metallic materials and bolted joints	*1.1*	*1.5*	*2.0*
Unconventional materials	*1.4*	*2.0*	*2.0*
Inserts and glued joints	*1.5*	*2.0*	*NA*

Definition of conventional and non-conventional materials:

Conventional materials:
All materials, also composites, for which sufficient statistical data are available to derive A values as defined in MIL-HDBK-5F, Section 1.4.11.

Unconventional materials, including SiC:
Those materials for which sufficient statistical data are not available.

Additional factors (e.g. fitting factors for load introduction points, stress concentration at cutouts or welding/casting factors, etc.) shall be justified by prior experience or test evidence.

5.6.3.2 Margins of Safety

TEEN-125 *All structural elements shall be designed to exhibit a positive margin of safety (MOS) after application of the relevant safety factors (yield and ultimate) for all worst load cases.*

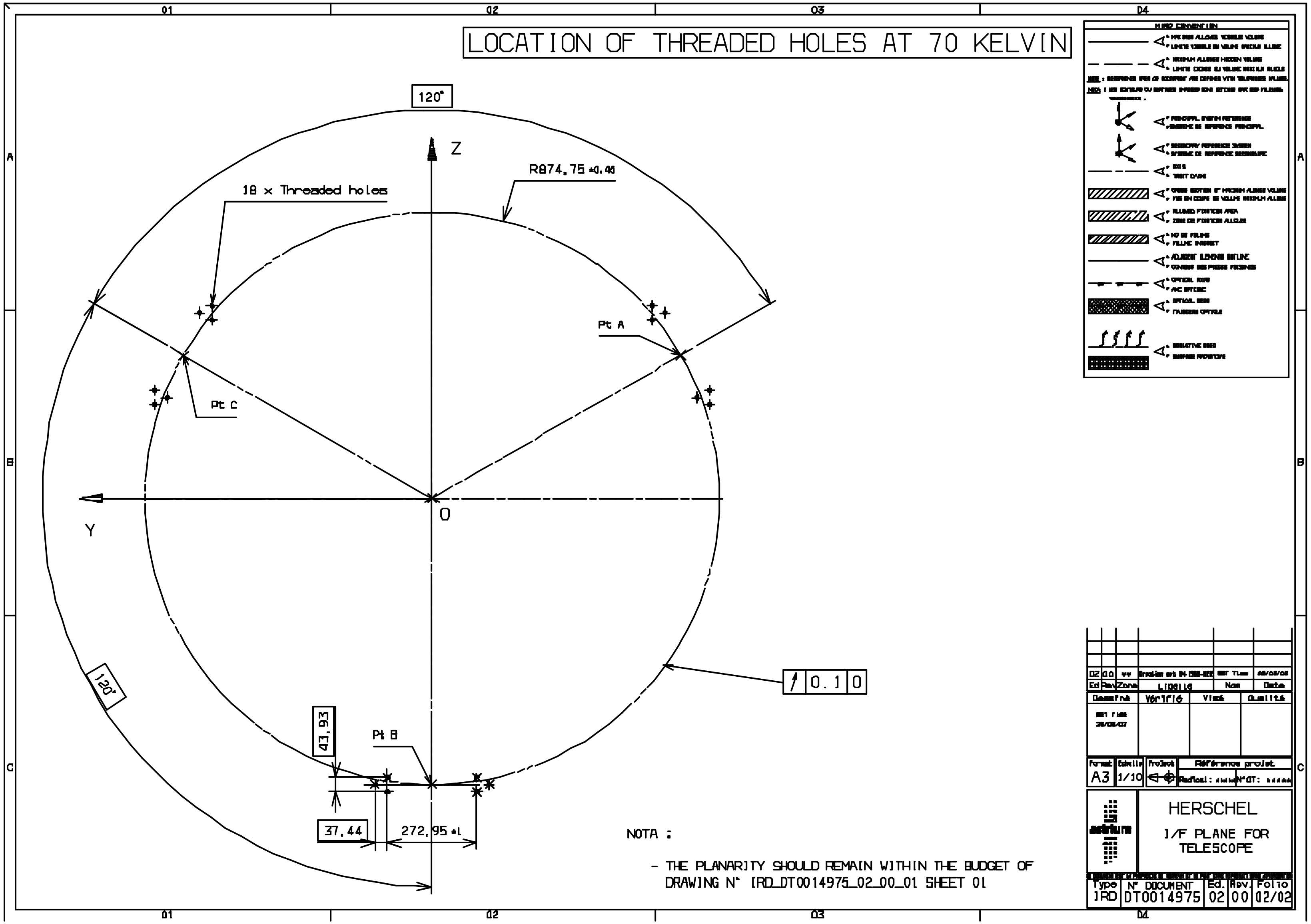
The margin of safety is defined as the ratio of the allowable load (or stress) to the applied load (or stress):

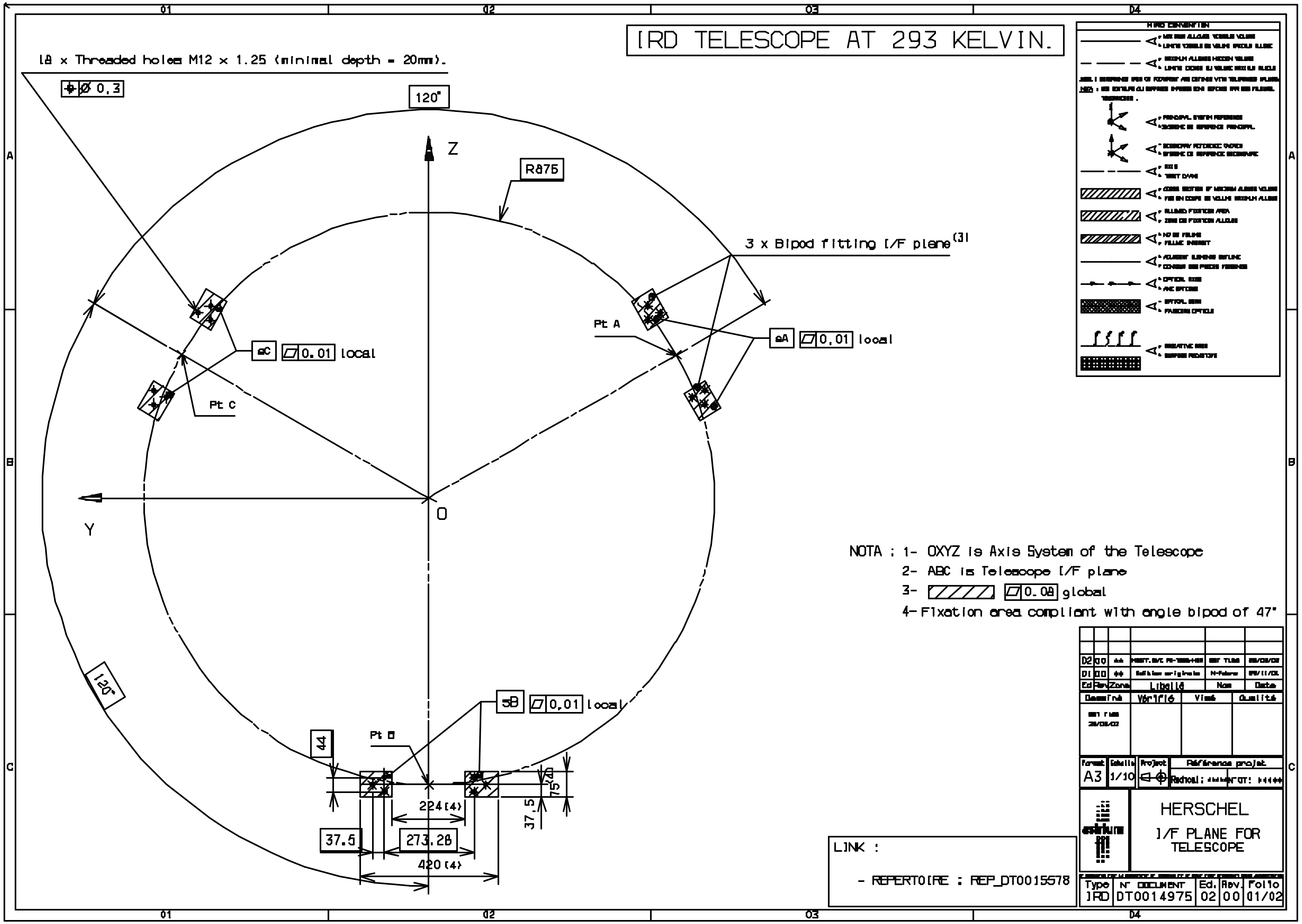
$$MOS = \frac{\text{Allowable load (or stress)}}{\text{Applied load (or stress)}} - 1$$

5.6.4 Mechanical Interface Points characteristics

Environmental effect (AIT, launch, cool-down and in-orbit) on the Herschel payload module will induce strength and torque at the mechanical interface point of the telescope.

TEEN-130 *The overall performance of the telescope defined in the § 4 shall be guaranteed when mounted on the PLM interface frame which mechanical characteristics are given in the following interface requirement drawings (ref DT0014975 ed2 rev 00).*


LOCATION OF THREADED HOLES AT 70 KELVIN
120°
Z
R874,75 ±0,44
18 x Threaded holes
Pt A
Pt C
Y
O
120°
43,93
Pt B
37,44
272,95 ±1
0.10
NOTA :
- THE PLANARITY SHOULD REMAIN WITHIN THE BUDGET OF DRAWING N° IRD_DT0014975_02_00_01 SHEET 01
HERSCHEL
I/F PLANE FOR TELESCOPE
A3
1/10
Type
IRD
N° DOCUMENT
DT0014975
Ed.
02
Rév.
00
Folio
02/02


IRD TELESCOPE AT 293 KELVIN.
18 x Threaded holes M12 x 1.25 (minimal depth = 20mm).
0,3
120°
Z
R875
3 x Bipod fitting I/F plane (3)
Pt A
A
0,01 local
C
0,01 local
Pt C
Y
O
NOTA : 1- OXYZ is Axis System of the Telescope
2- ABC is Telescope I/F plane
3- 0.08 global
4- Fixation area compliant with angle bipod of 47°
120°
B
0,01 local
Pt B
44
224 (4)
273.28
37.5
420 (4)
37.5
75
LINK :
- REPERTOIRE : REP_DT0015578
Dessiné
Vérifié
Visé
Qualité
Format A3
Echelle 1/10
Projet
Référence projet
HERSCHEL
I/F PLANE FOR TELESCOPE
Type IRD
N° DOCUMENT DT0014975
Ed. 02
Rev. 00
Folio 01/02

5.6.5 Sinusoidal Vibrations of the Telescope

During flight, the Herschel telescope is subjected to static and dynamic loads, which result from the Ariane 5 steady state acceleration and low frequency vibration.

5.6.5.1 Sinusoidal Test Levels

TEEN-135 The qualification sine vibration test spectrum to be applied at the base of the telescope is the following:

Vibration Type	*Axis*	*Frequency*	*Vibration Level*
Qualification sinusoidal vibration spectrum (sweep rate 2 Oct/min)	*Y, Z (lateral)*	*5 Hz -16 Hz 16 Hz - 20 Hz 20 Hz - 100 Hz*	*10 mm peak 10 g 2.5 g*
	X (longitudinal: axis of symmetry)	*5 Hz - 20 Hz 20 Hz - 30 Hz 30 Hz - 100 Hz*	*10 mm peak 12 g 2.5 g*

The acceptance test levels are to be derived by dividing the qualification levels by a factor 1.5. Acceptance sweep rate is 4 Oct/min.

Note: A notching procedure can be agreed based on the dynamical analysis results and after a low level run.

TEEN-140 Low-level sine test shall be performed to determine resonance frequencies to evaluate the behaviour of the test fixture and item integrity. Resonance search shall be carried out before and after vibration test for each axis between 5 and 2000 Hz.

TEEN-145 During the sine vibration qualification tests, the loads on the primary and secondary reflector CoGs, and on the secondary reflector support (tripod or hexapod) shall not exceed the Design Limit Loads as defined in paragraph 5.6.2. The torsional mode on the secondary mirror will be measured with adapted instrumentation.

5.6.6 Acoustic Vibrations of the Telescope

During flight, the Herschel telescope is subjected to acoustic vibrations defined in the ARIANE 5 launcher User's Manual, AD-8.

TEEN-150 The spectra for the acoustic vibration tests are defined as follows:

Octave Band Centre Frequency (Hz)	*Qualification Level*	*Acceptance Level*	*Test Tolerance*
	(O dB: ref. 2x10-^{5} Pascal)		
31.5	*132*	*128*	*-2, +4*
63	*134*	*130*	*-1, +3*
125	*139*	*135*	*-1, +3*
250	*143*	*139*	*-1, +3*
500	*138*	*134*	*-1, +3*
1000	*132*	*128*	*-1, +3*
2000	*128*	*124*	*-1, +3*
Overall Level	*146*	*142*	*-1, +3*
Duration	*2 min*	*1 min*	

Note: The tolerances indicated in the above table allow for standard test-equipment inaccuracy.

5.7 Interchangeability

TEEN-155 *Each element of the telescope shall be directly inter-changeable in form, fit and function with other element of the same part number (configuration item number). The performance characteristics and dimensions of like units shall be sufficiently uniform to permit interchange with a minimum of adjustment and re-calibration*.

5.8 Maintenance

TEEN-160 *The telescope design shall be such as to require a minimum of special tools, test equipment etc. to perform calibration, adjustment, fault identification and unit repair. Periodic maintenance requirements during storage and ground life shall be minimised and declared.*

5.9 Reliability

TEEN-165 *Electrical and electro-mechanical parts shall be selected in accordance with AD-5 and AD-9 and to optimise the reliability for the mission.*

TEEN-170 *Failure of one element shall not prevent the other from performing its intended function, nor the overall equipment from meeting its performance requirements*.

5.10 Parts, Material and Processes

5.10.1 General

TEEN-175 *The mechanical parts, material and processes shall comply with the requirements and environments as specified herein and with AD-3.*

5.10.2 Dissimilar Metals

TEEN-180 *To avoid electrolytic corrosion, dissimilar metals shall not be used in direct contact and shall comply with AD-3. Exception can be made for Aluminium, Invar and Titanium if requested.*

5.10.3 Magnetic Materials

TEEN-185 *Magnetic materials shall be used only if necessary for equipment operation. Materials used shall minimise the permanent, induced and transient magnetic fields, with attention paid to minimising surface currents. Exception can be made for low CTE materials (such as Invar) if requested*

5.10.4 Fungus Nutrient Materials

TEEN-190 *Materials that are nutrients for fungus shall not be used.*

5.10.5 Unstable Materials

TEEN-195 *Unstable materials shall not be used.*

5.10.6 Mechanical Parts

TEEN-200 *The selection of mechanical parts shall be justified by analysis, evaluation tests and their qualification for the required application shall be demonstrated*.

5.10.7 Finish

TEEN-205 *The surfaces of each major item of telescope shall be adequately finished to prevent deterioration from exposure to the on-ground and in-orbit environments that might jeopardise fulfilment of the specified performance.*
(Additional information on finish such as plating requirements, type and thickness of paint, coatings, etc., may be specified as required).

Surface finish shall comply with the requirements document AD-7.

5.10.8 Outgassing

TEEN-210 *Basic acceptable outgassing criteria for the selection of the materials are Total Mass Loss (TML) # 1% and Collected Volatile Condensable Material (CVCM) # 0.1%.*
In case of materials used in the vicinity of optical elements, the more stringent requirement of Recovered Mass Loss (RML) # 0.10% and CVCM # 0.01% shall apply. It should be noted that outgassing characteristics are determined during a vacuum test at 125°C for 24 hours according to AD-4.

5.10.9 Cleanliness/Contamination Control

TEEN-215 *All parts, materials and processes used for the telescope shall be selected such that the telescope transmission specification can be met as given in 4.2*

TEEN-220 *The telescope shall be designed such that contamination sensitive surfaces can be covered by suitable means to minimise or to avoid contamination (see also AD-2)*

TEEN-225 *Optical surfaces shall comply with the requirements as defined in AD-7.*

5.10.10 Susceptibility to Stress Corrosion

TEEN-230 *Metallic materials selected shall have a high resistance to stress corrosion cracking according to AD-6.*

5.10.11 Material brittleness

SiC material is known to be a brittle material due to its very low strain tolerance and the large scatter in its strength data.

TEEN-235 *All SiC telescope elements (especially at the high stress areas) shall be carefully verified first by proper refined stress analysis then by a rigorous inspection using NDI techniques (or any equivalent) during and after manufacturing.*

5.10.12 Grinding and polishing processes

TEEN-240 *Adequate measurement methods shall be used during the grinding and polishing processes of the Primary and Secondary reflectors to monitor and predict regularly their optical performance.*

5.11 EMC Requirements

TEEN-245 *All exposed surfaces that can collect electrical charges shall be made conductive to avoid electro-static charge and particular contamination. The surface conductivity shall be better than 1 MW per square.*

TEEN-250 *All metallic items shall be electrically grounded with a resistance of less than 100W to the interface grounding point.*

5.12 Identification and Marking

TEEN-255 *The identification and marking shall be done in accordance with the configuration item number respectively part designation, model designation, serial number as relevant and defined in the configuration control requirements.*

5.13 Workmanship

TEEN-260 *The Telescope Provider shall define workmanship requirements for the telescope items.*

TEEN-265 *The surface roughness R_q of the optical surfaces of the reflectors of the telescope shall be # 0.6 mm.*

TEEN-270 *Telescope items hardware shall be accompanied with a set of workmanship samples representative for each lot/batch of the manufacturing and integration process.*

The samples shall serve for following purposes:

1. *evaluation of material integrity*
2. *evaluation of surface reflectivity and stability*
3. *evaluation /measurement of optical surfaces*
4. *evaluation of the manufacturing parameters*
5. *life samples*
6. *contamination samples*
7. *destructive samples for material characterisation*
8. *others as required, i.e. reference/traceability samples*

Several samples shall be used as part of the qualification programme (e.g. coating durability).

5.14 Refurbishment

TEEN-275 *The telescope shall survive all environmental testing and ground life without performance degradation and without the need for refurbishment.*

5.15 Facilities

TEEN-280 *All GSE items which will be used for handling and testing the telescope shall be delivered together with the telescope*.

6 VERIFICATION REQUIREMENTS

6.1 Verification Methods, Programmes and Matrices

6.1.1 Verification Programme

TEVE-005 *The Telescope Provider shall establish a verification plan, which shall be reviewed and approved by ESA.*
The plan shall define how the requirements are being verified. The verification can be done by test, analysis or inspection.

The plan shall define the:
- *objective of the tests*
- *type of test to be performed*
- *sequence of tests*
- *hardware to be tested*
- *description/objectives of the qualification test*
- *level of test parameters*
- *special facilities/equipment needed*
- *acceptance/rejection criteria.*

TEVE-010 *During the development of the telescope and its primary reflector, the Telescope Provider shall evaluate and update the WFE budget.*
Annex A presents a typical WFE budget tree for the Herschel telescope.

6.1.2 Verification by tests and samples

TEVE-015 *The test sequence for the verification of the telescope shall be performed in agreement with the table of Annex B which is given for guidance and information.*
Additional tests may be added if considered necessary.

TEVE-020 *The Telescope Provider shall as part of his test/verification plan and procedures clearly define rejection/acceptance criteria in compliance with the objective of the test.*

TEVE-025 *The Telescope Provider shall define conditions when a retest may be acceptable.*

TEVE-030 *All samples used for verification in the development programme of the telescope shall be representative of the manufacturing process and of the environmental lifetime of the final telescope (i.e, thermal cycling, thermal shocks ...).*

6.2 Analysis, Inspection and Test

TEVE-035 *The requirement verification matrix shall be controlled by the Telescope Provider. Furthermore a rationale as to why various parameters are verified by analysis, inspection, similarity with other models or by testing shall be established by the Telescope Provider.*

6.3 Telescope Verification Testing

6.3.1 Mechanical Verification Testing of the Telescope

TEVE-040 *The mechanical verification of the telescope shall be performed in agreement with the specifications listed in section 5.6 and shall be performed before the thermal verification.*

6.3.2 Thermal Verification Testing of the Telescope

TEVE-045 *The verification of the optical performance of the telescope shall be performed by a combination of tests and analysis.*

TEVE-050 *The thermal qualification and acceptance testing of the telescope assembly shall be compatible with a LHe shroud cooled facility.*

TEVE-055 *The optical performance of both the flight and the flight spare model telescopes shall be as a minimum demonstrated for an average telescope temperature between 70 K and 90 K (TBC, depending on LHe facility). For both temperatures, the worst case environment w.r.t. temperature gradients as resulting from the cold, nominal and hot cases defined in paragraphs 3.5.2 and 5.5.1 shall be applied.*

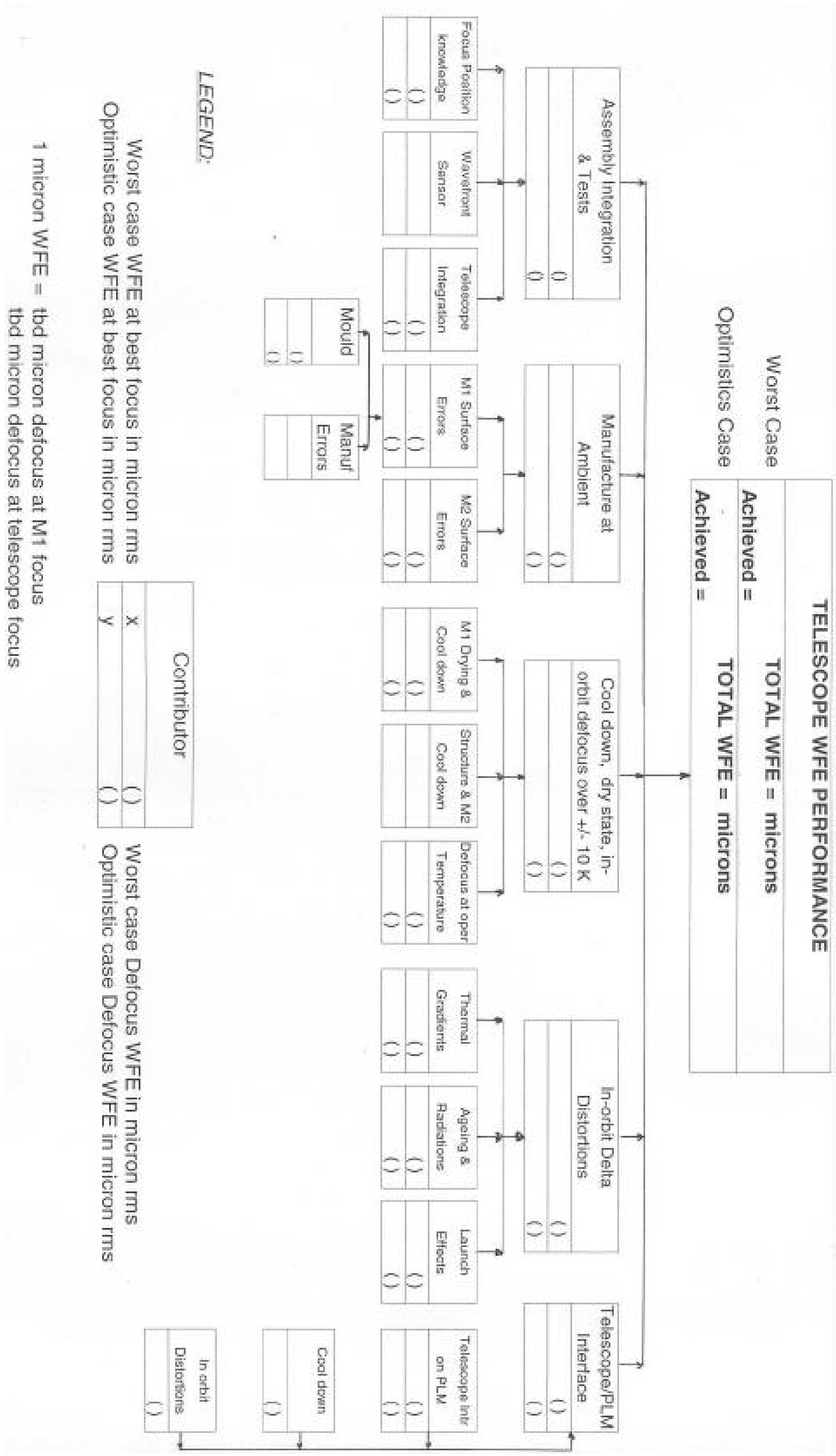
TEVE-060 *The compatibility of the telescope design with the contamination release and dry-out temperatures as defined in para 5.5.1 shall be demonstrated by test for both the flight spare models.*

TEVE-065 *The compatibility of the qualification model of the telescope with the thermal cycling requirements as defined in para 5.5.2 shall be demonstrated by test.*

TEVE-070 *The compatibility of the flight spare model of the telescope with the thermal cycling requirements as defined in para 5.5.2 shall be demonstrated by test.*

TEVE-075 *The compatibility of the flight model of the telescope assembly with the thermal cycling requirements as defined in para 5.5.2 shall be demonstrated by test.*

ANNEX A: WFE TREE BUDGET VERIFICATION



ANNEX B: TEST SEQUENCE

The test sequence for both the qualification model and the flight model of the telescope shall be as a minimum the following:

1. 3-D Contour measurement of the telescope

2. Optical Performance Measurement at Room Temperature

3. X, Y, Z axes Sine Vibrations

4. Optical Performance Measurement at Room Temperature

5. Acoustic Vibrations

6. Optical Performance Measurement at Room Temperature

7. Bake-out and Contamination Release in vacuum performed with heaters of telescope

8. Thermal Shock

9. Optical Performance Measurement at a temperature < 90K (*)

10. Optical Performance Measurement at a temperature close to 70K (*)

11. Thermal Cycling

12. Optical Performance Measurement at a temperature < 90K (*)

13. Optical Performance Measurement at a temperature close to 70K (*)

(*)(TBC, depending on LHe facility)