TOTAL PAGES : 56

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**HERSCHEL / PLANCK**

# Planck telescope specification

## Product Code : 22100

| | Function | Date | Signature |
|---|---|---|---|
| **Rédigé par/*Written by*** | **HERSCHEL / PLANCK TEAM** | | |
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(détentrice de l'original) :

| HERSCHEL/PLANCK | DISTRIBUTION RECORD | | |
|---|---|---|---|
| DOCUMENT NUMBER : H-P-3-ASPI-SP-0004 | Issue 2 Rev. :0<br>Date: 04/02/03² | | |
| **EXTERNAL DISTRIBUTION** | | **INTERNAL DISTRIBUTION** | |
| **ESA** | X | **HP team** | X |
| **ASTRIUM** | | | |
| **ALENIA** | | | |
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## ENREGISTREMENT DES EVOLUTIONS / *CHANGE RECORDS*

| ISSUE/ REV | DATE | § : DESCRIPTION DES EVOLUTIONS *§ : CHANGE RECORD* | REDACTEUR *AUTHOR* |
|---|---|---|---|
| 01/01 | 13/07/01 | P-TEL-PER-045 : and equipped of PR and SR and of representative MCI of baffle and FPA. | |
| 01/01 | 13/07/01 | P-TEL-PHY-015 : CoG is not ± TBD | |
| 01/01 | 13/07/01 | P-TEL-PHY-030 : with the specified mass | |
| 01/01 | 13/07/01 | P-TEL-PHY-055 : Deleted | |
| 01/01 | 13/07/01 | P-TEL-ENV-100 : Value are signed | |
| 01/01 | 13/07/01 | P-TEL- INT-100: Thermal conductance of the grounding electrical interface shall be known. | |
| 01/02 | 19/10/01 | Update of the AD list §3.1p 7 | |
| 01/02 | 19/10/01 | Update of the axis system definition p11 and 12 | |
| 01/02 | 19/10/01 | Update of the spacecraft axis system description figure 4-2 p13 | |
| 01/02 | 19/10/01 | P-TEL-PER-020 : complete the definition of Ztop and Zbot | |
| 01/02 | 19/10/01 | P-TEL-PER-030 : WFE degradation requirements are confirmed. Theritical WFE is defined. Apodisation definition is refined. Update of the table 5.2.1.5 | |
| 01/02 | 19/10/01 | P-TEL-PER-035 : Update of the minimum contributor list | |
| 01/02 | 19/10/01 | P-TEL-PER-045 : Update of the frequenciy requirements | |
| 01/02 | 19/10/01 | P-TEL-INT-065 : Renamed into P-TEL-PER-055 and delete of the edge PR panel requirement | |
| 01/02 | 19/10/01 | P-TEL-PER-050 : Renamed into P-TEL-PER-060 | |
| 01/02 | 19/10/01 | P-TEL-PER-060 : Renamed into P-TEL-PER-065. Conductance unit has been corrected | |
| 01/02 | 19/10/01 | P-TEL-PHY-010 : Update of the mass requirement. Delete of the goal | |
| 01/02 | 19/10/01 | P-TEL-PHY-015 : Update of the CoG requirement. | |
| 01/02 | 19/10/01 | P-TEL-PHY-030 : Update of the inertia requirement. | |
| 01/02 | 19/10/01 | P-TEL-PHY-045 : Nominal focus replaced by Ordp | |
| 01/02 | 19/10/01 | P-TEL-ENV-005 : Update of the QSL | |
| 01/02 | 19/10/01 | P-TEL-ENV-005 : Update of the QSL and of the lumprd mass definition | |
| 01/02 | 19/10/01 | P-TEL-ENV-015 : Update of the sine loads | |
| 01/02 | 19/10/01 | P-TEL-ENV-085 : Update of the shock loads | |
| 01/02 | 19/10/01 | §/ 5.6.1.6 - p 34 : Environment definition are completed by definition of relative displacement to be imposed at the telescope-cryostructure interface points (P-TEL-ENV-101) and loads at the Jfet box interface (P-TEL-ENV-102) | |
| 02 | 19/10/01 | P-TEL-INT-025 : the maximum loads at the PR interface are replaced by maximum displacements | |
| 02 | 19/10/01 | P-TEL-INT-030 : the maximum loads at the SR interface are replaced by maximum displacements | |
| 02 | 19/10/01 | P-TEL-INT-030 : the maximum loads at the SR interface are replaced by maximum displacements | |

| ISSUE | DATE | § : DESCRIPTION DES EVOLUTIONS<br>*§ : CHANGE RECORD* | REDACTEUR<br>*AUTHOR* |
|---|---|---|---|
| 01/02 | 19/10/01 | P-TEL-INT-040 : Update of the number of I/F points definition | |
| 01/02 | 19/10/01 | P-TEL-INT-045 : Update of the number of I/F points definition | |
| 01/02 | 19/10/01 | P-TEL-INT-050 : Update of the number of I/F points definition | |
| 01/02 | 19/10/01 | P-TEL-INT-055 : Update of the number of I/F points definition | |
| 01/02 | 19/10/01 | P-TEL-INT-070 : Update of the number of electrical connection with grounding system | |
| 01/02 | 19/10/01 | P-TEL-INT-075 : Update of the heat probe number | |
| 01/02 | 19/10/01 | P-TEL-INT-080 : Update of the PR panel, main frame and struts absorbtivity requirement | |
| 01/02 | 19/10/01 | P-TEL-INT-085 : definition of the requirement for the absorbtivity knowledge accuracy | |
| 01/02 | 19/10/01 | P-TEL-INT-090 : Update of the PR panel, main frame and struts heat capacity requirement | |
| 01/02 | 19/10/01 | P-TEL-INT-095 : definition of the requirement for the heat capacity knowledge accuracy | |
| 01/02 | 19/10/01 | P-TEL-INT-100 : Definition of the maximal conductance for the grounding interface | |
| 01/02 | 19/10/01 | § 5.8.3 : complete the tructural design requirement forstrength sizing by P-TEL-DES-027 | |
| 01/02 | 19/10/01 | P-TEL-VER-015 : Update the mass compliance approach | |
| 01/03 | 09/12/02 | Update of the applicable document numeration | |
| 01/03 | 09/12/02 | P-TEL-PERF-030 : Definition of the reflector MSSE computation method | |
| 01/03 | 09/12/02 | P-TEL-PERF-030 : table to define apodisation removed. Reference only made to the H-P-3-ASP-TN-166 | |
| 01/03 | 09/12/02 | P-TEL-PERF-045 : update of the instrument mass and cog data | |
| 01/03 | 09/12/02 | P-TEL-PERF-045 : update telescope Boundary conditions | |
| 01/03 | 09/12/02 | P-TEL-PERF-070 : update of the specification reference | |
| 01/03 | 09/12/02 | P-TEL-PERF-075 : update of the specification reference | |
| 01/03 | 09/12/02 | P-TEL-PERF-080 : update of the specification reference | |
| 01/03 | 09/12/02 | P-TEL-PHY-045 : Definition of the nominal focus | |
| 01/03 | 09/12/02 | P-TEL-PHY-045 : Definition of the nominal focus | |
| 01/03 | 09/12/02 | P-TEL-ENV-020 : Update of allowed notching | |
| 01/03 | 09/12/02 | P-TEL-ENV-022 : Definition of the damping factor | |
| 01/03 | 09/12/02 | P-TEL-ENV-90 : Update of the baffle thermoelastic interface loads | |
| 01/03 | 09/12/02 | P-TEL-ENV-95 : Update of the cryostructure thermoelastic interface loads | |
| 01/03 | 09/12/02 | P-TEL-ENV-100 : Update of the FPA thermoelastic interface loads | |

| ISSUE | DATE | § : DESCRIPTION DES EVOLUTIONS<br>*§ : CHANGE RECORD* | REDACTEUR<br>*AUTHOR* |
|---|---|---|---|
| 01/03 | 09/12/02 | P-TEL-ENV-101 : Update of the differential maximum displacement between the 6 telescope interface point along X axis | |
| 01/03 | 09/12/02 | P-TEL-ENV-102 : Update of the JFET thermoelastic interface loads | |
| 01/03 | 09/12/02 | P-TEL-ENV-103 : Update of the reflector thermoelastic interface loads | |
| 01/03 | 09/12/02 | P-TEL-ENV-104 : definition of mechanical environment to compute loads at instruments interfaces (wave guide lower structure) | |
| 01/03 | 09/12/02 | P-TEL-ENV-105 : definition of mechanical environment to compute loads at instruments interfaces (wave guide upper structure) | |
| 01/03 | 09/12/02 | P-TEL-ENV-106 : definition of mechanical environment to compute loads at instruments interfaces (bellow) | |
| 01/03 | 09/12/02 | P-TEL-ENV-109 : update of the P-TEL-ENV-105 requirement reference | |
| 01/03 | 09/12/02 | P-TEL-INT-033 : Definition PR and SR interface stability requirement | |
| 01/03 | 09/12/02 | P-TEL-INT-037 : Definition FPA interface stability requirement | |
| 01/03 | 09/12/02 | P-TEL-INT-077 : Definition surfacic electrical resistivity specification | |
| 01/03 | 09/12/02 | P-TEL-INT-105 : Tipo error correction | |
| 01/03 | 09/12/02 | P-TEL-INT-110 : Definition of MGSE forbidden volume | |
| 01/03 | 17/01/03 | P 14 Update of the Ordp definition | |
| 01/03 | 17/01/03 | P-TEL-PER-030 : Tipo error correction | |
| 01/03 | 17/01/03 | P-TEL-PER-045 : Update of the frequency requirements | |
| 01/03 | 17/01/03 | P-TEL-PER-065 : Tipo error corrected | |
| 01/03 | 17/01/03 | P-TEL-PHY-005 : Tipo error corrected | |
| 01/03 | 17/01/03 | P-TEL-ENV-005 : Update of qualification loads and boundary conditions | |
| 01/03 | 17/01/03 | P-TEL-ENV-010 : Update of limit loads loads conditions | |
| 01/03 | 17/01/03 | P-TEL-ENV-015 : Sine qualification level are updated. Note 2 removed | |
| 01/03 | 17/01/03 | P-TEL-ENV-020 : Notching philosophy is added | |
| 01/03 | 17/01/03 | P-TEL-ENV-107 : Tipo error corrected | |
| 01/03 | 17/01/03 | P-TEL-INT-005 - 020 : Tipo error corrected | |
| 01/03 | 17/01/03 | P-TEL-INT-015 : Numbering of the IF points updated | |
| 01/03 | 17/01/03 | P-TEL-INT-080 : Absortivity requirement for the internal face of the PR panel is updated | |
| 01/03 | 17/01/03 | P-TEL-INT-090 : Heat capacity are specified at 300 K | |
| 01/03 | 17/01/03 | P-TEL-VER-050 p 56: Direct emissivity measurement between 40K and 293K can be proposed as an alternative solution to the BRDF measurement | |
| 01/03 | 17/01/03 | P-TEL-VER-050 p 57: test representativity requirements added | |
| 02/00 | 04/02/03 | P 31 - P-TEL-PHY-010 : update of the telescope mass specification. The 56 Kg maximum mass specification is replaced by 72Kg. Compliance may be demonstrated at cryo-structure/telescope and baffle level if needed. | |

## TABLE OF CONTENTS

# 1. INTRODUCTION

PLANCK is the third Medium size mission of the ESA long term scientific plan Horizon 2000. The scientific payload forms an integrated mutually complementary package optimised to fulfil the scientific aims of the mission.

The objective of the PLANCK mission is to image over the whole sky the temperature anisotropies of the cosmic background radiation, with a sensitivity $DT/T<2x10^{-6}$ and an angular resolution of -10 arcminutes. To achieve this objective, the whole sky will be mapped using nine frequency channels ranging between 30 and 900 GHz, with a sensitivity and an angular resolution which allow the separation of the cosmological signal from all other sources of confusion.

The present concept for PLANCK satellite is mainly composed of a service module which supports the PLANCK telescope with an intermediate cryo-structure (Figure 5.2.1-1).

The Planck Telescope consists of two ellipsoidal reflectors (primary and secondary) and the supporting structures. The Planck Focal Plane Assembly includes both instruments, (LFI and HFI) and its mounting structure (3 bibodes) through which it is mounted to the telescope structure. The Focal Plane Assembly however is not part of the telescope. The reflectors are delivered by the Prime contractor to the telescope contractor. The RFD (Reflector Fixation Device) are part of the reflector delivery (not part of the telescope).

The Telescope main Baffle is not a part of the Telescope.

The in-orbit operational temperature of the Planck telescope is inside 40 - 65 K.

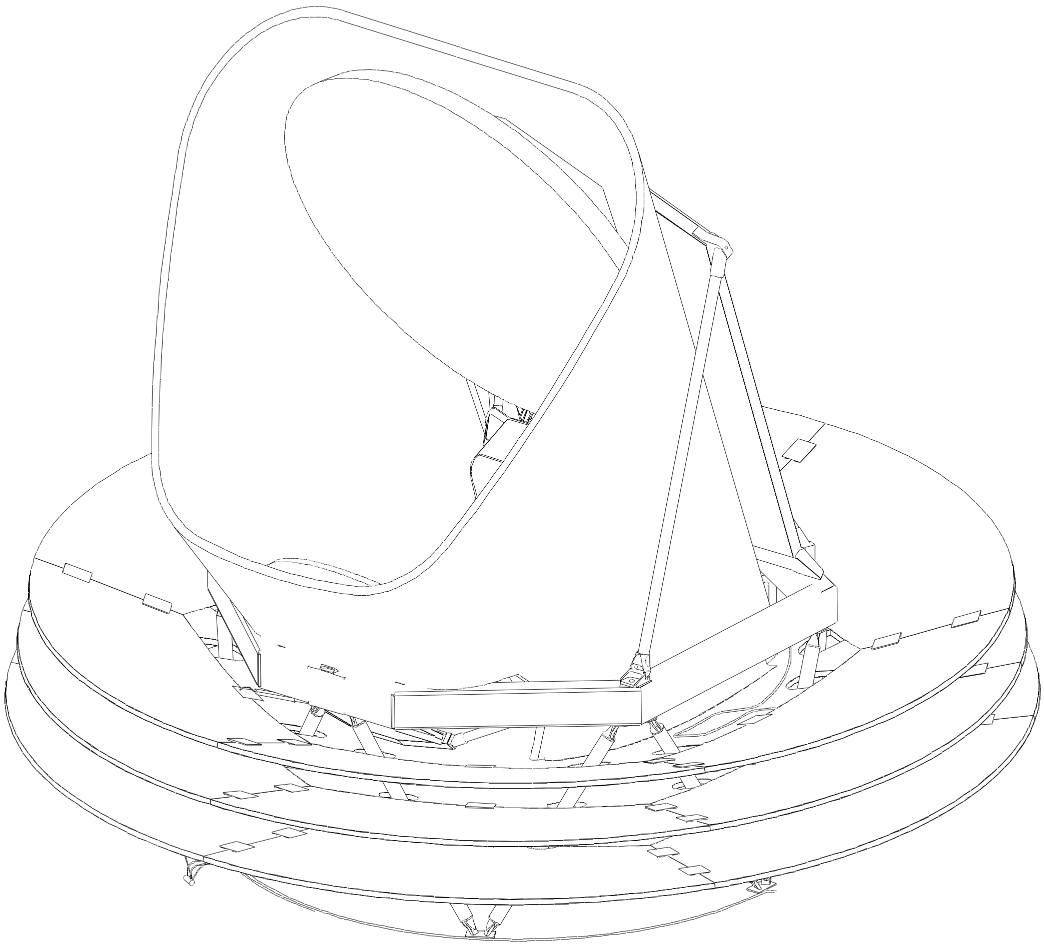


**Figure 5.2.1-1 :** Planck Payload Module overview

## 2. SCOPE

This design specification defines the design of the Planck Telescope and specifies the performance, development requirements and the qualification tests.

The Focal Plane Assembly is not part of the Planck telescope. The description of its specification is not included in this document.

## 2.1 Terms and Acronyms

| | |
|---|---|
| AD | Applicable Document |
| CFRP | Carbone Fiber Reinforced Plactic |
| CTE | Coefficient of thermal expansion |
| BOL | Begin of Life |
| EOL | End of Life |
| EP | Entrance Pupil |
| FPA | Focal Plane Assembly |
| FOV | Field-of-view |
| PPLM | Planck Payload Module |
| HFI | High Frequency Instrument |
| LFI | Low Frequency Instrument |
| LOS | Line Of Sight |
| MOS | Margin of Safety |
| N/A | Not applicable |
| PA | Product Assurance |
| PLM | Payload Module |
| PR | Primary Reflector |
| PtV | Pic to valley |
| RD | Reference Document |
| RFD | Reflector Fixation Device |
| RH | Relative Humidity |
| RMS | Root Mean Square |
| S/C | Spacecraft |
| SR | Secondary Reflector |
| TA | Telescope Assembly |
| TBC | To be confirmed |
| TBD | To be determined |
| WFE | Wave Front Error |
| wrt | With Regards To |

# 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 contents of this specification shall be considered a superseding requirement.

## 3.1 Applicable Documents (AD)

The following documents form a part of this specification.

| Ref. | No. | Issue/date | Title |
|---|---|---|---|
| AD 1 | H-P-3-ASPI-LI-0194 | latest issue | Planck telescope and cryo-structure list of applicable document |
| AD2 | H-P-3-ASP-SP-0021 | latest issue | Planck Cryostructure specification |
| | | | |

## 3.2 Reference Documents (RD)

| Ref. | No. | Issue/date | Title |
|---|---|---|---|
| RD 01 | PL AS TN 009 | 28/06/99 | Planck architect study optical report |
| | | | |

# 4. General description of the telescope

## 4.1 Description of the Planck telescope

The Planck Telescope is designed as an off-axis tilted system offering the advantage of an unblocked aperture. The telescope LOS lies in the Z, X plane of the spacecraft co-ordinate system and is tilted at an angle of 85° with respect to the X spacecraft axis.

The telescope has an off axis 1.5 m diameter projected aperture and operates at a temperature between 40K and 65K.

The telescope is composed of :

- an ellipsoidal primary reflector (PR)
- an ellipsoidal secondary reflector (SR)
- the telescope structure
- instrumentation for the telescope hardware as required (heaters, temperature sensors).
- the required hardware to interface with the PPLM (cryo-structure, baffle) and the instruments (FPA, Wave guide, harness, J-FET box)

Any readout/operation of telescope instrumentation is considered part of the PPLM, i.e. is not performed by the Planck telescope.

The telescope interfaces with the spacecraft (PPLM) and with the Planck FPA are defined in 5.7.

An overview of the telescope is given on Figure 5.2.1-1. The telescope structure is mainly composed of the following elements :

- the main frame interfacing with the cryo-structure and supporting the PR structure, the SR structure and the telescope baffle
- the primary reflector structure made of :
  - a sandwich panel on which is mounted the PR through flexible blades and inserts.
  - a set of struts fixed on the back side of the PR panel to increase its stiffness
  - 2 lateral struts to support the PR panel onto the main frame.
- the secondary reflector structure made of :
  - a triangular frame (or plate) on which is mounted the SR through flexible blades and inserts.
  - a set of struts which support SR plate onto the main frame

The PR panel and the main frame provide respectively 4 and 2 I/F points for FPA fixation (3 bipods).

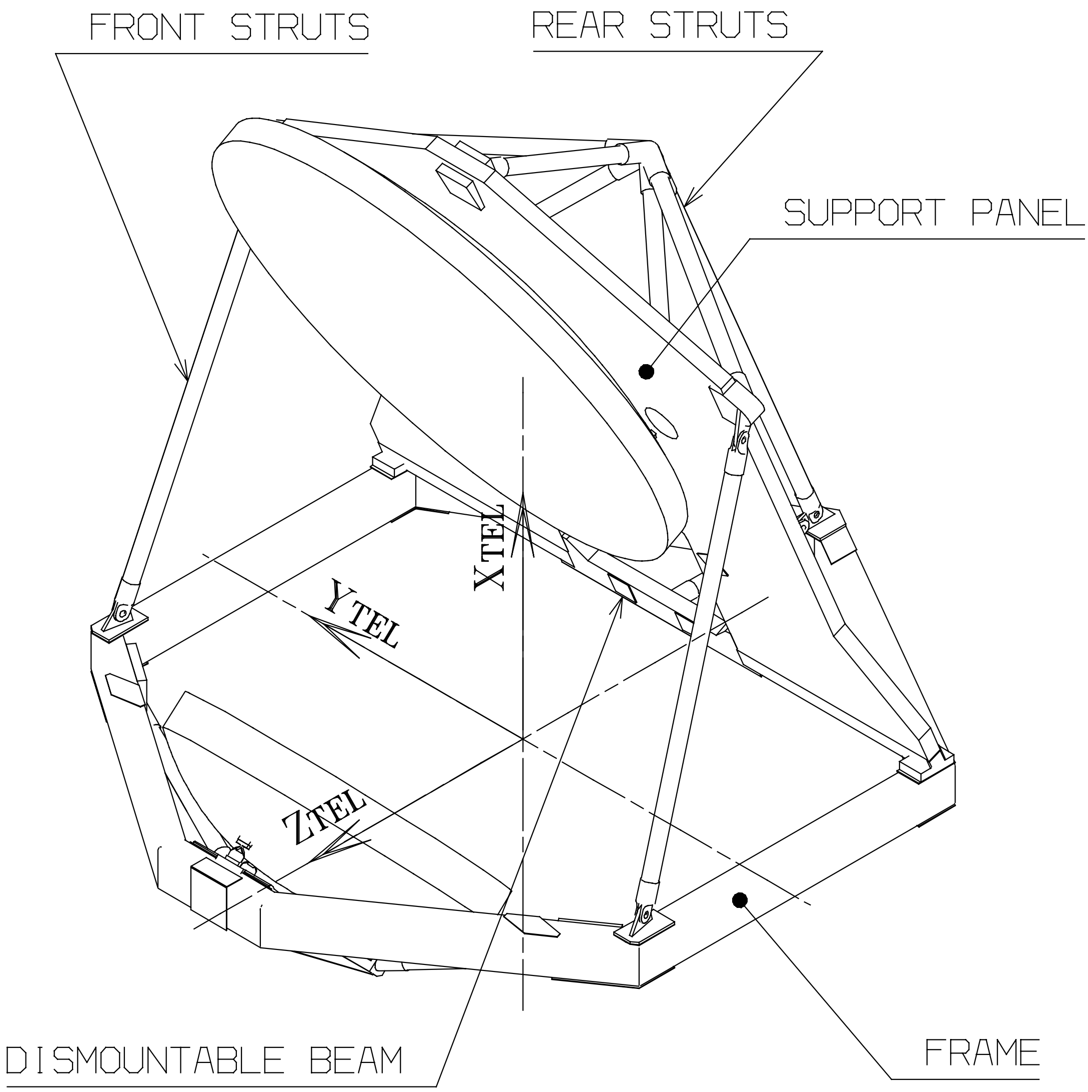



**Figure 5.2.1-1:** telescope overview

## 4.2 General functional requirement of the telescope

The telescope primary reflector shall collect the electromagnetic radiation and shall deliver the collected power via the secondary reflector to the Planck instruments

## 4.3 Axis System

Different axis systems are appropriate for the Planck s/c, the telescope, the FPU and the reflectors. These co-ordinate systems are summarised in this paragraph. All co-ordinate systems defined below are right-handed Cartesian systems.

### Planck s/c axis system

The Planck s/c co-ordinate system ($0_{sc}$, $X_{sc}$, $Y_{sc}$, $Z_{sc}$) is defined as follows (Figure 5.2.1-1) :

- the origin $0_{sc}$ is at centre of the s/c to launcher i/f,
- the $X_{sc}$ is the spin axis of the s/c with the sun nominally in –x direction,
- the Zsc axis is perpendicular to the Xsc axis and contained in the symmetry plane of the telescope, with the positive direction on the concave side of the telescope
- the $Y_{sc}$ complements the co-ordinate system.

### Planck Telescope axis system

The Planck Telescope co-ordinate system ($0_{Tel}$, $X_{Tel}$, $Y_{Tel}$, $Z_{Tel}$) is a shifted s/c co-ordinate system and defined as follows (see Figure 5.2.1-2) :

- the origin $0_{Tel}$ is the intersection of the interface plane P1 made by the lower face of the hexagonal frame and the $X_{sc}$,
- the $X_{Tel}$ is the s/c $X_{sc}$ axis,
- the $Y_{Tel}$ is the s/c $Y_{sc}$ axis,
- the $Z_{Tel}$ complements the co-ordinate system.

### Planck Telescope Primary Reflector axis system

The Planck Telescope Primary Reflector co-ordinate system ($0_{M1}$, $X_{M1}$, $Y_{M1}$, $Z_{M1}$) system is a local co-ordinate system and defined as follows (see Figure 5.2.1-3) :

- the origin $0_{M1}$ is at the vertex of the primary reflector,
- the $X_{M1}$ is along the minor axis of the ellipsoid, with positive direction toward the PR
- the $Z_{M1}$ is the $X_{M1}$ is along the major axis of the ellipsoid, with positive direction on the concave side of the PR
- $Y_{M1}$ complete the frame

### Planck Telescope Secondary Reflector axis system

The Planck Telescope Secondary Reflector co-ordinate system ($0_{M2}$, $X_{M2}$, $Y_{M2}$, $Z_{M2}$) system is a local co-ordinate system and defined as follows (see Figure 5.2.1-3):

- the origin $0_{M2}$ is at the vertex of the vertex of the SR
- the $X_{M2}$ is along the minor axis of the ellipsoid with positive direction toward the PR
- the $Z_{M2}$ is along the major axis of the ellipsoid, with positive direction on the convex side of the SR
- $Y_{M2}$ complete the frame

**Planck Telescope Reference Detector Plane axis system**

The Planck FPU co-ordinate system ($0_{RDP}$, $X_{RDP}$, $Y_{RDP}$, $Z_{RDP}$) is defined as follow (see Figure 5.2.1-2) :

- $0_{RDP}$ is the origin of the Focale plane reference frame
- the $Z_{RDP}$ is within the s/c X-Z plane, positive in the direction of the SR and tilted of 21.27° from $X_{M2}$
- the $X_{RDP}$ is perpendicular to the $Z_{FPU}$ axis, within the s/c X-Z plane, positive in the direction of the primary reflector
- the $Y_{RDP}$ complements the co-ordinate system.

The LOS nominal direction is defined as the direction of the incident beam in the object space which is imaged by the perfect telescope at the $0_{RDP}$ point.

The actual LOS direction is defined as the direction of the incident beam in the object space which is imaged by the actual telescope at the $0_{RDP}$ point.

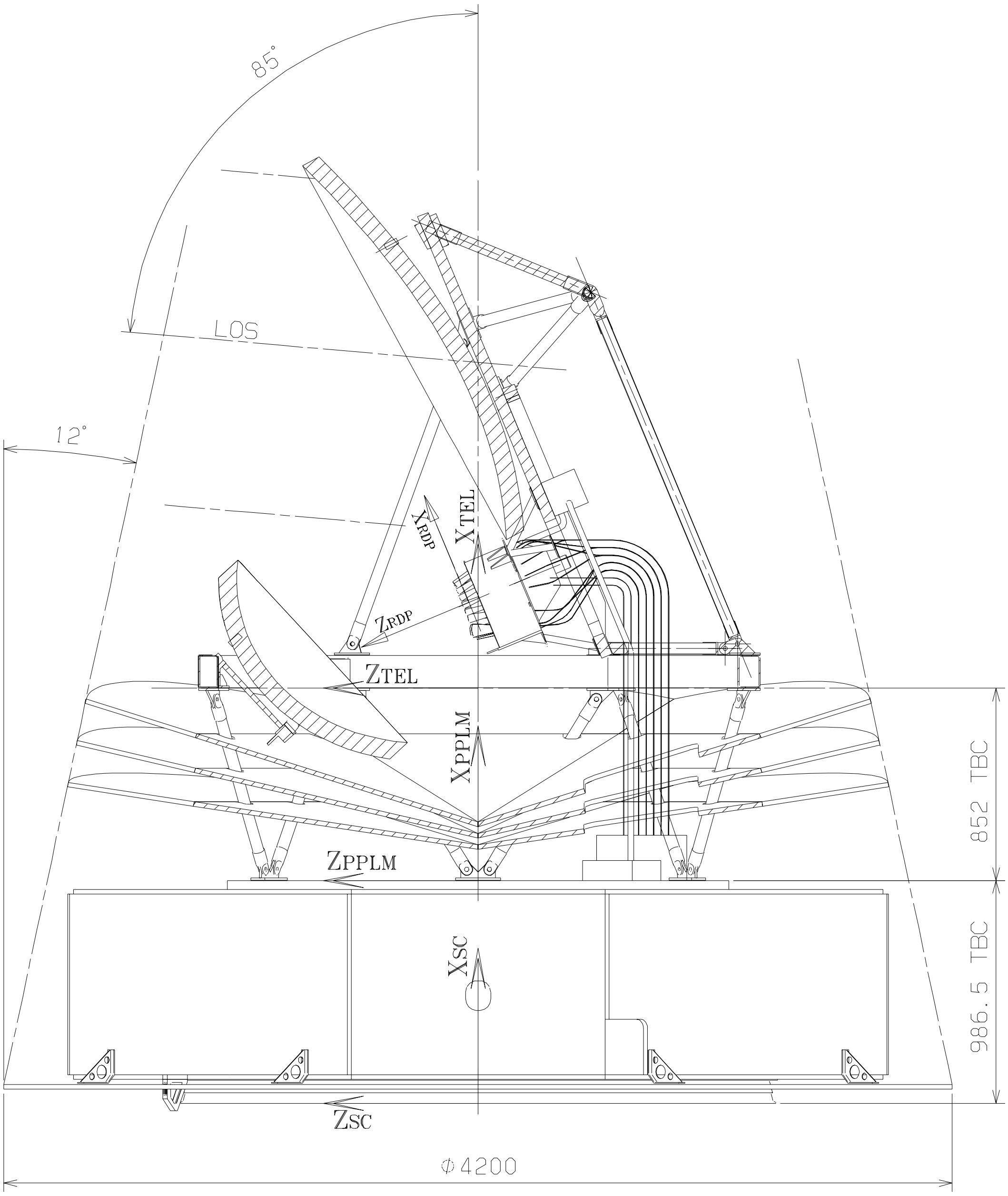



**Figure 5.2.1-1 :** Spacecraft axis system

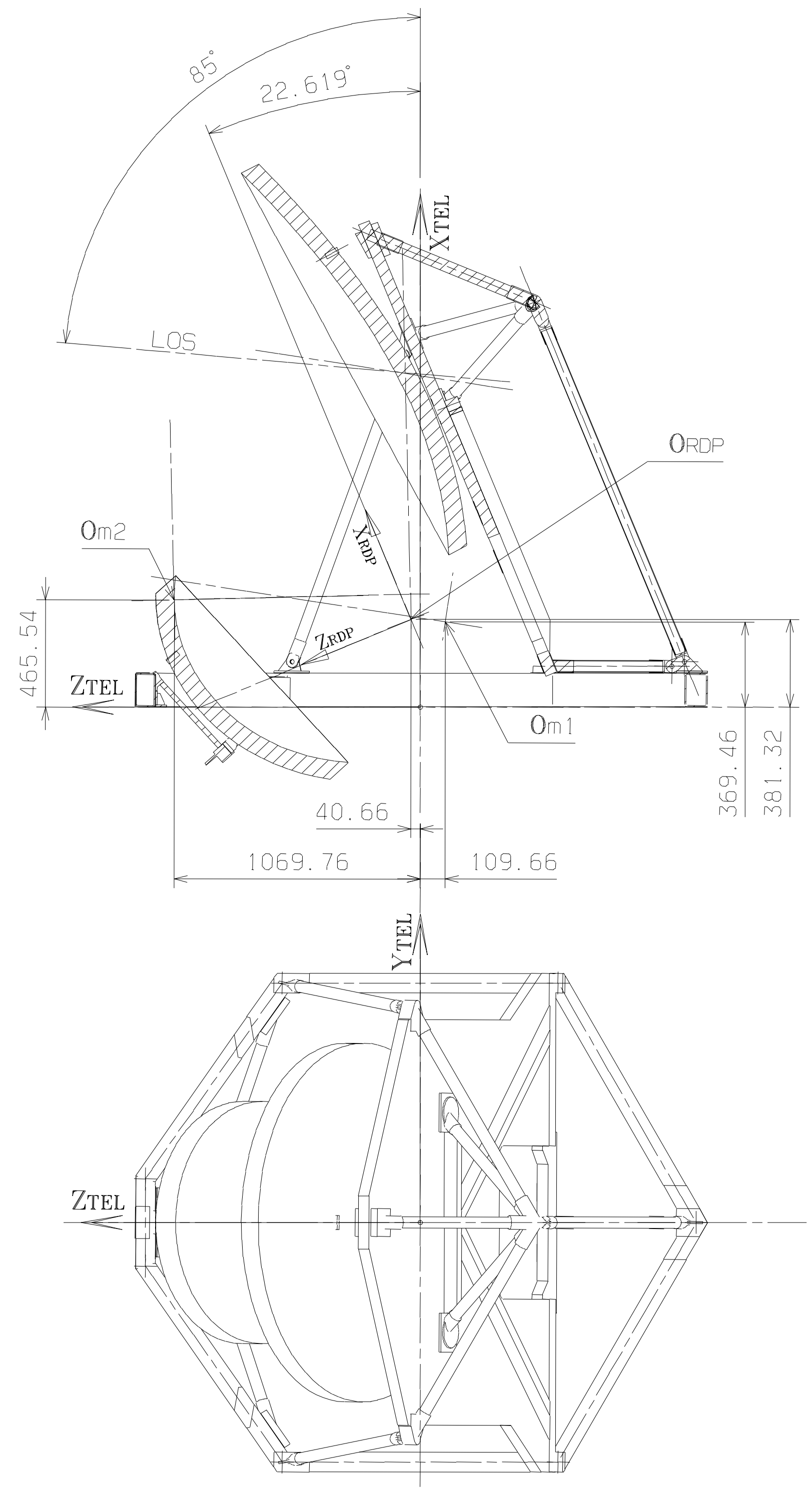



**Figure 5.2.1-2 :** Telescope, reflector and detector plane axis system

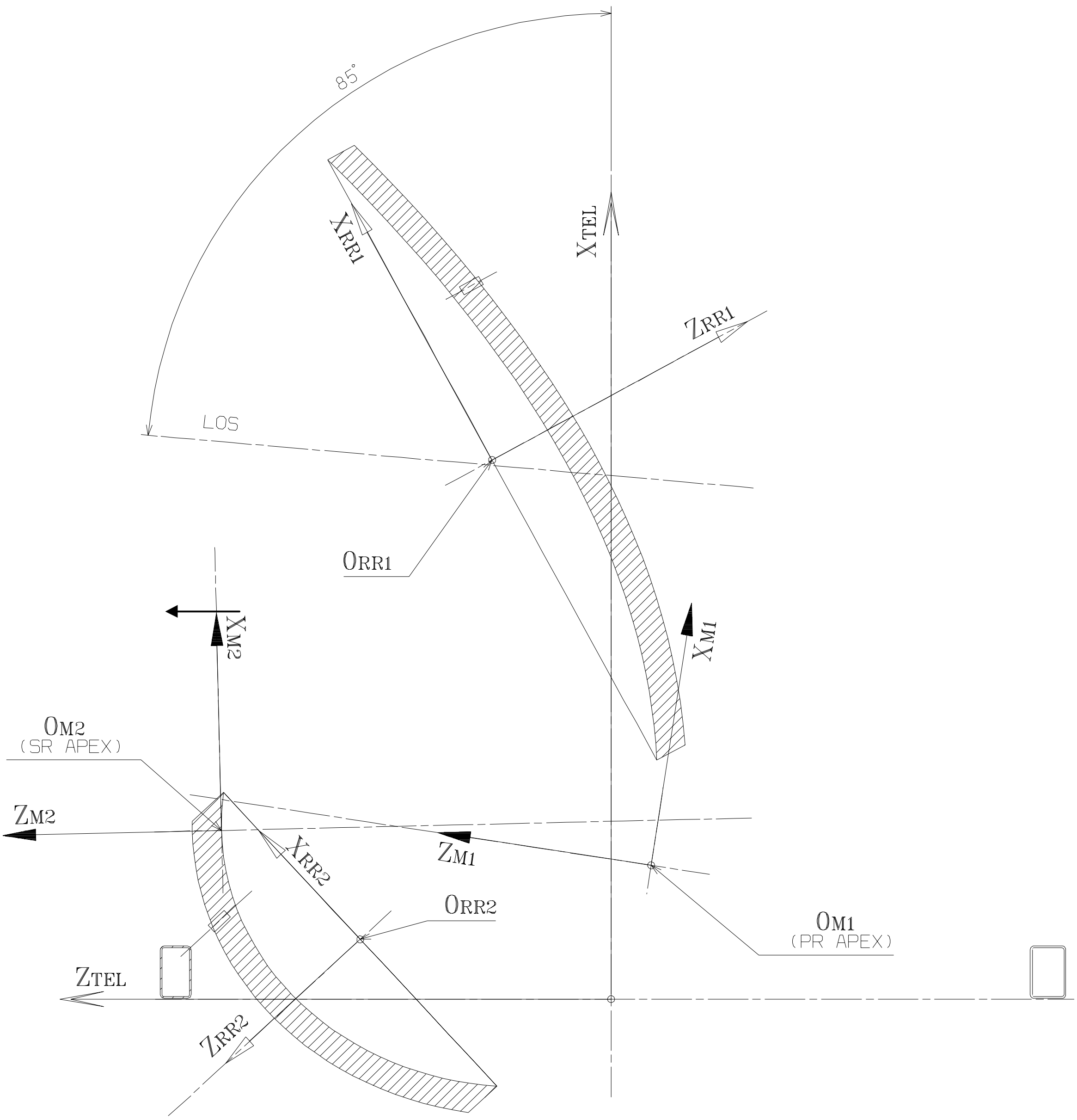



**Figure 5.2.1-3 :** Telescope and Reflectors axis system

# 5. REQUIREMENTS

## 5.1 General Specifications for the Planck Telescope

P-TEL-PER-005 The telescope shall meet its performance as defined in 5.2 within a temperature range of 40 K to 65 K

P-TEL-PER-010 The telescope shall maintain the specified performance defined in 5.2 over its lifetime

## 5.2 Opto-mechanical performance Requirements

### 5.2.1 Telescope Performance

P-TEL-PER-015 The telescope design shall be in line with the opto-mechanical definition given in Table 5.2.1-1 and. Figure 5.2.1-1.

P-TEL-PER-020 The telescope shall have an unobstructed Field of View (FOV) of ± 5°

| | | |
|---|---|---|
| Telescope | Angle of centre of FoV with respect to ZM1 axis<br>Field of View | -3.751° |
| Primary Reflector | See definition in SCI-PT-RS-07422 of AD1 | See definition in SCI-PT-RS-07422 of AD1 |
| Secondary Reflector | See definition in SCI-PT-RS-07422 of AD1 | See definition in SCI-PT-RS-07422 of AD1 |
| Position of Secondary reflectorr w.r.t Primary reflector (figure 5.2-1) | Angle between Axes (PSI)<br>Ztop (See definition in SCI-PT-RS-07422 of AD1)<br>Zbot (See definition in SCI-PT-RS-07422 of AD1) | 10.10°<br>481.737 mm<br>706.027 mm |
| Position of Reference Detector Plane (figure 5.2-2) | Decenter w.r.t. M2 axis: OH<br>Angle of Normal w.r.t. M2 axis: GAMA<br>HO2 | 108.420 mm<br>21.27°<br>1,026.830 mm |

**Table 5.2.1-1 :** Opto-mechanical Definition of the Planck Telescope

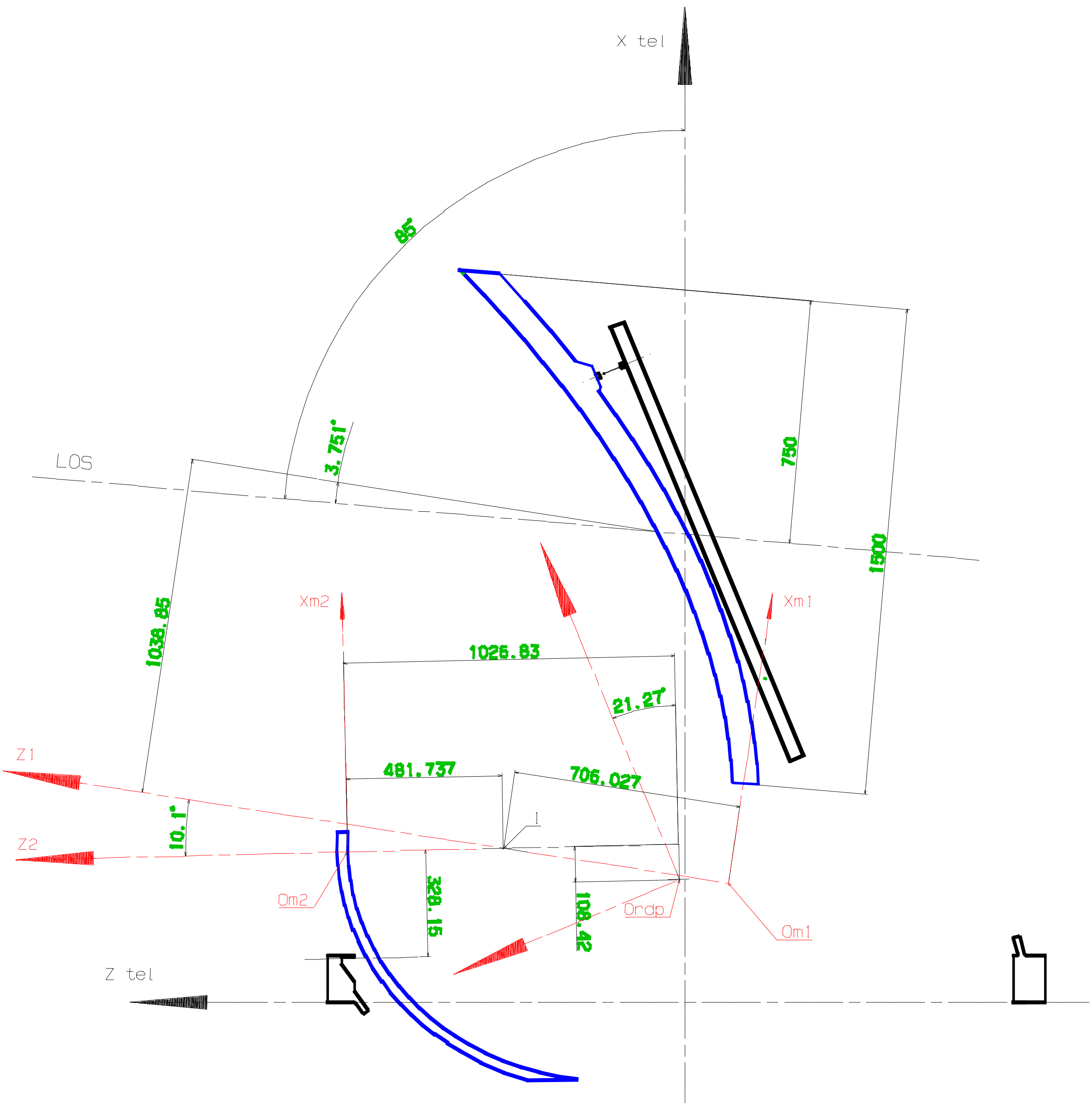



**Figure 5.2.1-1 :** Telescope optical design definition (operational environment)

P-TEL-PER-025 The total emissivity of the telescope optical surfaces within a temperature range of 40 K to 65 K and a frequency range of 25 to 1000 GHz, over the entire telescope FOV shall be :

Specification < 1 % at the delivery of the telescope
Specification < 5 % EOL
Goal < 2 % EOL goal

P-TEL-PER-030 For each position of the focal surface as defined in Table 5.2.1-2 and Table 5.2.1-3, the telescope shall achieve a WFE at operational conditions as described in 5.6, that does not degrade the theoretical value higher than as described in Table 5.2.1-4.

| Designation | X RDP (mm) | Y RDP (mm) | Z RDP (mm) |
|---|---|---|---|
| L-30-1 | -136.95 | 54.94 | 18.60 |
| L-30-2 | -136.95 | -54.94 | 18.60 |
| L-44-1 | -138.41 | 0.00 | 21.29 |
| L-44-2 | 55.32 | 133.27 | -17.90 |
| L-44-3 | 55.32 | -133.27 | -17.90 |
| L-70-1 | -76.38 | -69.37 | 14.54 |
| L-70-2 | -92.41 | -43.29 | 18.66 |
| L-70-3 | -101.86 | -17.69 | 20.86 |
| L-70-4 | -101.86 | 17.69 | 20.86 |
| L-70-5 | -92.41 | 43.29 | 18.66 |
| L-70-6 | -76.38 | 69.37 | 14.54 |
| L-100-2 | 103.15 | 16.58 | -19.40 |
| L-100-3 | 95.28 | 42.80 | -18.33 |
| L-100-4 | 80.77 | 65.82 | -16.03 |
| L-100-5 | 60.75 | 83.96 | -12.69 |
| L-100-6 | 36.77 | 96.04 | -8.68 |
| L-100-7 | 10.56 | 101.25 | -3.70 |
| L-100-8 | -15.95 | 99.42 | 1.81 |
| L-100-9 | -40.95 | 90.94 | 7.48 |
| L-100-10 | -40.95 | -90.94 | 7.48 |
| L-100-11 | -15.95 | -99.42 | 1.81 |
| L-100-12 | 10.56 | -101.25 | -3.70 |
| L-100-13 | 36.77 | -96.04 | -8.68 |
| L-100-14 | 60.75 | -83.96 | -12.69 |
| L-100-15 | 80.77 | -65.82 | -16.03 |
| L-100-16 | 95.28 | -42.80 | -18.33 |
| L-100-17 | 103.15 | -16.58 | -19.40 |

**Table 5.2.1-2 :** Definition of the focal surface point positions

| Designation | X RDP (mm) | Y RDP (mm) | Z RDP (mm) |
|---|---|---|---|
| H-100-1 | -47.570 | -32.966 | 14.847 |
| H-100-2 | -55.114 | -10.622 | 16.831 |
| H-100-3 | -55.114 | 10.622 | 16.831 |
| H-100-4 | -47.570 | 32.966 | 14.847 |
| H-143-1 | 33.184 | -39.106 | -1.280 |
| H-143-2 | 35.142 | -16.019 | -0.572 |
| H-143-3 | 34.424 | 16.013 | -0.390 |
| H-143-4 | 33.912 | 41.141 | -1.613 |
| H-143-5 | 48.960 | -32.843 | -4.919 |
| H-143-6 | 50.593 | -8.581 | -4.455 |
| H-143-7 | 49.882 | 8.578 | -4.263 |
| H-143-8 | 49.672 | 32.856 | -5.108 |
| H-217-1 | -31.180 | -27.749 | 12.776 |
| H-217-2 | -29.527 | -8.754 | 13.236 |
| H-217-3 | -30.307 | 8.752 | 13.362 |
| H-217-4 | -30.399 | 27.756 | 12.651 |
| H-217-5 | -16.174 | -34.288 | 9.791 |
| H-217-6 | -14.291 | -15.164 | 10.422 |
| H-217-7 | -15.051 | 15.160 | 10.563 |
| H-217-8 | -15.412 | 34.298 | 9.651 |
| H-353-1 | -3.268 | -58.369 | 5.117 |
| H-353-2 | -0.512 | -39.964 | 6.325 |
| H-353-3 | -0.073 | -23.141 | 7.308 |
| H-353-4 | 1.231 | -5.905 | 7.552 |
| H-353-5 | 0.409 | 10.332 | 7.649 |
| H-353-6 | 0.451 | 27.097 | 6.996 |
| H-353-7 | -1.536 | 42.928 | 6.290 |
| H-353-8 | -2.513 | 58.387 | 4.964 |
| H-545-1 | 12.049 | -58.768 | 1.867 |
| H-545-2 | 14.698 | -40.242 | 3.022 |
| H-545-3 | 13.702 | 43.225 | 3.004 |
| H-545-4 | 12.784 | 58.788 | 1.703 |
| H-857-1 | 15.072 | -23.799 | 3.974 |
| H-857-2 | 16.357 | -6.442 | 4.207 |
| H-857-3 | 15.568 | 9.909 | 4.332 |
| H-857-4 | 15.617 | 27.287 | 3.672 |

**Table 5.2.1-3 :** Definition of the focal surface point positions (con't)

| Position in the field | Maximum WFE degradation (µm rms) | |
|---|---|---|
| | Goal | Specification |
| H-857-1 to H-857-4 | 24 | 31 |
| H-545-1 to H-545-4 | 24 | 31 |
| H-353-1 to H-353-8 | 24 | 31 |
| H-217-1 to H-217-8 | 25 | 32 |
| H-143-1 to H-143-8 | 25 | 32 |
| H-100-1 to H-100-4 | 25 | 32 |
| L-100-1 to L-100-16 | 26 | 33 |
| L-70-1 to L-70-6 | 26 | 33 |
| L-44-1 to L-44-3 | 26 | 33 |
| L-30-1 to L-30-2 | 26 | 33 |

**Table 5.2.1-4 :** Maximum degradation of the theoretical WFE at different point of the field

**Note 1:** the WFE degradation is defined as follow :

$$Total\ \ final\ WFE\ at\ operational\ conditions = \sqrt{(\max\ theoritical\ WFE)^2 + (\max\ WFE\ \deg radation)^2}$$

The theoretical WFE is the WFE induced by the perfectly aligned optical lay-out. This performance is specified in H-P-3-ASP-TN-116 of AD1.

The max WFE degradation shall be computed including reflector degradation computed from SCI-PT-RS-07422 of AD1 and with the method as defined in H-P-3-ASP-TN-466 of AD1.

**Note 2 :** The WFE includes apodisation. The apodisation is used as a weighting function to determine the weighted root mean square of the optical path length difference. For each focal point location, the apodisation is applied at exit pupil level. It is a gaussian function centred in directions defined in Table 5.2.1-5 and Table 5.2.1-6, and as defined in H-P-3-ASP-TN-116 of AD1.

| Designation | Coord /XRDP | Coord /YRDP | Coord /ZRDP |
|---|---|---|---|
| L-30-1 | 0,24690468 | -0,10485568 | 0,963350 |
| L-30-2 | 0,24690468 | 0,10485568 | 0,963350 |
| L-44-1 | 0,25628937 | 0 | 0,966600 |
| L-44-2 | -0,11248793 | -0,25969551 | 0,959117 |
| L-44-3 | -0,11248793 | 0,25969551 | 0,959117 |
| L-70-1 | 0,1434935 | -0,14879962 | 0,978401 |
| L-70-2 | 0,1768077 | -0,0968395 | 0,979470 |
| L-70-3 | 0,19354392 | 0,03839294 | 0,980340 |
| L-70-4 | 0,19354392 | -0,03839294 | 0,980340 |
| L-70-5 | 0,1768077 | -0,0968395 | 0,979470 |
| L-70-6 | 0,1434935 | -0,14879962 | 0,978401 |
| L-100-2 | -0,21353428 | -0,03206533 | 0,976409 |
| L-100-3 | -0,19692679 | -0,08302317 | 0,976897 |
| L-100-4 | -0,1668227 | -0,12888873 | 0,977526 |
| L-100-5 | -0,12532985 | -0,16631833 | 0,978075 |
| L-100-6 | -0,07569471 | -0,1923591 | 0,978401 |
| L-100-7 | -0,02234264 | -0,20533375 | 0,978437 |
| L-100-8 | 0,0308704 | -0,20388032 | 0,978509 |
| L-100-9 | 0,08019984 | -0,18829903 | 0,978832 |
| L-100-10 | 0,08019984 | 0,18829903 | 0,978832 |
| L-100-11 | 0,0308704 | 0,20388032 | 0,978509 |
| L-100-12 | -0,02234264 | 0,20533375 | 0,978437 |
| L-100-13 | -0,07569471 | 0,1923591 | 0,978401 |
| L-100-14 | -0,12532985 | 0,16631833 | 0,978075 |
| L-100-15 | -0,1668227 | 0,12888873 | 0,977526 |
| L-100-16 | -0,19692679 | 0,08302317 | 0,976897 |
| L-100-17 | -0,21353428 | 0,03206533 | 0,976409 |

**Table 5.2.1-5 :** Apodization direction for each field position (Director vector in the RDP frame)

| Designation | Coord /XRDP | Coord /YRDP | Coord /ZRDP |
|---|---|---|---|
| H-100-1 | 0,095672 | 0,069159 | 0,993007 |
| H-100-2 | 0,111313 | 0,022304 | 0,993535 |
| H-100-3 | 0,111313 | -0,022304 | 0,993535 |
| H-100-4 | 0,095672 | -0,069159 | 0,993007 |
| H-143-1 | -0,069530 | 0,082452 | 0,994167 |
| H-143-2 | -0,073343 | 0,033936 | 0,996729 |
| H-143-3 | -0,071846 | -0,033939 | 0,996838 |
| H-143-4 | -0,071080 | -0,086675 | 0,993698 |
| H-143-5 | -0,102185 | 0,069114 | 0,992362 |
| H-143-6 | -0,105483 | 0,018119 | 0,994256 |
| H-143-7 | -0,104008 | -0,018121 | 0,994411 |
| H-143-8 | -0,103643 | -0,069121 | 0,992210 |
| H-217-1 | 0,063313 | 0,058579 | 0,996273 |
| H-217-2 | 0,060508 | 0,018535 | 0,997996 |
| H-217-3 | 0,062076 | -0,018533 | 0,997899 |
| H-217-4 | 0,061745 | -0,058602 | 0,996370 |
| H-217-5 | 0,032614 | 0,072486 | 0,996836 |
| H-217-6 | 0,029370 | 0,032199 | 0,999050 |
| H-217-7 | 0,030922 | -0,032180 | 0,999004 |
| H-217-8 | 0,031062 | -0,072507 | 0,996884 |
| H-353-1 | 0,005009 | 0,122457 | 0,992461 |
| H-353-2 | 0,000262 | 0,084460 | 0,996427 |
| H-353-3 | -0,000122 | 0,049129 | 0,998792 |
| H-353-4 | -0,002566 | 0,012566 | 0,999918 |
| H-353-5 | -0,000908 | -0,021972 | 0,999758 |
| H-353-6 | -0,001309 | -0,057477 | 0,998346 |
| H-353-7 | 0,002234 | -0,090632 | 0,995882 |
| H-353-8 | 0,003456 | -0,122492 | 0,992463 |
| H-545-1 | -0,026421 | 0,123281 | 0,992020 |
| H-545-2 | -0,031201 | 0,085028 | 0,995890 |
| H-545-3 | -0,029230 | -0,091237 | 0,995400 |
| H-545-4 | -0,027922 | -0,123311 | 0,991975 |
| H-857-1 | -0,031585 | 0,050498 | 0,998225 |
| H-857-2 | -0,034062 | 0,013692 | 0,999326 |
| H-857-3 | -0,032440 | -0,021071 | 0,999252 |
| H-857-4 | -0,032789 | -0,057864 | 0,997786 |

**Table 5.2.1-6 :** Apodization direction for each field position (Director vector in the RDP frame) (con't)

P-TEL-PER-035 The WFE degradation will be computed taking into account, as a minimum, contributors as defined in Figure 5.2.1-2 :

P-TEL-PER-040 The telescope LOS at operational conditions as described in § 5.6 shall remain within 0.1° of the nominal direction.

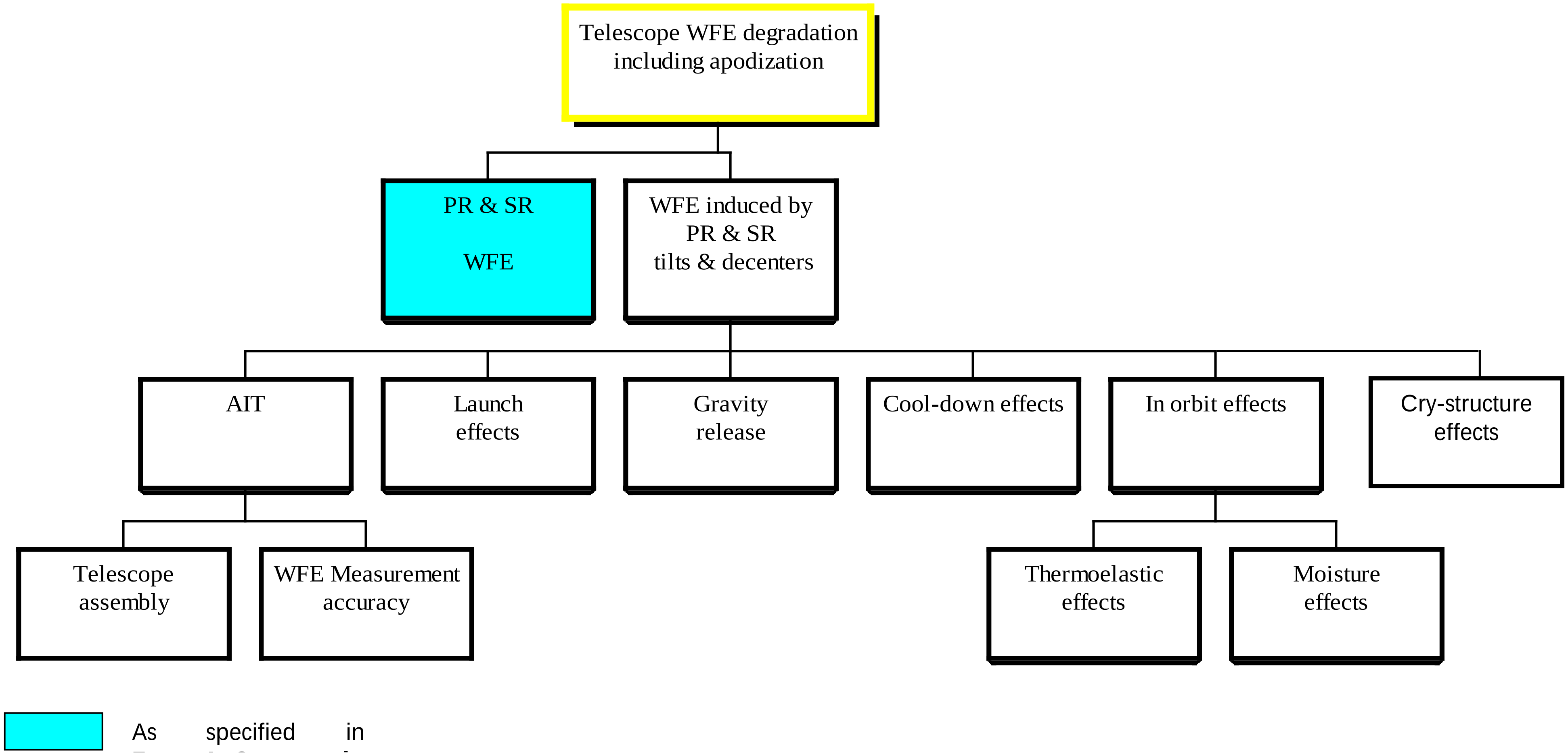



**Figure 5.2.1-2** : WFE main contributors

## 5.3 Mechanical requirements

### 5.3.1 Frequencies

P-TEL-PER-045 The telescope shall be compliant with the following frequency requirements at ambient temperature, when simply supported with radial translation free on rigid support through their interface points and equipped of PR and SR and representative MCI of the baffle and the FPA at interface points as defined in § 5.7.1.

| Items | Mode with mass >10% of the total maximum mass along $X_{tel}$ axis | Mode with mass >10% of the total maximum mass along $Y_{tel}$ and $Z_{tel}$ axis |
|---|---|---|
| **EQUIPED TELESCOPE STRUCTURE** (with Reflectors, Baffle, FPA and JFET masses) | **f longi ≥ 50 Hz (1)** | **f lat ≥ 45 Hz (1)** |

(1) These values will be confirmed after the Cryo-structure design agreed

For mechanical analyses, the FPA, JFET and the Baffle shall be connected to their interface points as defined in 5.7.1 on the telescope structure with linear relation elements (RBE3 in NASTRAN) in order to take into account the masses and their locations but without adding artificial stiffness in the telescope structure.

| Item | Lumped mass (max) | X (mm) | Y (mm) | Z (mm) | Coord rep |
|---|---|---|---|---|---|
| FPA (+1/6 WG +SCCE) | 56 kg | -52 | 0 | -180 | Rdp |
| J-FET | 2.4 kg | +263 | 0 | -560 | Rdp |
| J-FET harness | 2.4 kg | NSM on the PR Panel on +Y side of the cut out | | | Tel |
| Baffle | following CSAG MCI | / | / | / | Tel |
| PR (with ISM) | 30.6 kg | +1548.1 | 0 | +205.8 | Tel |
| SR (with ISM) | 15 kg | +52.7 | 0 | +813.9 | Tel |
| WG Upper Support Structure (+1/6 WG) | 4 kg | -238 | 0 | -724 | Rdp |
| WG Lower Support Structure (1/2 support + 1/3 WG) | 5 kg laterally (Y,Z)<br><br>0 kg axialy (X)* | +857 | 0 | -785 | PPLM |

* Due to the flexible blades in the axial direction between the WG Support and the Tel Frame : X mass directly and completely supported by the SVM.

## 5.4 Thermal requirements

P-TEL-PER-050 The telescope shall maintain the specified EOL performance defined in § 5.4. These performances must be guaranteed taking into account the analyses and test uncertainties.

### 5.4.1 Emissivity

P-TEL-PER-065 The emissivity and the IR reflectivity of the surfaces of the different elements shall be as defined in Table 5.4.1-1:

| Items | Temperature level | IR Emissivity | IR Reflectivity | |
|---|---|---|---|---|
| | | | diffuse | specular |
| Internal face of the PR panel | 293 K | ≤ 0.05 | ≤ 0.095 | ≥ 0.855 |
| | 65 K | ≤ 0.05 | ≤ 0.095 | ≥ 0.855 |
| External face of the PR panel | 40 K | ≥ 0.85 | ≤ 0.15 | 0 |
| Other component of the telescope structure | 40 K | ≥ 0.85 | ≤ 0.15 | 0 |

**Table 5.4.1-1 :** Emissivity and reflectivity requirements

### 5.4.2 Conductivity

P-TEL-PER-070 The frame of the telescope structure shall be compliant with the following conductance requirements at the defined reference temperature :

In the all direction : $\lambda * e >$ **$1.10^{-2}$ W/K** at 40 K
where : - $\lambda$ is the thermal conductivity of the material (in W/m/K)
- e is the thickness of the beam (in m)

P-TEL-PER-075 The PR supporting panel of the telescope structure shall be compliant with the following conductance requirements at the defined reference temperature :

| Items | Reference temperature (K) | Transversal conductance ($W/m^2/K$) (1) | Conductance in the plane direction of the sheets (W/K) (2) | Conductance in the plane direction of the honeycomb (W/K) (3) |
|---|---|---|---|---|
| PR support panel | 40 | **>7** | **> $5.10^{-3}$** | **> $2.10^{-2}$** |

**Table 5.4.2-1 :** Conductance requirement of the telescope structure elements

(1) : $\lambda$/L where : - $\lambda$ is the thermal conductivity of the material (in W/m/K)

- L is the total height of the sandwich (m)

(2) : λ*e where : - λ is the thermal conductivity of the material (in W/m/K)
- e is the thickness of each sheet (m)

(3) : λ*e where : - λ is the thermal conductivity of the material (in W/m/K)
- e is the thickness of the honeycomb (m)

P-TEL-PER-080 The conductance between the different sub-system of the telescope structure shall be compliant with the following requirements at the defined reference temperature :

| Items | Reference temperature (K) | Conductance (W/K) |
|---|---|---|
| Between the PR structure and the frame | 40 | **> 0.4** |
| Between the SR structure and the frame | 40 | **> 0.1** |

**Table 5.4.2-2 :** Conductance requirement between the telescope structure elements

## 5.5 PHYSICAL REQUIREMENTS

### 5.5.1 Dimensions and design

P-TEL-PHY-005 The telescope shall have dimensions at operational conditions as defined in the interface volume drawing PLATELSSW 10000A of AD1.

### 5.5.2 Mass – centering - Inertia

P-TEL-PHY-010 The total mass of the telescope structure (without reflectors and RFD), shall be minimised and shall not exceed, including margin :

Specification < 72 Kg

Compliance to the above mass requirement may, if needed, be demonstrated globally considering cryo-structure / telescope and baffle mass requirements.

The margin shall be defined as specified in GDIR of AD1.

P-TEL-PHY-015 The centre of gravity for the nominal mass of the telescope structure shall have the following position wrt the telescope reference frame :

Xcog < +500 mm
Ycog < ± 5 mm
Z = -50 mm ± 15 mm

P-TEL-PHY-020 The location of the centre of gravity of the telescope structure shall not deviate from the nominal position as specified in GDIR of AD1.

P-TEL-PHY-025 The centre of gravity of the telescope structure shall be known with an accuracy as specified in GDIR of AD1.

P-TEL-PHY-030 The inertia of the telescope structure with for the nominal mass and defined in the telescope reference frame shall be :

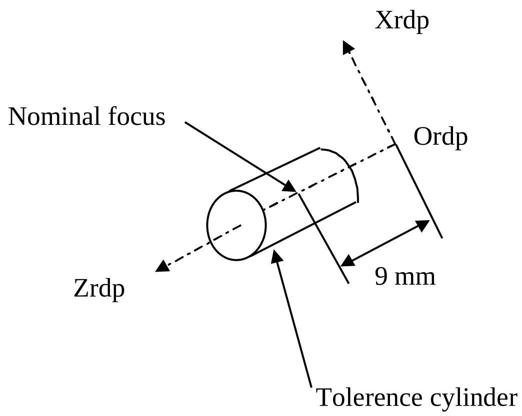
Ixx = 54 kg.m² ± 30%
Iyy < 65 kg.m²
Izz < 65 kg.m²
Coning angle < 40°

P-TEL-PHY-035 The inertia of the telescope shall not deviate from the nominal values as specified in GDIR of AD1

P-TEL-PHY-040 The inertia of the telescope shall be known with an accuracy as specified in GDIR of AD1

### **5.5.3** Alignment

P-TEL-PHY-045 The best focus of the telescope shall be within a cylinder of diameter of 1 mm and length of 5 mm around the nominal focus position, with the cylinder axis in the $Z_{RDP}$ direction of the FPU co-ordinate system. The $O_{RDP}$ is described in the drawing PLATELSW 10000A of AD1 and the nominal focus in the following figure :




P-TEL-PHY-050 The best focus of the telescope shall be known to be within a cylinder of diameter of 0.5 mm and length of 0.5 mm, with the cylinder axis in the $Z_{FPU}$ direction of the FPU co-ordinate system.

Note : the best focus of the telescope is the point along the telescope axis at which the WFE at operational condition is minimum.

P-TEL-PHY-055 The positions of the PR optical reference, SR optical reference and FPU mechanical interface shall be known wrt the optical alignment reference system defined in 5.7.3 with an accuracy better than 0.1 mm (± 0.05 mm) and 0.2 mrd (± 0.1 mrd).

P-TEL-PHY-060 The positions and accuracy of the telescope LOS at operational conditions shall be as defined in PLATELSW 10000A of AD1.

P-TEL-PHY-065 The positions of the telescope LOS at operational conditions shall be known with an accuracy better than 0.1 deg.

## 5.6 ENVIRONMENTAL REQUIREMENT

### 5.6.1 Mechanical

During flight, the PLANCK telescope is subjected to static and dynamic loads which result from the ARIANE 5 steady state acceleration and low frequency vibration. The random vibration loads are covered by the acoustic vibration. Therefore, random vibration survey is not required.

#### *5.6.1.1 Quasi-static load*

**Qualification loads :**

P-TEL-ENV-005 The qualification loads shall be applied on the telescope with its main baffle, the FPU, PR, SR and Jfet for the structural design considering in addition the safety factors defined in § 5.8.1. The telescope will be mounted on a structure representative of the CS stiffness (no groove mass . The CS design to be used shall be agreed by ASP.

| Load Cases | X (g) | Y (g) | Z (g) |
|---|---|---|---|
| 1 | 16.5 | / | 6 |
| 2 | 16.5 | / | -6 |
| 3 | / | 13 | / |
| 4 | 5 | / | 13 |
| 5 | 5 | / | -13 |

These values will be confirmed by ASP on the basis of analysis performed with the CS design including discrepancies (to be provided by CSAG)

The FPA and the Baffle shall be connected to their interface points on the telescope with linear relation elements (RBE3 in NASTRAN) in order to take into account the masses and their locations but without adding artificial stiffness in the telescope structure.

**Note :** locally, if loads at the telescope/baffle interface, induced by the above QSL are lower than dynamic loads expressed in P-TEL-ENV-015, then the dynamic loads defined in P-TEL-ENV-015 shall be applied for structural design.

**Flight limit loads :**

P-TEL-ENV-010 Flight limit loads are obtained by dividing the qualification loads by 1.25

### *5.6.1.2 Sinusoidal*

P-TEL-ENV-015 The qualification sine vibration test spectrum is the following. The telescope will be mounted on a structure representative of the CS stiffness. The CS design to be used shall be agreed by ASP

| Freq (Hz) | Long (X axis) | Freq (Hz) | Lat (Y or Z axis) |
|---|---|---|---|
| 5-10 | 10 mm | 5-10 | 10 mm |
| 10-50 | 2 g | 10-40 | 1.875 |
| 50-100 | 3.5 g | 40-70 | 5g |
| | | 70-100 | 2.5g |

Note : These values will be confirmed by ASP on the basis of analysis performed with the CS design including discrepancies (to be provided by CSAG)

P-TEL-ENV-020 Notching on sine input to avoid loads higher than QSL at telescope interface is authorised. Notching shall be agreed by ASP.

The following notching values are allowed for the Telescope structure sizing :

- SR : 45g spherical (point location in the reflector FEM : in the reflector/ISM interface plane, at the center of the 3 ISM)

- PR : 40g spherical (point location in the reflector FEM : in the reflector/ISM interface plane, at the center of the 3 ISM)

- FPU : 40g spherical (point location in the FPU FEM : at the FPU CoG )

P-TEL-ENV-022 For dynamic analysis, modal damping factor of 2% (Q factor of 25 for a 1 dof system) will be used.

P-TEL-ENV-025 Flight limit loads are obtained by dividing the qualification loads by 1.25.

### *5.6.1.3 Acoustic*

**Acoustic Vibrations - Acceptance Spectrum**

P-TEL-ENV-030 The spectrum for the acceptance acoustic test of the telescope is defined in EVTR of AD1.

P-TEL-ENV-035 The design of telescope shall guarantee that during the acoustic acceptance test of the telescope equipped of the baffle and the reflectors, the Flight Limit Loads as defined in § 5.6.1.1 multiplied by the yield safety factor are not exceeded

P-TEL-ENV-040 The contractor shall verify that during the acoustic acceptance test of the telescope equipped of the baffle and the reflectors, the Flight Limit Loads as defined in § 5.6.1.1 multiplied by the yield safety factor are not exceeded

P-TEL-ENV-045 The telescope shall withstand the acceptance acoustic test without any degradation

**Acoustic Vibrations - Qualification Spectrum**

P-TEL-ENV-050 The spectrum for the acceptance acoustic test of the telescope is defined in EVTR of AD1

P-TEL-ENV-055 The design of telescope shall guarantee that during the acoustic qualification test of the telescope equipped of the baffle and the reflectors, the Flight Limit Loads as defined in § 5.6.1.1 multiplied by the yield safety factor are not exceeded

P-TEL-ENV-060 The contractor shall verify that during the acoustic qualification test of the telescope equipped of the baffle and the reflectors, the Flight Limit Loads as defined in § 5.6.1.1 multiplied by the yield safety factor multiplied by the qualification safety factor are not exceeded.

P-TEL-ENV-065 The telescope shall withstand the qualification acoustic test without any degradation

#### *5.6.1.4 Maximum displacements*

P-TEL-ENV-070 The maximum displacement induced by dynamics behaviour and distortion of the telescope structure during the acceptance sinus and acoustic test, of any point of the telescope shall be lower than 3.2 mm.

P-TEL-ENV-080 The maximum displacement induced by dynamics behaviour and distortion of the telescope structure during the qualification sinus and acoustic test, of any point of the telescope shall be lower than 5 mm.

#### *5.6.1.5 Shocks*

P-TEL-ENV-085 The telescope shall be compatible with the following shock response spectrum levels

| Frequencies (Hz) | Shocks level (g) |
|---|---|
| 100 | 20 |
| 1300 | 200 |
| 10 000 | 200 |

#### *5.6.1.6 Interface loads*

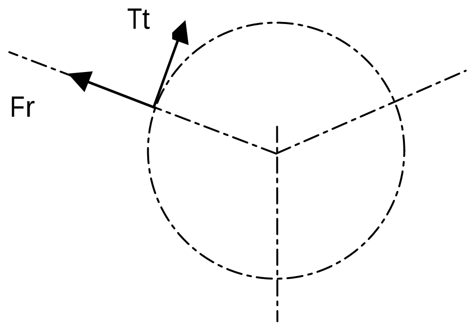
P-TEL-ENV-090 The telescope shall be design to withstand thermoelastic loads at the baffle interface points without degradation of its performances. The thermoelastic loads shall be computed by CSAG when the baffle is mounted via its fixation devices on the telescope structure and cool down from ambient to qualification temperature as defined in § 5.6.2 and AD2. The computed loads shall be agreed by ASP.

P-TEL-ENV-095 The telescope shall be design to withstand thermoelastic loads at the cryo-structure interface points without degradation of its paerformances. The thermoelastic loads shall be computed by CSAG when the telescope is mounted on the cryo-structure and cool down from ambient to qualification temperature as defined in § 5.6.2 and AD2. The computed loads shall be agreed by ASP.

P-TEL-ENV-100 The telescope shall be design to withstand the following thermoelastic loads at the FPA/PR Support Panel points without performance degradation :

F radial = **-2100 N**
Tangential torque : **204 N.m**

The interface loads are generated by the FPU in hard mounted conditions and at operational temperature. This loads have to be applied at each of the 6 interface points between FPU bipods end fittings and the PR Panel.




P-TEL-ENV-101 The telescope performance shall be compatible with a 0.15 mm relative displacement in the $X_{tel}$ direction of the 6 telescope-cryo-structure interface points:

P-TEL-ENV-102 The telescope shall be design to withstand the following thermoelastic loads at the Jfet/PR Support Panel interface points without performance degradation :

F radial = -360 N on 4 attachment points .

The interface loads are generated by the JFET in hard mounted conditions and at operational temperature.

P-TEL-ENV-103 The telescope shall be design to withstand the following thermoelastic loads at the PR and SR interfaces without performance degradation. The interface loads are generated by the reflectors and their supporting devices in hard mounted conditions and at operational temperature.

| Item | Blades location | Primary Reflector | Secondary Reflector |
|---|---|---|---|
| **Fz [N] (radial)** | **upper (+X)** | **340** | **170** |
| **Fx [N] (tangential)** | **lower (-X)** | **110** | **55** |
| **Fz [N] (radial)** | **lower (-X)** | **160** | **90** |

### *5.6.1.7 Mechanical environment for loads definition at instrument interfaces*

P-TEL-ENV-104 The telescope shall be design to withstand the following mechanical loads at the WG Lower Support structure interface (on frame lower side) when the following environment is applied :

- qualification acceleration in the in the PPLM coord system : 30g Y, Z combined
- Mass : 5 kg (1/2 support + 1/3 WG) attached on the 2 IF areas on the frame

- CoG location in PPLM coord system :
X : +857 mm (lower plane side of the frame)
Y : 0
Z : -785 mm

Note : load in X direction is negligible because of flexible blades implemented in the support structure (at the frame IF).

P-TEL-ENV-105 The telescope shall be design to withstand the following mechanical loads at the WG upper Support structure interface (on the pr panel rear side) when the following environment is applied :

- qualification acceleration in the in the PPLM coord system :
  - 30g X, Y, Z not combined
  - 20g combined in 2 directions
- Mass : 6 kg (support + 1/3 WG) attached on the 4 IF areas on the Panel
- - CoG location in Ordp coord system :
  X : -238 mm
  Y : 0
  Z : -724 mm

P-TEL-ENV-106 The telescope shall be design to withstand the following mechanical loads at the bellow interface (on the pr panel rear side) when the following environment is applied for one support with 2 attachements points:

- In support plane directions : 30g (qualif) in the tube lateral direction
- Out of the support plane direction : 30g qualif
- Mass : 2 Kg

Distance between the Bellow CoG and the support plane (panel surface) is 30 mm.

## 5.6.2 Thermal

### *5.6.2.1 Temperature*

P-TEL-ENV-107 The telescope with its surface coating shall withstand without performance degradation's the thermal environment :

| Items | Transient | Operational | Qualification | | Acceptance | |
|---|---|---|---|---|---|---|
| | | | **Min** | **Max** | **Min** | **Max** |
| Material & Process (sample) | | / | 30 K | 85 °C | / | / |
| telescope | See figure 5.6.2-1 | See figure 5.6.2-2 | 40 K | 85 °C | 45 K | 80 °C |

TBD figure

**Figure 5.6.2-1** : Telescope temperature distribution during transient (worst case)

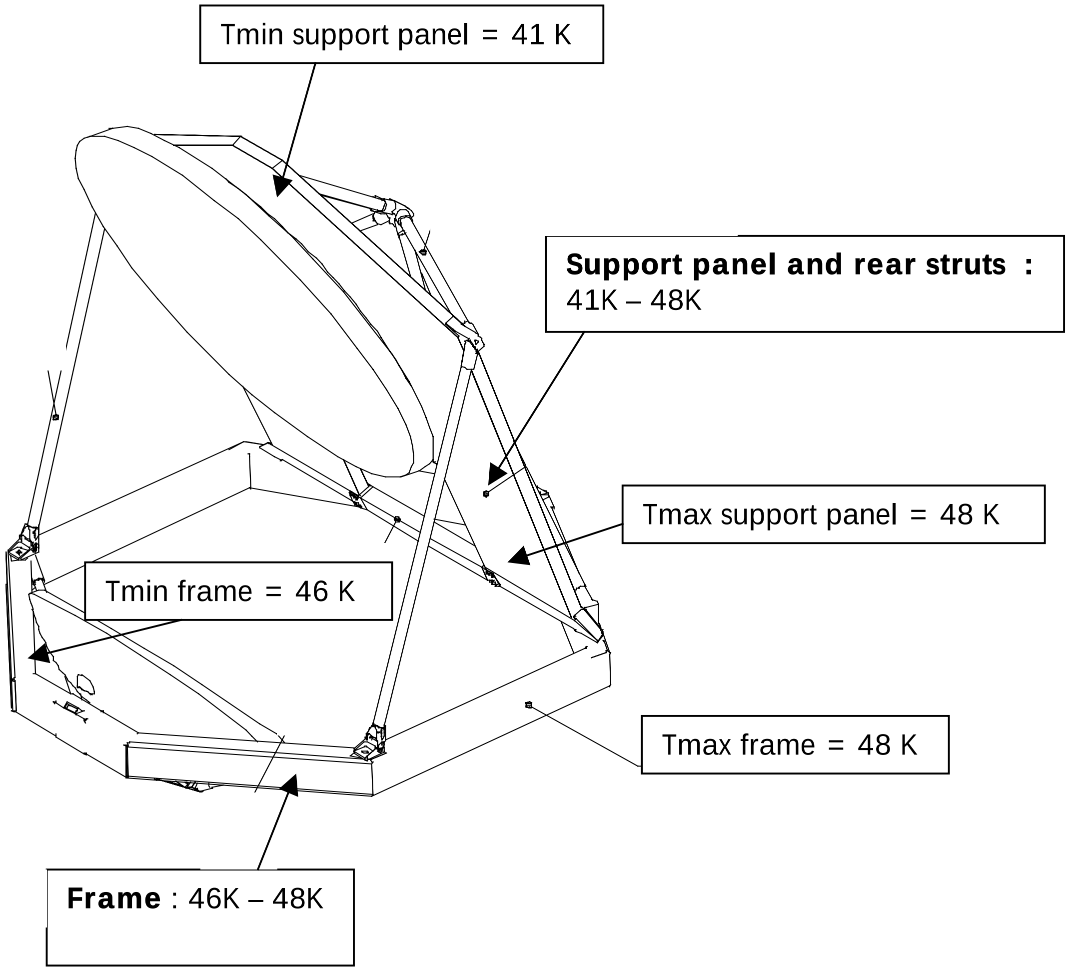



**Figure 5.6.2-2** : Telescope temperature distribution at operational conditions

*5.6.2.2 Thermal Shock*

P-TEL-ENV-110 The telescope with its surface coating shall withstand without performance degradation's a cool-down induced by a radiative temperature change of the thermal vacuum facility from 300 K to 50 K under vacuum within 5 hours

#### *5.6.2.3 Thermal Cycling*

P-TEL-ENV-115 The telescope with its surface coating shall withstand, without performance degradation's, in vacuum conditions, thermal cycling performed at telescope level and 2 cycles of temperature variations between 40 K and 323 K and 1 cycles of temperature variations between 40 K and the ambient performed at satellite level. Each cycle shall include a soak time long enough to achieve thermal equilibrium of the structure (the equilibrium condition is reached when any temperature rate-of-change is lower than 1°C/hour).

#### *5.6.2.4 Bake-out*

P-TEL-ENV-120 A bake-out of 80°C for a duration of 48 H on the telescope structure or a bake-out of 50°C for a duration of TBD H on the telescope structure equipped of the reflectors shall be applied to the telescope before delivery

P-TEL-ENV-125 The telescope shall withstand without degradation a bake-out temperature of 50°C in vacuum for a duration of 15 days (tbc).

### 5.6.3 Pressure

P-TEL-ENV-130 The telescope shall withstand any external air pressure between ambient (0.115 MPa) to vacuum ($<10^{-4}$ Pa).

P-TEL-ENV-135 Cavities within the telescope shall have adequate means of venting which can cope with the depressurisation profile as defined in AD 6.

### 5.6.4 Humidity

P-TEL-ENV-140 The telescope with its surface coating shall withstand without performance degradation's, a relative humidity as defined in EVTR of AD1.

### 5.6.5 Radiation

P-TEL-ENV-145 The telescope with its surface coating shall withstand without performance degradation's the radiation environment (type, total dose and dose rate) as defined in EVTR of AD1

### 5.6.6 Cleanliness/Cleanability

P-TEL-ENV-150 The telescope shall be manufactured such that it is cleanable in order to be able to remove contamination deposited during on-ground operations

P-TEL-ENV-155 The exposure of the coated surfaces to the ambient has to be minimised

P-TEL-ENV-160 The surface of the telescope shall be manufactured to withstand cleaning operations without degradation of the specified performance

P-TEL-ENV-165 Any product used during cleaning operations shall be submitted to ALCATEL approval

P-TEL-ENV-170 The maximum molecular contamination for the telescope shall not exceed $5.10^{-7}$ $g/cm^2$ at the delivery

P-TEL-ENV-175 The maximum particular contamination shall be lower than 900 ppm at telescope delivery in Alcatel premises.

### 5.6.7 Lifetime, Storage and Transport

#### *5.6.7.1 Lifetime*

P-TEL-ENV-180 The telescope shall be manufactured to withstand 6 years on-ground operations (including the storage conditions) followed by 2 years of in-orbit operations with no EOL performance degradation.

#### *5.6.7.2 Storage Environment*

P-TEL-ENV-185 The storage conditions and storage environment (container, clean room ...) shall not degrade the telescope EOL performances as specified in this document

#### *5.6.7.3 Transportability*

P-TEL-ENV-190 The telescope shall be able to be transported in horizontal and vertical position in an adequate transportation container

P-TEL-ENV-195 The design of the container for the telescope shall be compatible with all ground operations for transport in Europe.

P-TEL-ENV-200 The transportation environment (loads, temperatures, humidity, pressure ...) is as defined in the EVTR of AD1.

## 5.7 INTERFACE REQUIREMENTS

### 5.7.1 Mechanical

P-TEL-INT-005 The design of the telescope shall be compatible with the interface volume defined in PLATELSSW1000A of AD1.

P-TEL-INT-010 Interfaces defines in PLATELSSW1000A, PLATELSSW1100A and PLAFRAMW1000A of AD1 are at operational conditions..

P-TEL-INT-015 The telescope shall provides 6 I/F fixation points located on the main frame as described in Figure 5.7.1-1 and defined in PLATELSSW1100A and PLAFRAMW1000A of AD1 for telescope mounting onto the Cryo-structure

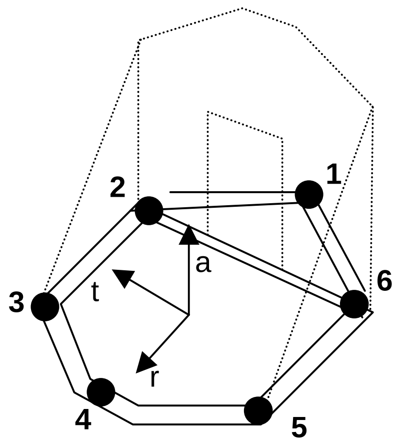



**Figure 5.7.1-1 :** Telescope/cryo-structure description

P-TEL-INT-020 The telescope shall provides 7 I/F points located on the main frame and the PR support panel for the fixation of the baffle as defined in Figure 5.7.1-2 and PLATELSSW1100A of AD1.

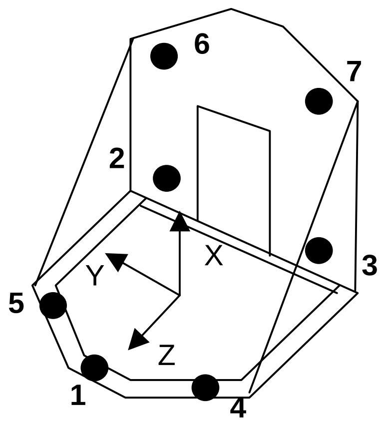


**Figure 5.7.1-2 :** Telescope/Baffle interface description

P-TEL-INT-025 The telescope shall provides 3 I/F points located on the PR panel for the fixation of the PR. Position at operational conditions are defined in PLATELSSW1100A of AD1.

**Table 5.7.1-1 :** Maximum displacement at the PR interface

P-TEL-INT-030 The telescope shall provides 3 I/F points located on the SR panel for the fixation of the SR. Position at operational conditions are defined in PLATELSSW1100A of AD1.

P-TEL-INT-033 The unstability of the PR and SR interface points between integration and EOL shall be lower than :

| | **Interface definition** | **Maximum displacement/rotation :** | **µm/µrd** | **Environment to be considered** |
|---|---|---|---|---|
| 1.1 | PR/telescope structure & SR/telescope structure | In the panel plane translation : homogeneous and signed radial displacement of the 3 I/F | + 100 | From integration to operational EOL |
| 1.2 | PR/telescope structure & SR/telescope structure | In the panel plane translation : random displacement of each I/F point | ± 10 | From integration to operational EOL |
| 1.3 | PR/telescope structure & SR/telescope structure | Out of the plane translation : random displacement of 1 I/F wrt the 2 others | ± 10 | From integration to operational EOL |
| 1.4 | PR/telescope structure & SR/telescope structure | Rotation around the axis in the panel plane : rotation of each I/F | ± 100 | From integration to operational EOL |
| 1.5 | PR/telescope structure & SR/telescope structure | Rotation around the axis perpendicular to the panel plane | Covered by the 1.2 | From integration to operational EOL |

P-TEL-INT-035 The telescope shall provides 4 I/F points located on the PR support panel and 2 I/F points located on the beam panel for the fixation of the FPA as defined in PLATELSW1100A of AD1.

P-TEL-PHY-037 The unstability of the FPA/PR panel interface points between integration and EOL shall be lower than :

| | Interface definition | Maximum displacement/rotation : | µm/µrd | Environment to be considered |
|---|---|---|---|---|
| 2.1 | FPU/telescope structure | In the panel plane translation (along Xordp or Yordp) : Average global displacement of the 6 I/F areas in the a same direction | ± 50 | After alignment operation to operational EOL |
| 2.2 | FPU/telescope structure | Out of the panel plane translation (along Zordp) : Average global displacement of the 6 I/F areas in the a same direction | ± 25 | After alignment operation to operational EOL |
| 2.3 | FPU/telescope structure | Rotation around the axis in the panel plan (Xordp and Yordp) : Average global rotation of the 6 I/F areas in the a same direction | ± 100 | After alignment operation to operational EOL |
| 2.4 | FPU/telescope structure | Rotation around the axis perpendicular to the panel plan (Zordp) : global rotation of the 6 I/F areas | Covered by 2.5 | From integration to operational EOL |
| 2.5 | FPU/telescope structure | In the panel plane translation (along Xordp or Yordp) : random displacement of each I/F area | ± 50 | From integration to operational EOL |
| 2.6 | FPU/telescope structure | Out the panel plane translation (along Zordp : random displacement of each I/F area | ± 25 (TBC) | From integration to operational EOL |
| 2.7 | FPU/telescope structure | Rotation around the axis in the panel plan (Xordp and Yordp) : random rotation of each I/F area | ± 200 (TBC) | From integration to operational EOL |

P-TEL-INT-040 The telescope shall provides 4 I/F points located on the PR panel and the frame for the Jfet and its bellow fixation as defined in PLATELSW1100A of AD1

P-TEL-INT-045 The telescope shall provides 6 (TBC) I/F points located on the PR panel and the frame for thermal braid fixation as defined in PLATELSW1100A of AD1

P-TEL-INT-050 The telescope shall provide 6 lifting points and transportation interfaces on the main frame for handling, integration, test and transportation

### 5.7.2 Instrumentation

P-TEL-INT-055 The telescope shall be equipped of 18 heat probes. The design and the location of the heat probes will be defined by the prime contractor.

### 5.7.3 optical

P-TEL-INT-060 The telescope main frame shall be equipped of optical alignment references (2 pin balls an2 corner cubes) for alignment purpose at satellite level. The definition and location of the optical alignment references will be defined by Alcatel.

### 5.7.4 Electrical

P-TEL-INT-070 The telescope have 2 electrical connections with the grounding system. The interface for the connection are TBD.

P-TEL-INT-075 The telescope have 2 electrical connections with the cryo-structure for temperature probes and heaters connection. The interface for the connection are TBD.

P-CRY-INT-077 The surfacic electrical resistivity of the coating shall be as follow :

**a**/ RS at 100 K is inferior to 1.10+9 ohm/square, when measured by ASTM D257-99 methodology at T ≤100 K

b/ RS is inferior to 1.10+11 ohm/square, when measured

- under electron gun irradiation 20 – 30 Kev, 1 nA .cm-2
- at T ≤100 K
- under vacuum (about 10-6 mbar)
- in representative moisture state

### 5.7.5 Thermal

P-TEL-INT-080 The solar absorptance of the surfaces of the different elements at their operational temperature shall be as defined in the following table :

| Items | Solar absorptivity EOL |
|---|---|
| | |
| Internal face of the PR panel | α ≤ 0.2 |
| External face of the PR panel | 0.8 ≤ α ≤ 1 |
| Other components | 0.8 ≤ α ≤ 1 |

P-TEL-INT-085 The solar absorptance of the surfaces of all elements of the telescope structure shall be known with an accuracy better than 10 %

P-TEL-INT-090 The heat capacity of the different elements at 293 K shall be as defined in the following table :

| Items | Heat capacity (W/kg/K) |
|---|---|
| | |
| PR panel | 860 ± 15% |
| SR panel | 860 ± 15% |
| Main frame | 850 ± 15% |
| Struts | 850 ± 15% |

P-TEL-INT-095 The heat capacity of all elements of the telescope structure shall be known with an accuracy better than 10 %.

P-TEL-INT-100 The thermal conductivity of the grounding electrical interface shall be known. The conductance of the grounding electrical interface shall not exceed 0.1 W/K in order to not disturb the telescope thermal control.

### 5.7.6 MGSE

P-TEL-INT-105 The telescope MGSE shall be design taking into account requirements defined in H-P-1-ASP-SP-066 of AD1

P-CRY-INT-110 The telescope MGSE shall be design taking into account volume and accessibility constraints defined in PLA CRYS S 8100A af AD1.

## 5.8 DESIGN AND CONSTRUCTION REQUIREMENTS

### 5.8.1 Safety factors

Following safety factors 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.

P-TEL-DES-005 To cover the qualification test loads the flight limit loads shall be increased by the qualification factor as defined in GDIR of AD1..

P-TEL-DES-010 To avoid permanent deformation or any elastic deformation resulting in performance degradation the following yield safety factor shall be applied as defined in GDIR of AD1.

P-TEL-DES-015 To avoid rupture, buckling or permanent deformation leading to loss of functionality, the ultimate safety factor as defined in GDIR of AD1 shall be applied

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

### 5.8.2 Sizing Factors

P-TEL-DES-020 The material strength data for metals as well as composites with a 99% statistical probability at a confidence level of 95% (A-values) shall be used for Margin of Safety evaluation.

P-TEL-DES-025 For the design of the telescope, the sizing factors as defined in GDIR of AD1 shall be applied to limit loads. Defined in 5.4.1.1

### 5.8.3 Structural Design

P-TEL-DES-027 The structural strength dimensioning shall take into account masses increased of 15% for strength calculations.

P-TEL-DES-030 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 in GDIR of AD1.

### **5.8.4** Assembly requirements

P-TEL-DES-035 The telescope shall be designed so that the lower dismountable beam of the PR panel structure defined in PLATELSW1100A of AD1 could be removed from the telescope without WFE performance degradation.

P-TEL-DES-040 The telescope shall be designed so that the lower dismountable beam of the PR panel structure defined in PLATELSW1100A of AD1 could be removed from the telescope without dismounting of the other components and taking into account the volume constraints as defined in PLA CRYS S 8100A af AD1.

# 6. PRODUCT ASSURANCE REQUIREMENTS

Product assurance requirements are defined in H-P-1-ASP-SP-018 of AD1

# 7. VERIFICATION REQUIREMENTS

## 7.1 Similarity, Analysis, Inspection and Test

P-TEL-VER-010 The requirements verification matrix shall be established with a rationale as to why various parameters are verified by analysis, inspection, similarity with other models or by testing:

## 7.2 Minimum test programme

P-TEL-VER-015 The following verification matrix defines the verifications and controls which are required on development samples, manufacturing witness samples and telescope models as a minimum

Some environment test (as thermal, radiation,..) required on development samples can be cancelled if the contractor can justify the similarity of materials and process with an other qualified hardware.

## 7.3 Acceptance/Rejection Criteria

P-TEL-VER-045 The Subcontractor shall as part of his test/verification plan and procedures clearly define rejection/acceptance criteria in compliance with the objective of the test

P-TEL-VER-050 The Subcontractor shall define conditions when a retest may be acceptable

| **Requirement** | **Verification** | | | |
|---|---|---|---|---|
| | Inspection / revue | Analysis | Test | |
| | | | Sample **(1)** | Telescope (QM & FM) |
| GENERAL FUNCTIONNAL REQUIREMENTS | X | X | X | X |
| | | | | |
| PERFORMANCE REQUIREMENTS | | | | |
| Opto-mechanical performance Requirements | | | | |
| Telescope design | X | X | | X |
| Telescope FoV | | X | | X |
| Emissivity | X | X | X | |
| WFE performance **(2)** | X | X | | X |
| WFE contributors | X | | | |
| LOS stability **(3)** | X | X | | X |
| Mechanical requirements | | | | |
| Frequencies | | X | | X |
| Thermal requirements | | | | |
| Thermal properties of the surfaces **(4)** | X | X | X | |
| Conductivity **(5)** | | X | X | |
| | | | | |
| PHYSICAL REQUIREMENTS | | | | |
| Dimensions and design | X | X | | X |
| Mass, Center of gravity, inertia **(8)** | X | X | | |
| Alignment **(6)** | X | X | | X |
| | | | | |
| ENVIRONMENTAL REQUIREMENTS | | | | |
| Mechanical | | | | |
| Quasi-static loads | | X | | X |
| Sinusoidal **(9)** | | X | | X |
| Acoustic | | X | | X |
| Maximum displacements | | X | | X |
| Shocks | | X | | |
| Interface loads | | X | | X |

| **Requirement** | **Verification** | | | |
|---|---|---|---|---|
| | Inspection / revue | Analysis | Test | |
| | | | Sample **(1)** | Telescope QM & FM |
| Thermal | | | | |
| Temperature **(5)** | X | X | | X |
| Thermal Shock | X | X | X | |
| Thermal Cycling | X | X | | X |
| Bake-out | X | X | X | |
| Pressure | X | | | |
| Humidity | X | X | X | |
| Radiation | X | X | X | |
| Cleanliness/Cleanability | X | | X | |
| Lifetime, Storage, Handling and Transport | | | | |
| Lifetime | X | X | | |
| Storage Environment | X | X | | |
| Handling | X | | | |
| Transportability | X | X | | |
| | | | | |
| INTERFACE REQUIREMENTS | | | | |
| Mechanical **(6)** | X | X | | X |
| Electrical | | | | |
| Therma | X | X | X | |
| MGSE | X | X | | |
| | | | | |
| DESIGN AND CONSTRUCTION REQUIREMENTS | | | | |
| Sizing Factors | X | X | | |
| Structural Design Margins | X | X | | |
| Assembly requirements **(7)** | X | X | | X |
| | X | | | |

**(1)** : Tests shall be performed on samples representative of the design and manufacturing process of the parts on which the specification is applied. The number of samples and the procedure to obtain them shall guaranteed that the test results can be extrapolated for the all surface or part.

**(2)** The WFE measurement shall include :

- WFE at ambient, before and after mechanical test. The test shall include measurement at the centre of the field and at minimum 4 point at the edge of the field. The WFE at the other position in the field shall be computed.

- Specific WFE measurement to identify gravity effects

- - WFE measurement at cryogenic temperature. . The test shall include measurement at the centre of the field and at minimum 4 (TBC) point at the edge of the field. The WFE at the other position in the field shall be computed.

Map of WFE shall be provided.

**(3)** Alignment measurement shall be performed :
- at ambient before and after mechanical test
- at cryogenic temperature

**(4)** As a minimum, the verification program to test the high emissivity at low temperature, shall include :

1. High emissivity coating

- Emissivity of the coating

| | T = 293 K | T = 150 K | T = 50 K |
|---|---|---|---|
| Total hemispherical emissivity | × | × | |
| Normal reflectance | All the spectrum of wavelength | All the spectrum of wave length | All the spectrum of wave length |
| BRDF(*) | • For different incidences between 8° and 75°<br>• For different wavelength between 30 µm and 200 µm | NA | NA |

(*)Direct Spectral Emissivity measurements could be proposed instead of BRDF measurements. In that case, they shall be as defined here after :

| | |
|---|---|
| Direct Spectral Emissivity measutrements | • Between 40 K and 293 K<br>• For different incidences between 0° and 75° |

TBD coated samples representative of the manufacturing coating process shall be provided to Alcatel.

2. Low emissivity coating

The measurement of the total hemispherical emissivity at 293 K shall be performed.

**(5)** Properties such as :
Mechanical properties (modulus, strength of the material and junction),
Thermal properties (CTE, Conductivity)
thermo-optical (absortivity, emisivity, reflectivity)

Shall be measured at operational temperature and over the temperature range included between ambient and the operational.

**(6)** Position and stability of the FPU interfaces could be measured using FPU alignment dummy

**(7)** Shall be validate with WFE measurement before and after dismounting/mounting operation

**(8)** :Compliance to the mass requirement can be reached at telescope-cryostructure level

**(9)** Test structure support to be used for the telescope sine test shall be representative of the CS stiffness such that general dynamic behaviour (telescope main modes, equipment dynamic response) will be representative of the modelled dynamic behaviour (telescope main modes, equipment dynamic response) within :

- telescope main mode : 5% (TBC)
- equipment dynamic response : TBD %

------------------------------------------------ End of Document -----------------------------------------