



Programme: **ELT**

Project: **ELT MCAO Construction – MORFEO**

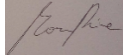

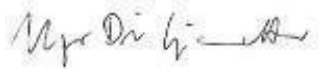
# MORFEO MAIN STRUCTURE AND HANDLING TOOLS COMMON REQUIREMENTS

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## Change Record from previous version

Date	Affected Section(s)	Changes / Reason / Remarks
30-10-2025	all	first draft
23/12/25	Sec 3.1.2.	New IAA loads



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## 1 Related Documents

### 1.1 Applicable Documents

#### MAO-PM0-1.6 Applicable documents

The following documents, of the exact version shown, form part of this document to the extent specified herein. In the event of conflict between the documents referenced herein and the content of this document, the content of this document shall be considered as superseding the others.

- AD1. E-MAO-PM0-INA-SPE-004 PM0 Technical Specifications
- AD2. E-MAO-SE0-INA-SPE-007 NASMYTH INTERFACE REQUIREMENTS FOR MORFEO MAIN STRUCTURE SUBSYSTEM and HANDLING TOOLS<sup>1</sup>
- AD3. ESO-044295 Electrical and Electronic Design Standards v:4
- AD4. Execution of steel structures and aluminium structures; EN 1090
- AD5. Standard Components and Guidelines for Cooling Circuits; ESO-254314 Version 6
- AD6. ESO-193497 SAF-GEN-MAN-3444 ESO Safety Conformity Assessment Procedure, issue 5
- AD7. ESO-192984 ESO Mechanical Standards, issue 2
- AD8. ESO-191462 ESO Engineering Analysis Standard, issue 2
- AD9. ESO-262825 E-ELT Electrical and Electronic Design Requirements

### 1.2 Reference Documents

- RD1. ESO-225669 Packing Recommendations Issue 3

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<sup>1</sup> This document is a flow down of the ESO document ESO-253082 Common ICD between the E-ELT Nasmyth Instruments and the Rest of the E-ELT system, that cannot be published in the cft, but only shared with the assigned contractor.



## 2 Introduction

### 2.1 Scope

MORFEO (formerly known as MAORY) is the Adaptive Optics Module for ELT.

This document contains the requirements extracted from the ESO-254547 “Common requirement for ELT Instruments that are applicable to the MORFEO Main Structure.

### 2.2 Naming Convention

Requirements are identified with a requirement tag following the format [MAO-PM0-XXX], where XXX is a unique, non-speaking number.

In section [7](#) is reported for each requirement the minimum verification method to be applied for the requirement verification during the main project phases.

### 2.3 Abbreviations and Acronyms

AD	Applicable Document
AO	Adaptive Optics
ARR	Acceptance Readiness Review
CNRS	Centre National de la Recherche Scientifique
CII	Core Integration Infrastructure
DER	Design Report
DM	Deformable Mirror
DMAMU	DM Adaptive Mirror unit
DMLCS	DM Local Control System
DMKS	DM Kinematic support
ELT	European Extremely Large Telescope
ESO	European Southern Observatory
FDR	Final Design Review
FoV	Field of View
HW	Hardware
IAA	Instrument Assembly Area
ICD	Interface Control Document
ICH	Instrument Control Hardware



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I-PXX/SE0	Interface between PXX subsystem and DMs subsystem
INAF	Istituto Nazionale di AstroFisica
INS	Instrumentation Software
INSU	Institut National des Sciences de l'Univers
IWS	Instrument Workstation
IORR	Instrument Operations Readiness Review
IPAG	Institut de Planétologie et d'Astrophysique de Grenoble
IRD	Interface Requirement Document
LCI	Local Communication Infrastructure
LGS	Laser Guide Stars
LOR	Low Order and Reference
MAIT	Manufacturing Assembly Integration and Test
MORFEO	Multi conjugate adaptive Optics Relay For ELT Observatory
MCAO	Multi Conjugate Adaptive Optics
MCMT	Maximum Corrective Maintenance Time
MICADO	Multi-AO Imaging Camera for Deep Observations
MDT	Mean Down Time
MOI	Moment of Inertia
MTBF	Mean Time Between Failures
N/A	Not Applicable
NGS	Natural Guide Star
NP	Nasmyth Platform
NUIG	School of Physics at the National University of Ireland Galway
OAA	Osservatorio Astrofisico di Arcetri
OAAB	Osservatorio Astronomico d' Abruzzo
OAB	Osservatorio Astronomico di Brera
OACN	Osservatorio Astronomico di Capodimonte
OAPD	Osservatorio Astronomico di Padova
OAS	Osservatorio di Astrofisica e Scienza dello Spazio di Bologna
PAC	Preliminary Acceptance Review in Chile
PAE	Preliminary Acceptance Europe
PDR	Preliminary Design Review
PLC	Program Logic Controller
PFS	Primary Focal Station
SE0	MORFEO DM subsystem
PH0	MORFEO Instrument control Electronics Subsystem
PI	Principal Investigator
PM	Project Manager
PM0	MORFEO Main Support Structure Subsystem
PSF	Point Spread Function
PT	Product Tree
PR0	MORFEO RTC subsystem



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PSO	MORFEO Software subsystem
PTO	MORFEO Thermal control subsystem
RAMS	Reliability, Availability, Maintainability and Safety
RBM	Rigid Body Motion
RD	Reference Document
RMS	Root Mean Square
RON	Read Out Noise
RTC	Real-Time Computer
SAT	System Architect Team
SCAO	Single-conjugate Adaptive Optics
SCS	Standard Coordinates System
SE	System Engineer
SET	System Engineering Team
SOW	Statement of Work
SMR	Spherical Mounted retroreflector
SMU	Sensor Monitor Unit
SR	Strehl Ratio
SRR	System Requirements Review
SRS	Standard Reference System
SW	Software
TBC	To Be Confirmed
TBD	To Be Defined
TBW	To Be Written
TP	Temperature Probe
WFS	Wavefront Sensor
WP	Work Package
WS	Workstation

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## 3 Common Requirement

### 3.1 Environmental Conditions

#### *3.1.1 MAO-PM0-2.1.1: Nominal Operating Conditions*

##### **MAO-PM0-2.1.1.1: info operational condition definition**

###### *INFO*

###### Operational Conditions:

The Operational Conditions are those under which Morfeo-Main Structure shall meet all the performance requirements specified in its Technical Specification and applicable documents.

##### **MAO-PM0-2.1.1.2: info functional condition definition**

###### *INFO*

###### Functional Conditions:

The Functional Conditions are those under which Morfeo-Main Structure shall still be fully functional albeit not necessarily meeting all the performance requirements specified in its Technical Specification.

##### **MAO-PM0-2.1.1.3: info survival condition definition**

###### *INFO*

###### Survival Conditions:

Survival Conditions are occasional (2-5 times within 10 years) accidental conditions of different severity which may be experienced by Morfeo-Main Structure during their lifetime. Morfeo-Main Structure shall survive such events and shall be able to restart operation after their occurrence:

- a) No damage of Morfeo-Main Structure is allowed.
- b) All the functional and performance requirements defined in the present technical specifications shall still be met after actions taken as defined in the Operations Manual agreed with the consortium.

##### **MAO-PM0-2.1.1.4: Applicability of operating condition**

###### *REQUIREMENT*

Unless otherwise specified all the requirements in this document shall be met under the nominal operating conditions defined in [Nasmyth nominal Operating conditions](#)

*Note:*

*NA*

#### 3.1.1.1 MAO-PM0-2.1.1.5: Nasmyth Instruments



**MAO-PM0-2.1.1.5.1: Nasmyth nominal Operating conditions**

**INFO**

The Nominal Operating Conditions for Morfeo-Main Structure are provided in the Table below:

	<b>Operational</b>	<b>Functional</b>	<b>Survival</b>
<b>Air density</b>	0.87kg/m <sup>3</sup> (Median)		0.92kg/m <sup>3</sup>
<b>Air Pressure</b>	712 mbar ± 50 mbar		N/A
<b>Air Temperature</b>	0°C to +15°C	-5°C to +20°C	-10°C to +25°C
<b>Air temperature gradient at night time</b>	-0.55°C/h to +0.5°C/h	-1.0 °C/h to +1.4°C/h	-10.0°C/h to +10.0°C/h (over 30 min) -5.0°C/h to +5.0°C/h (over 1 h)
<b>Relative Humidity range</b>	5% to 80%		3% to 100% with condensation
<b>Average wind speed</b>	<2 m/s	<3 m/s	<16 m/s
<b>Ozone Concentration</b>	<180µg/m <sup>3</sup>		
<b>Dust and Sand</b>	ISO 7.2 (median) and ISO 8 (90% percentile), according to EN ISO 14644-1: 1999.		
<b>Aggressive Atmosphere</b>	NO ≤ 3ppb, NO <sub>2</sub> ≤ 3ppb, SO <sub>2</sub> ≤ 3ppb		

this requirement is refined by MAO-PM0-1.1.2 of AD1

**MAO-PM0-2.1.1.5.2 Derived from Earthquake loads Vs eigenfreq**

**REQUIREMENT**



The applicable quasi-static earthquake acceleration shall depend on the instrument's<sup>2</sup> first lowest eigenfrequency and shall be given by the following table:

Instrument's 1 <sup>st</sup> Eigenfrequency [Hz]	Quasi-static acceleration	
	Horizontal (x,y) [g]	Vertical (z) [g]
7	3.6	2.3
8	3.6	2.25
9	3.6	2.21
10	3.00	2.16
11	2.92	2.12
12	2.83	2.07
13	2.75	2.02
14	2.67	1.98
15	2.58	1.93
16	2.50	1.88
17	2.30	1.84
18	2.10	1.79
19	1.90	1.75
20	1.7	1.7
21	1.7	1.7
22	1.7	1.7
23	1.7	1.7

#### MAO-PM0-2.1.1.5.3 Temperature inside the dome

##### INFO

The temperature inside the Dome (i.e., in the telescope chamber) will be typically maintained during the day at a reference temperature (usually the expected temperature for the beginning of the next night minus one or two degrees).

This typical approach may vary due to operational constraints or strong outside temperature variations. Hence instruments designs shall not consider the telescope chamber as a precise thermally controlled environment. Nevertheless, aiming to provide a thermal environment for instruments calibration as close as possible to the nighttime temperature, the daytime temperature target in the (at least) first two hours after closing the Dome will be kept equal to the outside temperature at the time of closing the Dome, except in the cases where operational constraints will prevent doing so.

At the beginning of the night the Dome is opened and the temperature inside the Dome will follow the outside ambient night temperature.

#### MAO-PM0-2.1.1.5.4 Yearly median Night Temperature

##### INFO

<sup>2</sup> Being the main structure the host of the payloads, the analysis shall be performed including all the payload defined in AD1. The eigenfrequency to be considered is the one of the complete assembly payloads included

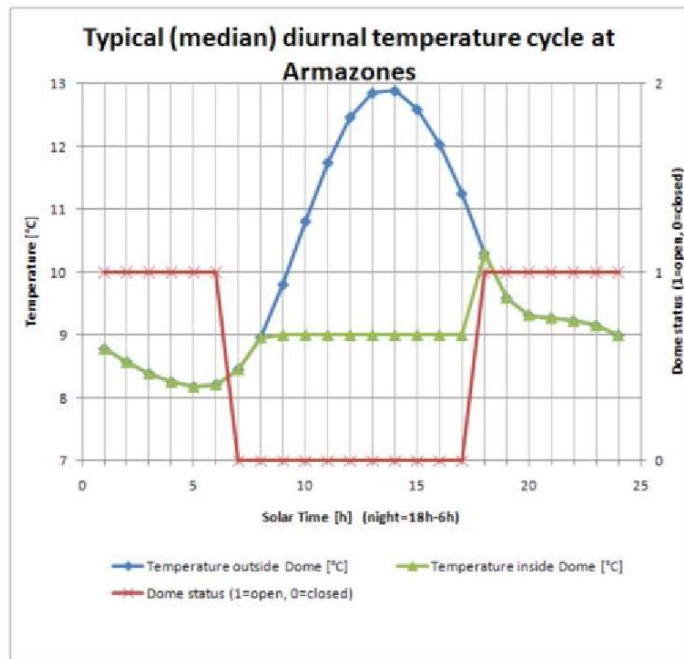


The yearly median night-time air temperature is 9.1°C with ± 1.5°C median seasonal variations.

**MAO-PM0-2.1.1.5.5 Typical diurnal temperature cycle**

**INFO**

Solar time [h] night=18h-6h	Temperature outside Dome [°C]	Dome status 1=open, 0=closed	Temperature inside Dome [°C]
1	8.78	1	8.78
2	8.57	1	8.57
3	8.39	1	8.39
4	8.25	1	8.25
5	8.18	1	8.18
6	8.21	1	8.21
7	8.46	0	8.46
8	8.96	0	8.96
9	9.80	0	9.00
10	10.81	0	9.00
11	11.74	0	9.00
12	12.47	0	9.00
13	12.85	0	9.00
14	12.89	0	9.00
15	12.59	0	9.00
16	12.04	0	9.00
17	11.25	0	9.00
18	10.30	1	10.30
19	9.59	1	9.59
20	9.31	1	9.31
21	9.27	1	9.27
22	9.22	1	9.22
23	9.15	1	9.15
24	8.99	1	8.99



A typical (median) diurnal temperature cycle is defined in the figure below for both natural environment and induced environment inside the Dome. In case this cycle is used in a simulation with time step smaller than 1 h, note that the time to open or close the Dome shall be assumed to be 12 minutes. Regarding the typical temperature profile during daytime.

**MAO-PM0-2.1.1.5.6 Bolometric Sky Temperature**

**INFO**

The bolometric sky temperature (relevant for radiative heat transfer computation) in cloudless nights is given by the formula

$$T_{sky} = T_{amb} - 45.75 + 6.52 \times \ln(PWV) + 2.5 \times 10^{-4} \times \theta^2.5$$

where  $T_{amb}$  is the ambient air temperature 7 meters above the ground measured in Kelvin,  $PWV$  is in mm, and the zenith distance  $\theta$  is measured in degrees. The function  $\ln()$  denotes the natural logarithm (basis e).

At  $PWV = 2.40$  mm (or 1.48 mm, 3.91 mm, respectively) and  $\theta = 37^\circ$ , the sky is colder than the ambient air by  $T_{sky} - T_{amb} = -38$  K (or  $-41.1$  K,  $-34.8$  K).



**3.1.2 MAO-PM0-2.1.2: Specific Conditions**

**MAO-PM0-2.1.2.1: definition of specific operating condition**

**INFO**

The Specific Operating Conditions apply to:

- Morfeo-Main Structure (Re-)assembly at the Observatory
- Morfeo-Main Structure Integration
- Maintenance
- Transport and Storage

**3.1.2.1 MAO-PM0-2.1.2.2: Conditions Applicable to (Re-)Assembly, Integration and Maintenance**

**MAO-PM0-2.1.2.2.1: Applicability of Reassembly Integration and Maintenance condition**

**REQUIREMENT**

The conditions defined in 2.1.2.2.1 shall apply to the (re-)assembly, integration and maintenance of MORFEO t the observatory.

Note:

NA

**MAO-PM0-2.1.2.2.2: Reassembly Integration and Maintenance condition**

**INFO**

	Typical	Survival
<b>Gravity orientation (Z<sub>c</sub> wrt vertical*)</b>	< 1 deg	NA
<b>Air Pressure</b>	712mbar +/-50mbar	NA
<b>Air Temperature</b>	0°C to +15°C inside the telescope dome	NA
	+15°C to +21°C inside the Instrument Assembly Area	NA



<b>Earthquake</b>	none	<p>For the Instrument Assembly Area as defined in <b>MAO-PM0-2.1.2.2.3</b> in combination with <b>MAO-PM0-2.1.2.2.4</b>,</p> <p>For the Nasmyth Platform as defined in <b>MAO-PM0-2.1.2.2.5</b></p>
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**MAO-PM0-2.1.2.2.3: Earthquake acceleration in IAA**

**REQUIREMENT**

The applicable quasi-static earthquake acceleration in the Instrument Assembly Area shall depend on the MSS, or part of it to be (re)-assembled, integrated or maintained, first lowest eigenfrequency (any direction for horizontal acceleration x/y, and the first vertical eigenmode with significant, i.e. > 10%, effective mass along vertical direction (z) for vertical acceleration z), and shall be given by the following table:

1 <sup>st</sup> eigenfreq [Hz]	Horizontal [x] g	Horizontal [y] g	Vertical [z] g
9	0.29	0.26	3.89
10	0.29	0.26	3.57
11	0.19	0.10	1.95
12	0.16	0.10	1.62
15	0.08	0.06	1.30
20	0.06	0.04	0.81
30	0.05	0.04	0.32
50	0.04	0.04	0.32

Note:

NA

**MAO-PM0-2.1.2.2.4: Earthquake acceleration derating factor**

**REQUIREMENT**

In case of a time duration for the (re)-assembly, integration or maintenance of the instrument in the Instrument Assembly Area of shorter than 180 days, the following derating factors may be applied to the applicable accelerations defined in **MAO-PM0-2.1.2.2.3**:

For time durations longer than 180 days the following factors shall be applied

Actual time duration [d] for the (re)-assembly, integration or maintenance ≤	Horizontal [x] g
1	0.00



7	0.34
14	0.43
30	0.55
60	0.69
90	0.80
120	0.88
180	1.00
1 yr	1.27
2 yr	1.59
5 yr	2.16

Note:

NA

**MAO-PM0-2.1.2.2.5: Earthquake acceleration in Nasmyth (limited time)**

**REQUIREMENT**

The applicable quasi-static earthquake acceleration on the Nasmyth Platform for assemblies of a limited time period of less or equal 180 days shall depend on the assembly's lowest eigenfrequency as well as on the duration for which the assembly is on the platform, and shall be given by the following table:

<b>Frequency and time dependent quasi-static accelerations on the ELT Nasmyth Platform</b>						
<b>No frequency constraints</b>				<b>Assembly's 1st Eigenfrequency</b>		<b>All modes possibly excited* All &lt; 1Hz</b>
				<b>&gt;7 Hz</b>	<b>&gt;10 Hz</b>	
<b>Time Duration</b>	<b>Horizontal [x] g</b>	<b>Horizontal [y] g</b>	<b>Vertical [z] g</b>	<b>Horizontal [x] g</b>	<b>Horizontal [y] g</b>	<b>Vertical [z] g</b>
<2 h	0.0	0.0	0.0	0.0	0.0	0.0
2h – 10h	0.10	0.10	0.10	0.10	0.10	0.10
1d	0.16	0.10	0.10	0.10	0.10	0.10
3d	0.52	0.29	0.22	0.15	0.10	0.10
10d	1.82	1.04	0.78	0.52	0.13	0.10
30d	5.73	3.28	2.46	1.30	0.41	0.16
60d	7.00	4.00	3.00	1.30	0.50	0.20
90d	7.00	4.00	3.00	1.30	0.50	0.20
180d	7.00	4.00	3.00	1.30	0.50	0.20



*Note: \* This needs to be agreed with ESO on a case-by-case basis. It can be justified for instance, if the first modes are efficiently decoupling all the system from the excitation. It would mean that basically all the energy of the earthquake is “absorbed” by the first modes < 1 Hz translating in very slow motion of the whole system and not leading to higher frequency excitations that could potentially cause structural damage.*

NA

### 3.1.2.2 MAO-PM0-2.1.2.3: Conditions Applicable to Transport and Storage

#### MAO-PM0-2.1.2.3.1: definition of transport operating condition 1

**INFO**

Transport Conditions are those to which Morfeo-Main Structure will be exposed on the way to its intended place of operation. This might refer to transport from Europe to Chile as well as transport at the observatory site or from Paranal to Armazones.

#### MAO-PM0-2.1.2.3.2: definition of transport operating condition 2

**INFO**

	Typical	Survival
<b>Gravity orientation (Z<sub>c</sub> wrt vertical*)</b>	< 1 deg	NA
<b>Air Pressure</b>	712mbar +/-50mbar	NA
<b>Air Temperature</b>	0°C to +15°C inside the telescope dome	NA
	+15°C to +21°C inside the Instrument Assembly Area	NA
<b>Earthquake</b>	none	±1.3 g quasi static in any direction



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	Typical	Survival
<b>Gravity orientation (wrt ZC axis)</b>	As specified in packing requirements	NA
<b>Air Pressure</b>	570 mbar to 1045 mbar	NA
<b>Air Temperature</b>	-15°C to +45 °C	-33°C to +85 °C (*)
<b>Rain</b>	None	10 cm/h with a droplet size of 0.5 to 4.5 mm and a wind velocity of 18 m/s
<b>Relative Humidity range</b>	3% to 100% condensing	NA
<b>Blowing Dust and Sand</b>	Particle size 74 to 1000 micrometers, mostly 74 to 350 micrometers  Particle concentration: 1.0 g/m <sup>3</sup>  Wind speed 18 to 30 m/s	NA
<b>Shipping vibration loads</b>	As defined by PSD in MAO-SF0-2.1.2.3.4	NA



<b>Quasi-static load accelerations</b>	As defined in MAO-SF0-2.1.2.3.6	NA
<b>Salt concentration</b>	5% ± 1%	20%
<b>Mechanical shocks</b>	none	Drop height 20 cm
<b>Earthquake</b>	none	± 1.3 g quasi static in any direction

(\*) These are the most severe or extreme induced conditions, such as storage in unprotected areas (cold) or within enclosed compartments with glazed or transparent panels upon sun radiation (hot).

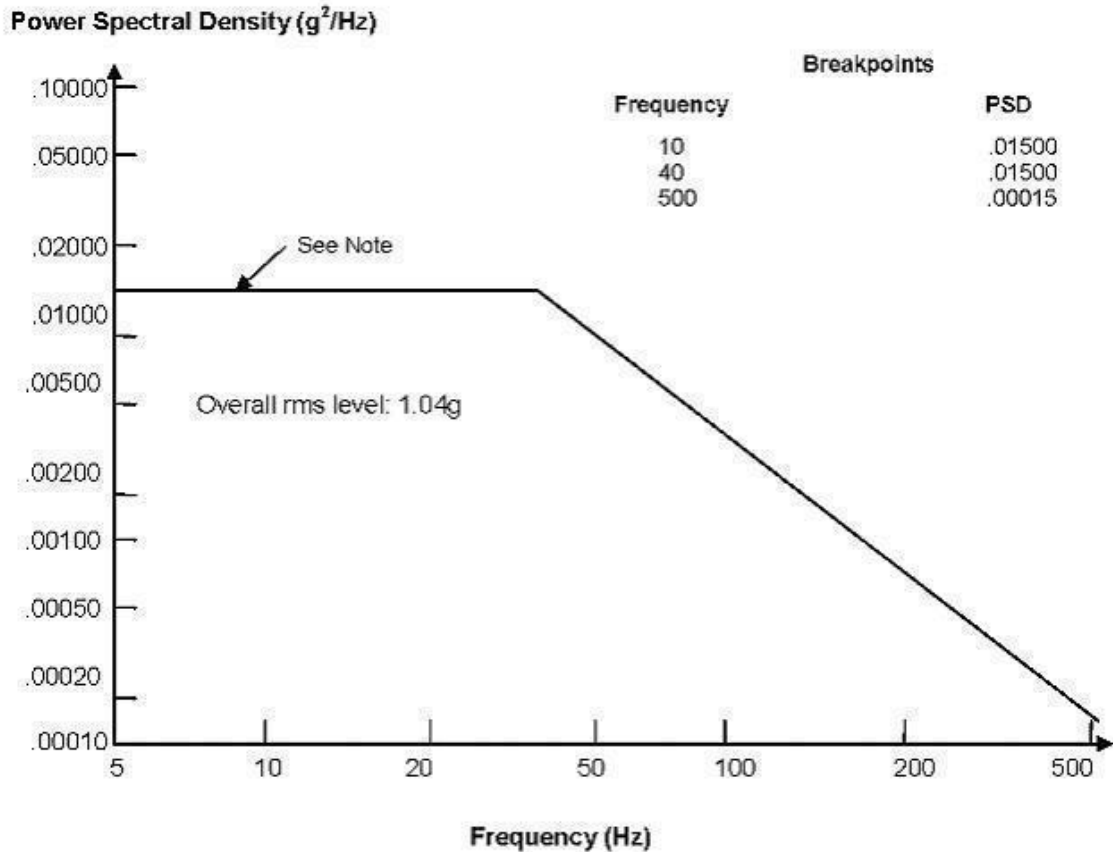
### **MAO-PM0-2.1.2.3.3: definition of transport operating condition 3**

#### **INFO**

The power spectral density of accelerations applicable to transport is defined in the figure below:

### **MAO-PM0-2.1.2.3.4: definition of transport operating condition 4**

#### **INFO**



NOTE: If the item is resonant below 10 Hz, extend the curve to the lowest resonant frequency

**MAO-PM0-2.1.2.3.5: Applicability of transport and storage condition**

**REQUIREMENT**

The conditions defined in 2.1.2.3.2, 2.1.2.3.3, 2.1.2.3.4 and 2.1.2.3.6 shall apply when transporting and storing Morfeo-Main Structure .

Note:

NA

**MAO-PM0-2.1.2.3.6: Transport quasi static acceleration**

**INFO**

Unless otherwise specified by applicable norms and guidelines and approved by the consortium, the following quasi-static accelerations occurring during transport shall be assumed :

Mode of transport	Acceleration acting
-------------------	---------------------



	<b>in the direction of travel</b>	<b>sideways</b>	<b>vertical</b>
Road	1g (forward) 0.5g (backward)	±0.6g	±1.5g
Rail	±4g (subject to shunting) ±1g (combined/intermodal)	±0.5g	±0.4g
Sea	±0.4g	±0.8g	±2g (front of ship bay) ±0.5g (central bay) ±1g (rear bay)
Air	±1.5g	±1.5g	±3g

Note: combined/intermodal is meant for wagons with containers, swap-bodies, semi-trailers and trucks and also "block trains" (UIC and RIV)

Note:

NA

### 3.1.3 MAO-PM0-2.1.3: Load Combination Factors

#### MAO-PM0-2.1.3.1: Applicability of load combination factors

##### REQUIREMENT

For the verification of the performance and structural integrity, as a minimum the following load combinations and corresponding factors shall be analysed:

Note:

NA

#### MAO-PM0-2.1.3.2: load combination factors definition

##### INFO

				Load combination factor
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Load combination	Load Category	Section	Permanent load	Survival temperature	Maximum acceleration (earthquake, shock)
LC1	Operational Conditions	3.1.1 Nominal Operating Conditions	1.0 x O <sup>(1)</sup>		
LC2	Survival/Accidental	3.1.1 Nominal Operating Conditions	1.0 x O <sup>(1)</sup>	1.0	
LC3	Survival/Accidental	3.1.1 Nominal Operating Conditions	1.0 x O <sup>(1)</sup>		1.0
LC4	Survival/Accidental	3.1.2.1 Conditions applicable to assembly	As per section 3.1.2.1		1.0
LC5	Survival/Accidental	3.1.2.1 Conditions applicable to integration and alignment into the telescope	As per section 3.1.2.1		1.0
LC6	Survival/Accidental	3.1.2.2 Transport	As per section 3.1.2.2	1.0	
LC7 (Shock Load)	Survival/Accidental	3.1.2.2 Transport	As per section 3.1.2.2	0.7	1.0
LC8 (Earthquake)	Survival/Accidental	4.2.2 Storage	As per section 4.2.2		1.0

O: Operational load conditions (i.e. gravity, operational temperature range, internal stress).

“1.0 x O (1)” means that the operational load conditions defined in section 4.1 has to be multiplied with the load combination factor of 1.0. The operational load conditions are defined in the table of [MAO-PM0-2.1.1.5.1] in the column “Operational”

## 3.2 MAO-PM0-2.2: Physical, Functional and Performance Requirements

### 3.2.1 MAO-PM0-2.2.1 Physical Characteristics

#### MAO-PM0-2.2.1.1 Specific Design volume definition

##### INFO

The maximum allowed design volume is specified in AD1.

##### INFO



### **MAO-PM0-2.2.1.2 Specific Access requirement definition**

#### **INFO**

Access requirements (e.g., category of access, dimensions) are specified in AD1. This may include access to the base of the prefocal station for maintenance personnel as well as to MORFEO-Main Structure subsystem and modules with adjacent design volumes.

### **MAO-PM0-2.2.1.3 Specific mass definition**

#### **INFO**

The maximum allowed mass is specified in AD1

## **3.2.2 MAO-PM0-2.2.2 Eigenfrequencies**

### **. MAO-PM0-2.2.2.1 Eigenfrequency limit**

#### **REQUIREMENT**

The lowest eigenfrequency of MORFEO-Main Structure including all the supported payloads shall be higher than 9.5Hz. The corresponding analytical verification shall assume infinitely rigid interfaces with all payload included.

## **3.2.3 MAO-PM0-2.2.3 Calibration**

### **MAO-PM0-2.2.3.1.1 Telescope Daytime activity**

#### **INFO**

During daytime various activities will be usually scheduled to take place inside the telescope enclosure, requiring varying levels of illumination.

### **MAO-PM0-2.2.3.1.2 Calibration independency**

#### **REQUIREMENT**

MORFEO-Main Structure subsystem shall be designed and built to be insensitive (TBC) to outside illumination (see #743) so that all calibration procedures needed by MORFEO-Main Structure subsystem can be performed without affecting or being affected by routine observatory operations (including also the operation of other MORFEO-Main Structure subsystem ).

## **3.4 MAO-PM0-2.4: Access and Handling**

### **3.4.1 MAO-PM0-2.4.1: Access**

#### **3.4.1.1 MAO-PM0-2.4.1.1: Nasmyth Platforms**

##### **MAO-PM0-2.4.1.1.1: Nasmyth accessibility**

#### **INFO**



Both Nasmyth Platforms can be accessed via elevator and stairs for transport of people or material.

#### **MAO-PM0-2.4.1.1.2: Size and mass of loads (stairs)**

##### **REQUIREMENT**

Size and mass of loads intended for transport via the elevator shall be compliant with the limits and restrictions given in AD2, Sec. 14.1.4.1.

#### **MAO-PM0-2.4.1.1.3: Size and mass of loads (elevator)**

##### **REQUIREMENT**

Size and mass of loads intended for transport via the stairs shall be compliant with the limits and restrictions given in AD2, Sec. 14.1.4.1.

#### **MAO-PM0-2.4.1.1.4: Extra loads (crane)**

##### **REQUIREMENT**

Loads that can neither be transported via elevator nor via stairs shall be handled with the crane considering the specifications given in AD2, Sec. 14.1.4.3.

#### **MAO-PM0-2.4.1.1.5: Restriction of operation Accessibility**

##### **REQUIREMENT**

Access to the Nasmyth Morfeo-Main Structure shall be for the following purposes:

- assembly and integration
- installation and deinstallation
- commissioning
- maintenance (preventive and corrective)

*Note:*

#### **MAO-PM0-2.4.1.1.6 Access provider**

##### **INFO**

Access up to the MORFEO-Main Structure subsystem 's design volume is provided by the telescope.

#### **MAO-PM0-2.4.1.1.7 Subsystem accessibilty volume**

##### **REQUIREMENT**

MORFEO-Support structure subsystem shall provide access within its design volume to the MORFEO sub-systems for the various purposes defined in 2.4.1.1.5.

#### **MAO-PM0-2.4.1.1.8 Access category definition**

##### **REQUIREMENT**

The access provided by MORFEO-Main Structure subsystem within its design volume shall comply with the access categories defined in AD2 Sec. 7.4.1.



### **MAO-PM0-2.4.1.1.9: Access and maintainability requirement**

#### **REQUIREMENT**

The access provided by Morfeo-Main Structure within its design volume shall be consistent with the maintainability requirements given in MAO-PM0-2.6.4 [Maintenance Requirements](#)

Note:

NA

#### **3.4.2 MAO-PM0-2.4.2: Handling**

##### **3.4.2.1 MAO-PM0-2.4.2.1: General**

###### **MAO-PM0-2.4.2.1.1: Integration facility specifications**

#### **REQUIREMENT**

Specifications of the facilities and equipment mentioned in this section shall be taken from AD2.

###### **MAO-PM0-2.4.2.1.4 Disassembly after PAE**

#### **REQUIREMENT**

After Provisional Acceptance in Europe (PAE) MORFEO-Main Structure subsystem sections shall be disassembled to the degree necessary for transport, and packed for the mode of transport (air/sea).

###### **MAO-PM0-2.4.2.1.5 Chile Host indoor space available verification**

#### **REQUIREMENT**

At the latest, prior to packing in Europe it shall be determined whether enough space for indoor storage is available upon arrival on site. If outdoor storage is necessary or cannot be excluded the packing shall be suitable for outdoor storage and allow opening for incoming inspection and re-closing for storage.

###### **MAO-PM0-2.4.2.1.6 Door size limitation**

#### **INFO**

The incoming transport weight and dimensions at the two facilities are limited by the halls' entrance door sizes and the cranes' lifting capacity for unloading (see AD2).

###### **MAO-PM0-2.4.2.1.7 Facility limitation**

#### **REQUIREMENT**



For MORFEO-Main Structure subsystem integration, the limitations of the respective facility shall be taken into account.

### **3.4.2.2 MAO-PM0-2.4.2.2: Instrument Arrival and Integration**

#### **MAO-PM0-2.4.2.2.1 Use of dedicated services**

##### **REQUIREMENT**

MORFEO-Main Structure subsystem transport and installation inside the Observatory shall be possible with, and make use of, the dedicated Observatory services as described in AD2.

#### **MAO-PM0-2.4.2.2.3 MORFEO-Main Structure subsystem removal**

##### **INFO**

MORFEO will only be removed from the focal station for very major maintenance or overhaul interventions. This means work lasting more than 10 days.

#### **MAO-PM0-2.4.2.2.4 no-major maintenance on Nasmith**

##### **REQUIREMENT**

Main Structure shall be designed to undertake all non-major maintenance activities (see 2.4.2.2.3) while installed at the focal station.

#### **MAO-PM0-2.4.2.2.5 Cleaning before integration**

##### **REQUIREMENT**

Before entering the integration facilities the load shall be cleaned from dust.

#### **MAO-PM0-2.4.2.2.6 Location of load entering point**

##### **INFO**

The load enters the entrance hall on the public road transport vehicle.

#### **MAO-PM0-2.4.2.2.7 Inspection request**

##### **REQUIREMENT**

The packing shall be inspected for obvious damage.

#### **MAO-PM0-2.4.2.2.8 Shipping responsibility end**

##### **INFO**

The responsibility of the shipping company ends once the shipment arrives on site at the integration facility.

#### **MAO-PM0-2.4.2.2.9 Unloading requirement**

##### **REQUIREMENT**

In the hall entrance the load shall be unloaded using the E-ELT entrance hall crane or a forklift.



#### **MAO-PM0-2.4.2.2.10 Opening for inspection**

##### **INFO**

The packing will be opened for an incoming inspection.

#### **MAO-PM0-2.4.2.2.11 unpacking completion**

##### **INFO**

The unpacking will be completed and the packing material disposed of.

#### **MAO-PM0-2.4.2.2.12 Location of cleaning prior to installation**

##### **REQUIREMENT**

MORFEO-Main Structure subsystem components shall be cleaned and loaded on the E-ELT Flat Platform Truck (FPT). The E-ELT FPT moves MORFEO-Main Structure subsystem components into MORFEO-Main Structure subsystem assembly area, where they are unloaded with MORFEO-Main Structure subsystem hall crane.

#### **MAO-PM0-2.4.2.2.13 on site integration plan needs**

##### **REQUIREMENT**

MORFEO-Main Structure subsystem shall be assembled and tested according to the on-site integration and commissioning plan.

### 3.4.2.2.1 MAO-PM0-2.4.2.2.14 MORFEO-Main Structure subsystem Installation at the Nasmyth Platform

#### **MAO-PM0-2.4.2.2.14.1 lifting eyes**

##### **REQUIREMENT**

MORFEO-Main Structure subsystem or their equipment that have to be lifted by using a crane shall be provided with dedicated lifting eyes suitable for the purpose.

#### **MAO-PM0-2.4.2.2.14.2 Disassembly towards the telescope**

##### **REQUIREMENT**

When MORFEO-Main Structure subsystem is ready to go on the telescope, if necessary it shall be disassembled to the degree necessary for installation on the telescope.

#### **MAO-PM0-2.4.2.2.14.3 Motion steps**

##### **REQUIREMENT**

MORFEO-Main Structure subsystem sections shall be loaded on the E-ELT FPT and moved to the main transit ring. From there the sections shall be lifted with the Dome crane to the respective location on the Nasmyth platforms for installation.

#### **MAO-PM0-2.4.2.2.14.4 Clearance during motion**

##### **REQUIREMENT**



If not otherwise specified, when passing through doors or another type of access path, there shall be a minimum clearance of 0.5 m on both sides and 0.2 m at the top.

#### **MAO-PM0-2.4.2.2.14.5 Dismounting procedure**

##### **INFO**

The same handling scenario will be used if MORFEO-Main Structure subsystem is dismantled from the Nasmyth platform for decommissioning, major maintenance or other interventions.

#### **3.4.2.3 MAO-PM0-2.4.2.4: Storage**

##### **MAO-PM0-2.4.2.4.1: Needs of separate storage stand**

###### **REQUIREMENT**

A separate storage stand or base shall be provided for Morfeo-Main Structure when it is not installed on the telescope or Nasmyth platform if the transportation carriage cannot fulfil this function. The requirements for earthquake and other safety aspects apply to such storage devices, especially when they support the Morfeo-Main Structure .

*Note:*

NA

##### **MAO-PM0-2.4.2.4.2: Carriages certification**

###### **REQUIREMENT**

Morfeo-Main Structure carriages shall be certified for compliance with applicable safety regulations by an approved agency (such as TÜV or equivalent).

*Note:*

NA

##### **MAO-PM0-2.4.2.4.3: Protecting cover needs**

###### **REQUIREMENT**

If Morfeo-Main Structure are not otherwise protected from dust ingress and mechanical damage when dismantled from the telescope shall be provided with protective cover(s).

*Note:*

NA

#### **3.4.2.3.1 MAO-PM0-2.4.2.4.4 Packing**

##### **MAO-PM0-2.4.2.4.4.1 Packing material non reused**

###### **INFO**

The packing material used for the incoming transport will normally not be reused and will be disposed of following applicable regulations.

##### **MAO-PM0-2.4.2.4.4.2 Qualification of packing if needed for outdoor protection**

###### **REQUIREMENT**



In case MORFEO-Main Structure subsystem need to be stored in an indoor or outdoor storage space before integration then the packing can be used to protect the equipment in that period. In this case, the packing shall be qualified for such use.

### **3.4.2.3 MAO-PM0-2.4.2.5: Tools**

#### **MAO-PM0-2.4.2.5.1: Special tools delivery**

##### **REQUIREMENT**

If special tools or equipment other than the one provided by the observatory (see AD2) is needed for the MORFEO-Main Structure subsystem , its handling, integration, maintenance, transportation and/or modification, then such tools shall be delivered together with MORFEO-Main Structure subsystem and become property of the observatory. *Note:*

NA

#### **MAO-PM0-2.4.2.5.2: Documentation required for tools**

##### **REQUIREMENT**

Such tools shall be designed and fully documented in order to allow their safe use by Consortium (and ESO) personnel over the full lifetime of the Morfeo-Main Structure . A maintenance plan shall be available.

*Note:*

NA

#### **MAO-PM0-2.4.2.5.3: Certification of the lifting tools**

##### **REQUIREMENT**

Lifting tools shall come with a proper certification (as defined in AD6) that is still valid for at least one year from the time when it is handed over to ESO.

*Note:*

NA

#### **MAO-PM0-2.4.2.5.4 retrofit allowance**

##### **INFO**

Retrofit or modifications of these tools may be done by ESO under ESO responsibility to improve the usage of the tools, or to make the tool usable for other use cases.

#### **MAO-PM0-2.4.2.5.5: Tools storage outdoor**

##### **REQUIREMENT**

Storage space at the observatory is limited. Storage of large handling equipment shall be preferably in an outdoor storage area with a levelled gravel surface. Cleaning and inspection of the equipment before use is planned. Protection covers, e.g. for rubber or plastic parts, shall be included when needed for long term outdoor storage.

*Note:*



NA

#### **MAO-PM0-2.4.2.5.6: Tool storage indoor**

##### **REQUIREMENT**

In the case of delicate tools for optics or vacuum use, or when delicate mechanisms are incorporated, then indoor storage in an unheated shelter with concrete floor will be possible. This shall be discussed and agreed with the consortium on a case by case basis by latest at FDR.

*Note:*

NA

#### **MAO-PM0-2.4.2.5.7: Tools exceeding 40 Kg handling**

##### **REQUIREMENT**

The tools exceeding a mass of 40 kg shall have both, interfaces for forklift handling and interfaces for crane handling and shall be compatible (e.g. include rigging points) with the transport on a flatbed truck.

*Note:*

NA

#### **MAO-PM0-2.4.2.5.8: Transport containers**

##### **REQUIREMENT**

Transport containers for Line Replaceable Units (LRUs) or other Morfeo-Main Structure components which are needed for maintenance shall be considered as "Special tools" in the sense of 2.4.2.5.1 and 2.4.2.5.2.

*Note:*

NA

### **3.5 MAO-PM0-2.5: Design and Construction**

#### **3.5.1 MAO-PM0-2.5.1: Optomechanical**

##### **MAO-PM0-2.5.1.1: surface blackening**

##### **REQUIREMENT**

Surfaces identified as potential sources of stray light for other components of the telescope shall be blackened.

*Note:*

NA

##### **MAO-PM0-2.5.1.2: Cleanability of external optical surface**

##### **REQUIREMENT**

Main Structure shall not prevent the cleanability of the optical surfaces.

*Note:*

NA



### **MAO-PM0-2.5.1.3: Prevent object and fluid falling to Optical surfaces**

#### **REQUIREMENT**

Provisions shall be made to prevent objects (e.g., tools, fasteners ...) and fluids (e.g., lubricants, coolants ...) from falling/dropping onto sensitive parts or equipment (such as optical surfaces, electronics, ...) belonging to the Morfeo-Main Structure or to the telescope, in particular if such parts or equipment are unprotected.

*Note:*

NA

### **MAO-PM0-2.5.1.4: prevent fasteners falling**

#### **REQUIREMENT**

In particular, fasteners (e.g. screws, bolts, fixation devices or components) that can fall on potentially fragile elements shall remain attached to their holding components, in case of improper tightening or fixing.

*Note:*

NA

### **MAO-PM0-2.5.1.5: prevent liquid trapping**

#### **REQUIREMENT**

The design of Morfeo-Main Structure and its sub-systems shall ensure that, for all permitted orientations of the Morfeo-Main Structure, liquids do not become trapped. An exception to this is under survival conditions (MAO-PM0-2.1.1.3).

*Note:*

NA

### **MAO-PM0-2.5.1.6: Washing compatibility of item fixed to mirrors**

#### **REQUIREMENT**

Morfeo Main Structure shall either be compatible with washing agents (as required to remove the specified coating) or easy to protect in a safe manner. If lubricants are present in the said items (e.g. in joints of a permanently mounted support system) they shall also meet this requirement.

*Note:*

NA

## **3.5.2 MAO-PM0-2.5.2: Mechanical**

### **3.5.2.1 MAO-PM0-2.5.2.1: Welding**

#### **MAO-PM0-2.5.2.1.1: welding norms applicability**

#### **REQUIREMENT**

The design of welded structures shall be done according to the regulations of the EUROCODEs. For the fabrication and test of welded structures AD4 shall be applied.



*Note:*

NA

### **MAO-PM0-2.5.2.2: General mechanical requirements**

#### **REQUIREMENT**

Morfeo-Main Structure shall conform to AD7.

*Note:*

NA

### **MAO-PM0-2.5.2.3 Repeatability of remounting requirement**

#### **REQUIREMENT**

Mounting points, such as e.g. flanges, which need to be opened for maintenance and that affect the alignment of optics or other mechanisms shall be equipped with cylindrical pins with reamed holes, or other equivalent means, that are suitable to ensure precise repositioning.

The meaning of "precise" depends on the particular alignment requirements that are impacted by the opening of the mounting point, and is better specified in AD1.

#### **3.5.3 MAO-PM0-2.5.3: Cooling**

##### **MAO-PM0-2.5.3.1: Cooling reference document**

#### **INFO**

The instruments' cooling system shall use and follow the "Standard Components and Guidelines for the Cooling Circuits" AD5).

(note that for MORFEO the applicable REQ-72 is: Parts which get in contact with the cooling fluid specified in R-COL-251 and R-COL-254 shall be made of stainless steel or of aluminium alloys series 6000)

#### **3.5.4 MAO-PM0-2.5.5: Electric and Electronic**

##### **MAO-PM0-2.5.5.1: Electrical bonding**

#### **REQUIREMENT**

MORFEO-Main Structure subsystem shall be electrically bonded. The bonding shall be compliant with AD9.

*Note:*

NA

#### **3.5.5 MAO-PM0-2.5.6: Electromagnetic Compatibility**

##### **MAO-PM0-2.5.6.1: General electromagnetic requirements**

#### **REQUIREMENT**



Morfeo-Main Structure shall conform to the electromagnetic compatibility requirements specified in AD9.

*Note:*

NA

### **3.5.6 MAO-PM0-2.5.10: Interchangeability**

#### **MAO-PM0-2.5.10.1: interchangeability of items**

##### **REQUIREMENT**

Items produced according to identical specifications shall be interchangeable. Interchange may be contingent upon specific adjustments, provided such adjustments can be done on-site within the boundaries of the specified maintainability requirements.

*Note:*

NA

### **3.5.7 MAO-PM0-2.5.11: Workmanship**

#### **MAO-PM0-2.5.11.1: industrial state of the art**

##### **REQUIREMENT**

Industrial state of the art methods, processes and procedures shall be consistently applied in all fields relevant to design, construction and operation.

*Note:*

NA

#### **MAO-PM0-2.5.11.2: verified procedures applicability**

##### **REQUIREMENT**

Where possible, workmanship shall be achieved through the application of established and/or verified procedures.

*Note:*

NA

#### **MAO-PM0-2.5.11.3: Inspection in different phases**

##### **REQUIREMENT**

Proper workmanship shall be verified by inspections during all phases of Morfeo-Main Structure design and construction.

*Note:*

NA

#### **MAO-PM0-2.5.11.4: training of personnel**

##### **REQUIREMENT**



Proper workmanship shall be achieved by employing trained professionals who are fit for the job, and re-trained when necessary.

Note:

NA

### 3.5.8 MAO-PM0-2.5.12: Induced Environment

#### 3.5.8.1 MAO-PM0-2.5.12.1 Vibration Requirements

##### MAO-PM0-2.5.12.1.1 Induced vibration limit

###### REQUIREMENT

The RMS forces generated by the vibrational sources of each subsystem of MORFEO per one-third octave frequency bands shall be smaller than the values defined in the following table for the given frequency intervals.

Unit	Frequency range [Hz]		
	1 – 4.45	4.45 – 56	56 - 110
Nasmyth Instruments (Force (x,y,z) [N] RMS per one-third octave frequency bands)	1	0.4	2

##### MAO-PM0-2.5.12.1.2 vibration definition

###### INFO

Assuming a rigid (i.e. infinitely stiff) interface, the vibration emitted by an MORFEO-Main Structure subsystem is constrained by the temporal RMS force [N] at a reference point on the Nasmyth platform. This reference point is defined as the 'centre of area' of the relevant MORFEO-Main Structure subsystem interface footprint.

#### 3.5.8.2 MAO-PM0-2.5.12.2 Thermal Requirements

##### MAO-PM0-2.5.12.2.1 Daytime temperature difference

###### REQUIREMENT

During day time, the temperature difference between the MORFEO-Main Structure subsystem (or any associated equipment) outer surface and the ambient air shall not be larger than:  $\pm 2.5$  °C

##### MAO-PM0-2.5.12.2.2 Heat load daytime

###### INFO

In addition, the convected heat load during day time (averaged over 10min.) is specified in MAO-PM0-1.

##### MAO-PM0-2.5.12.2.3 Nighttime temperature difference

###### REQUIREMENT



During night time, the temperature difference between the MORFEO-Main Structure subsystem (or any associated equipment) outer surface and the ambient air in still wind conditions (a wind speed inside the dome of 2 m/sec and a convection coefficient of 2W/m<sup>2</sup>/K) shall not be larger than:  $\pm 1.5$  °C

#### **MAO-PM0-2.5.12.2.4 Heat load nighttime**

##### **INFO**

In addition, the convected heat load during night time (averaged over 10min.) is specified in the individual technical requirement specification document.

### **3.5.8.3 MAO-PM0-2.5.12.3: Contamination and Pollution Requirements**

#### **MAO-PM0-2.5.12.3.1: Surface emissivity**

##### **REQUIREMENT**

MORFEO-Main Structure subsystem shall not have any sources inside the telescope chamber that emit light (in the wavelength range from 0.29 to 24 micrometer) when not in operational state. In operational state this is allowed as long as no other ELT system functionality is affected (to be discussed by customer and supplier on a case by case basis).

In addition, no infrared remote controllers shall be used in operational state.

Note: This requirement refers to artificial radiative sources, not to the natural thermal emission.

Note:

NA

#### **MAO-PM0-2.5.12.3.2: optical component protection**

##### **REQUIREMENT**

The design shall make sure that optical components are not exposed to contamination by dust, exhaust, fumes and contaminants (solid or liquid) or, in the circumstances where such exposure cannot be avoided, that they are protected from such contamination.

Note:

NA

#### **MAO-PM0-2.5.12.3.3: Dust limitation**

##### **REQUIREMENT**

Any dust generated by the equipment shall remain compatible with the site cleanliness class which is better than ISO 7.2 (median) and ISO 8 (90% percentile).

Note:

NA



### **3.5.9 MAO-PM0-2.5.13: Site Adaptation**

#### **MAO-PM0-2.5.13.1: Onsite adjustment plan**

##### **REQUIREMENT**

Any adjustment that may need to be done on site (e.g. due to the atmospheric pressure or site dryness) shall be identified and the related procedure defined.

*Note:*

NA

## **3.6 MAO-PM0-2.6: Lifetime and Reliability, Availability and Maintainability (RAM)**

### **3.6.1 MAO-PM0-2.6.1: Lifetime**

#### **MAO-PM0-2.6.1.1 Lifetime**

##### **REQUIREMENT**

Starting from the point in time when the instrument is available to the Integration site on duty as per its intended use, the hardware deliverables shall have a minimum lifetime of 15 years under the assumptions of MAO-PM0-2.6.2.2.2 and MAO-PM0-2.6.2.2.3.

#### **MAO-PM0-2.6.1.2: Maintenance consideration for lifetime definition**

##### **REQUIREMENT**

For the demonstration of the lifetime requirements it shall be assumed that preventive/predictive maintenance, including environmental protection will be performed in a plan (focused on resources and accessibility) to be agreed with the consortium within the final design phase but within the limits defined by Maintenance requirement.

*Note:*

NA

### **3.6.2 MAO-PM0-2.6.2: Reliability**

#### **3.6.2.1 MAO-PM0-2.6.2.1: Failure Definition**

##### **MAO-PM0-2.6.2.1.1: Severity definition**

##### **REQUIREMENT**

For the purpose of defining the Reliability and Availability requirements of the Morfeo-Main structure deliverables, the categories of functional failures described herein shall be considered:

- Severity 2: The occurrence of a functional failure of the system that will cause, if not rectified, directly or indirectly, a loss of functionality or a corrective maintenance



- Severity 1: The occurrence of a functional failure of the system that will cause, if not rectified, directly or indirectly, a performance degradation

Note:

NA

#### **MAO-PM0-2.6.2.1.2: List of failures**

##### **REQUIREMENT**

With assistance from consortium, an exhaustive list of failures shall be provided by the supplier in the RAM Analysis. Each failure shall be categorized according to the definition given in the table above (MAO-PM0-2.6.2.1.1).

Note:

NA

#### **MAO-PM0-2.6.2.1.3: Failure definition**

##### **INFO**

A failure is a defect causing the termination of the ability of an item to perform a required function within the specified performance.

#### **3.6.2.2 MAO-PM0-2.6.2.2: Reliability Requirements**

##### **MAO-PM0-2.6.2.2.3: Clock time**

##### **REQUIREMENT**

The time for the identification of the MTBF shall be the clock time.

Note:

NA

##### **MAO-PM0-2.6.2.2.6: Random accounting failures**

##### **REQUIREMENT**

Accounting of failures shall take into account only those failures whose root cause is random (non repeatable) and not due, for instance, to human operator error, maintenance induced failures, design flaw, improper manufacturing and inspection, etc.

Note:

NA

##### **MAO-PM0-2.6.2.2.7: Activity of provider +consortium**

##### **REQUIREMENT**

The provider and the Consortium shall jointly:

- identify those items of the Morfeo-Main Structure that require special attention because of complexity and state-of-the-art techniques



- evaluate the potential failure modes of those items
- evaluate the impact of these failure modes on safety, readiness, availability and demand for Maintenance/Logistics support for the Morfeo-Main Structure
- work together to estimate MTBF, MCMT and MTTR for critical components, mechanisms or sub-assemblies and model these data to obtain an overall Morfeo-Main Structure availability which meets the top-down availability allocation for Morfeo-Main Structure .

*Note:*

NA

### **3.6.3 MAO-PM0-2.6.3: Maintainability**

#### **3.6.3.1 MAO-PM0-2.6.3.1: General**

##### **MAO-PM0-2.6.3.1.1: System identifications**

###### **REQUIREMENT**

System identification that provides the capability of tracing wiring, power sources, etc. for the identification of components without use of drawings shall be maximised.

*Note:*

NA

##### **MAO-PM0-2.6.3.1.2: Use of non standard tools**

###### **REQUIREMENT**

ESO and the consortium will have standard support and test equipment tools for maintenance on Europe and Chilean site. The use of non-standard maintenance equipment specific to the selected design of Morfeo-Main Structure shall be minimised and subject to consortium Review (at FDR).

*Note:*

NA

##### **MAO-PM0-2.6.3.1.3: maximisation of LRU**

###### **REQUIREMENT**

Where possible, maintenance shall be mainly performed at assembly and subassembly level by exchange of LRUs, taking into consideration that the LRU principle applies to components outside the vacuum cryogenics system that can be replaced in reasonable time.

*Note:*

NA



#### **MAO-PM0-2.6.3.1.4: LRU definition**

##### **INFO**

LRU's are defined as units which can be easily exchanged (without extensive calibration, of sufficient low mass and dimension for easiness of handling, etc.) by maintenance staff of technician level.

#### **MAO-PM0-2.6.3.1.5: replacement of cables**

##### **REQUIREMENT**

Where possible, provisions shall be made that replacement of cables and connectors is possible without dismounting additional elements.

*Note:*

NA

#### **MAO-PM0-2.6.3.1.6: list of LRU**

##### **REQUIREMENT**

The list of LRU is design dependent and shall be identified by the Contractor.

*Note:*

NA

#### **MAO-PM0-2.6.3.1.7: In situ maintenance operations**

##### **REQUIREMENT**

Dismounting and refurbishment of Main Structure components shall be performed in-situ for as many parts as possible.

*Note:*

NA

#### **MAO-PM0-2.6.3.1.8: in situ operations on LRU**

##### **REQUIREMENT**

As a goal all LRU shall be replaceable in situ.

*Note:*

NA

### **3.6.4 MAO-PM0-2.6.4: Maintenance Requirements**

#### **3.6.4.1 MAO-PM0-2.6.4.1: Corrective Maintenance**

##### **MAO-PM0-2.6.4.1.1: MCMT definition**

##### **INFO**



The maximum corrective maintenance time (MCMT) is defined as that value of maintenance downtime below which a specified percentage of all corrective maintenance actions considered are expected to be completed

#### **MAO-PM0-2.6.4.1.3: MCMT reference time**

##### **REQUIREMENT**

The MCMT reference shall be considered to be the clock time.

*Note:*

NA

#### **MAO-PM0-2.6.4.1.4: logistic and administrative delays does not count**

##### **REQUIREMENT**

For the computation of MCMT and MTTR, time lost due to logistic delays and administrative delays shall not be considered.

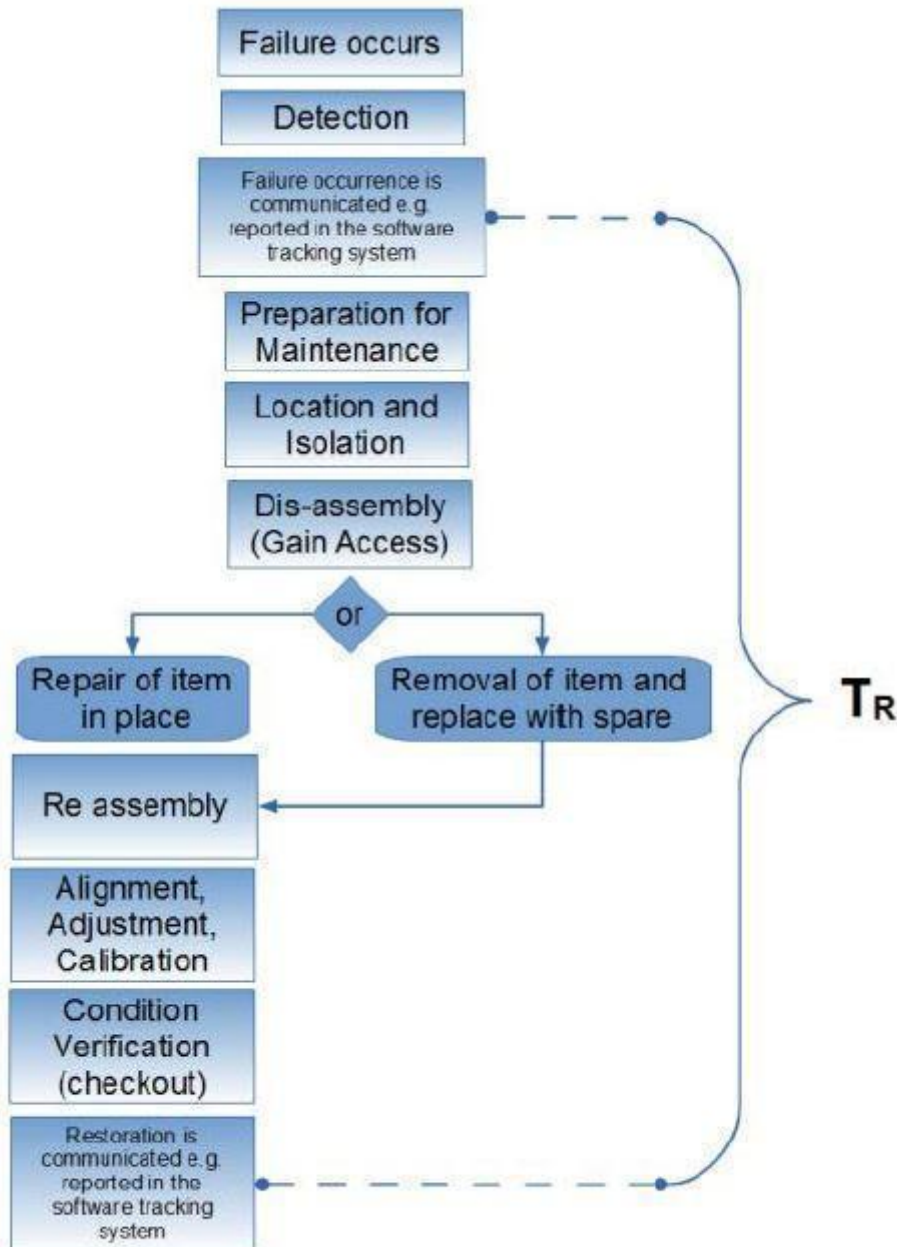
*Note:*

NA

#### **MAO-PM0-2.6.4.1.5: TR definition**

##### **INFO**

The Time to Repair (TR) is considered as the elapsed time between the event of communicating the occurrence of a failure (e.g. reporting the occurrence in a software tracking system) and the event of communicating the restoration of the System (reporting the failure resolution in a software tracking system) but it excludes the access time for reaching MORFEO and initiating the corrective maintenance action. This assumes that the spares, necessary manpower, tools and documentation (manuals) are readily available where applicable.



### ***Time to Repair Breakdown***

#### **MAO-PM0-2.6.4.1.6: personnel limitation for maintenance**

##### **REQUIREMENT**

Any corrective maintenance action shall be performed with a maximum of 2 qualified engineers or technicians, using standard tools and/or special tools specific to Morfeo-Main Structure .

*Note:*



NA

### 3.6.4.2 MAO-PM0-2.6.4.2: Preventive/Predictive Maintenance

#### MAO-PM0-2.6.4.2.1: actions limitations

##### REQUIREMENT

For Morfeo-Main Structure all preventive and predictive maintenance actions shall be carried out during non-observational hours that are in a daytime maintenance period window of 8 (eight) hours each day.

Note:

NA

#### MAO-PM0-2.6.4.2.2: splitability over more days

##### REQUIREMENT

If preventive/predictive maintenance action duration lasts more than 8 staff-hours, it shall be possible to split the task over more maintenance shifts in order to not interfere with the nighttime operations.

Note:

NA

#### MAO-PM0-2.6.4.2.4: specific investigation/action

##### REQUIREMENT

If the loss of a function caused by any failure mode will not become apparent to the operator under normal circumstances (e.g. the failure mode is not monitored) then preventive/predictive maintenance actions shall be identified for ensuring the availability of that specific function.

Note:

NA

### 3.6.4.3 MAO-PM0-2.6.4.3: Overhaul Maintenance Requirements

#### MAO-PM0-2.6.4.3.1: Overhaul planning

##### INFO

Overhaul is a planned major maintenance operation, performed at specific intervals.

### 3.6.4.4 MAO-PM0-2.6.4.4: Design for Reliability and Maintainability Requirements

#### MAO-PM0-2.6.4.4.1: Marking requirement

##### REQUIREMENT

All Morfeo-Main Structure and their component LRUs, spare units, etc, shall be marked with unique identification numbers. The number shall consist of the original equipment manufacturer item number and company name.

Note:



NA

#### **MAO-PM0-2.6.4.4.2: Morfeo-Main Structure contractor guidelines**

##### **REQUIREMENT**

When designing for Maintenance, the Contractor shall assume the following:

- The user is a skilled technician with access to but no prior knowledge of the as-built characteristics of the Morfeo-Main Structure ;
- The user is able to run extended diagnostics to determine the scope of preventive or corrective maintenance;
- The user is unable to make any hardware modification beyond replacement of spare parts (LRUs).

*Note:*

NA

#### **MAO-PM0-2.6.4.4.3: Morfeo-Main Structure design guidelines**

##### **REQUIREMENT**

The design for maintainability of Morfeo-Main Structure shall take into account the following aspects as a minimum:

- Conditions relating to health and safety;
- Handling, human and ergonomic factors;
- Displays and indicators;
- Visibility;
- Identification;
- Accessibility to and also within the piece of equipment;
- Accessibility of low reliability equipment;
- Testability: the potential for the use of automatic diagnostics as a means of Fault Detection, Isolation and Recovery (FDIR). The latter includes the internal diagnostic systems, referred to as Built-In-Test-Equipment (BITE), and external diagnostic systems, referred to as Automatic Test Equipment (ATE), or offline test equipment;
- Health Status and Monitoring (HSM) capability;
- Repair-ability;
- Interchangeability (including Standardization and Modularity).

*Note:*

NA

#### **MAO-PM0-2.6.4.4.4: fixed lugs and attachment points**

##### **REQUIREMENT**

For installation, removal and handling of equipment and LRUs consideration shall be given to the installation of fixed lugs or attachment points.



*Note:*

NA

#### **MAO-PM0-2.6.4.4.5: Wear-out forbidden**

##### **REQUIREMENT**

No wear-out functional failure mechanism, characterised by an increasing failure rate, shall occur in the lifetime of the equipment. Any components requiring preventive replacement in order to achieve this requirement shall be clearly highlighted for consideration and approval by ESO.

*Note:*

NA

#### **MAO-PM0-2.6.4.4.6: Spares deliverables**

##### **REQUIREMENT**

The Contractor shall provide the Spares needed for the whole expected lifetime

*Note:*

NA

### **3.6.5 MAO-PM0-2.6.5: Computerised maintenance management system**

#### **MAO-PM0-2.6.5.1: Compatibility with CMMS**

##### **REQUIREMENT**

All information necessary to include Morfeo-Main Structure into the CMMS shall be delivered by the consortium in a Maintenance Plan and in computer readable form (TBD).

*Note:*

NA

#### **MAO-PM0-2.6.5.2: inventory control**

##### **INFO**

Paranal Engineering department uses a computerised maintenance management system (CMMS), for inventory control of spare parts and tools including their locations, planning of preventive maintenance, work order generation from preventive maintenance plans, failure reporting and tracking, workflow monitoring, etc.

## **3.7 MAO-PM0-2.7: Safety**

#### **MAO-PM0-2.7.1: EU directives applicability**

##### **REQUIREMENT**

Morfeo-Main Structure and all of its subsystems shall conform to the applicable EU Directives and their Essential Health and Safety Requirements given in annex 1 of these Directives.

*Note:*

NA



#### **MAO-PM0-2.7.2: Harmonized standards applicability**

##### **REQUIREMENT**

In order to comply with these essential safety requirements, harmonised standards under these Directives shall be used in addition to the requirements set forth in ESO Technical Specifications AD6.

*Note:*

NA

#### **MAO-PM0-2.7.3: Hazard analysis and risk assessment**

##### **REQUIREMENT**

A hazard analysis and risk assessment shall be conducted according to the principles noted down in AD6. The hazard analysis process shall commence with a preliminary Hazard Analysis (HA) in the early stages of the project and continue throughout the system life cycle.

*Note:*

NA

#### **MAO-PM0-2.7.4: Hazard operation states**

##### **INFO**

Hazards may be related to different operational states of the system. This includes (but is not necessarily limited to) operation, shutdown and maintenance including handling procedures.

#### **MAO-PM0-2.7.5: Additional types of failures**

##### **REQUIREMENT**

Within the process of hazard analysis and risk assessment any combination of two of the following additional types of failures (including two identical ones) shall be analysed:

- a) Hardware failure,
- b) Software failure,
- c) Operator error.

*Note:*

NA

#### **MAO-PM0-2.7.6: undesirable hazards**

##### **REQUIREMENT**

None of these events shall lead to an unacceptable or undesirable hazard as defined in AD6. This includes the mechanical limitation of stroke of all moving parts.

*Note:*

NA

#### **MAO-PM0-2.7.7: declaration of incorporation**

##### **REQUIREMENT**



In case the system can be considered as a component or sub-assembly for another, bigger machine and cannot be considered as safe when delivered by the manufacturer it shall be identified which aspects of the essential requirements have been fulfilled and it shall be instructed which of them have to be fulfilled by the machine manufacturer or assembler. For this purpose a declaration of incorporation shall be issued (as laid out in AD6).

*Note:*

NA

#### **MAO-PM0-2.7.9: conformity applicability**

##### **REQUIREMENT**

The conformity shall apply under all conditions (assembly, disassembly, testing, storage, integration, verification, operation, maintenance, power off, etc), including but not limited to all environmental factors and where subsystems are not fully operational.

*Note:*

NA

#### **MAO-PM0-2.7.10: maximise risk reduction**

##### **REQUIREMENT**

(Sub)systems that are deemed to present a risk regarding safety on the basis of that Hazard Analysis shall be evaluated in order to propose measures for further risk reduction to an acceptable level.

*Note:*

NA

#### **MAO-PM0-2.7.11: Telescope ILS**

##### **INFO**

The Interlock and Safety System (ILS) ensures all components of the Telescope Control System (TCS) are operated in a safe manner according to the various telescope operational modes. It provides control and monitoring of the various observatory safety components. The ILS does not implement Morfeo-Main Structure -specific safety rules that are part of the function of an Morfeo-Main Structure 's Local Control and Safety System, but brings additional safeguards as may be required from subsystems interactions as they are integrated and operate together.

#### **MAO-PM0-2.7.12: Morfeo-Main Structure ILS**

##### **REQUIREMENT**

Morfeo-Main Structure shall implement its own Interlock and Safety (ILS) System that controls safety functions and interlocks. The ILS system shall be based on the same hardware that is implemented in the ILS of the TCS, and allow interfacing between both.

*Note:*

NA



### **MAO-PM0-2.7.13: SIL and PL**

#### **REQUIREMENT**

After defining the measures to reduce risk to an acceptable level (based on the Preliminary Hazard Analysis and Risk Assessment) the Consortium shall contact ESO to assess and agree on the required Safety Integrity Level (SIL) or Performance Level (PL) in case the risk is to be reduced by a safety function. ESO shall be entitled to set a minimum SIL or PL level for any safety related control measure.

*Note:*

NA

## **3.8 MAO-PM0-2.8: Preparation for Delivery**

### **3.8.1 MAO-PM0-2.8.1: Cleaning**

#### **MAO-PM0-2.8.1.1: cleaning before packing**

##### **REQUIREMENT**

Morfeo-Main Structure components, Auxiliary Equipment and transport equipment shall be cleaned before packing (for storage or transport, as appropriate) into their transport container. Emphasis is put on:

- a) grease and lubricants
- b) corrosive, abrasive dust or powders

*Note:*

NA

### **3.8.2 MAO-PM0-2.8.2: Packaging and Transport**

#### **MAO-PM0-2.8.2.1: Packing datapack**

##### **REQUIREMENT**

Morfeo-Main Structure components shall be packed with its accompanying documentation and samples, including as-build documents and handling procedures.

*Note:*

NA

#### **MAO-PM0-2.8.2.2: desert transportation**

##### **INFO**

Morfeo-Main Structure will have to be transported by road in a desert environment. All critical and/or mounted parts should be properly protected against liquid spills, exhaust fumes, rain and abrasive dust.



#### **MAO-PM0-2.8.2.3: Packing specification definition I**

**INFO**

For Morfeo-Main Structure transport the specifications and recommendations will be issued at beginning of phase C

#### **MAO-PM0-2.8.2.4: land and sea**

**INFO**

Transport containers should allow land, sea and air freight.

#### **MAO-PM0-2.8.2.5: containers norms**

**INFO**

Transport containers should fit in standard ISO shipping containers (ITUs, Intermodal Transport Units or isotainers, ISO norm 668).

#### **MAO-PM0-2.8.2.6: minimum volume loss**

**INFO**

The dimensions of the transport containers should be defined for minimum volume loss in standard ISO shipping containers.

#### **MAO-PM0-2.8.2.7: special transport**

**INFO**

Special transport conditions should be avoided.

#### **MAO-PM0-2.8.2.8: woods specifications**

**INFO**

If wood is to be used, special regulations from Chile should be taken into account during the material selection. All wood packing material (WPM) should be treated and certified according to the International Standards For Phytosanitary Measures No. 15 (ISPM 15), in addition WPM must be free of bark.

#### **MAO-PM0-2.8.2.9: transport design**

**INFO**

If transport requires additional fixtures of particular sub-systems or components this should be taken into account in the design.

### **3.9 MAO-PM0-2.9: Precedence**

#### **MAO-PM0-2.9.1: human safety requirement precedence**

**INFO**



In the event of conflict between requirements specified herein and requirements pertinent to human safety, the latter shall take precedence.

#### **MAO-PM0-2.9.2: integrity Morfeo-Main Structure requirement precedence**

##### **INFO**

Without prejudice of the provisions of the previous requirement, in the event of conflict between requirements specified herein and requirements pertinent to the integrity of the Morfeo-Main Structure , the latter shall take precedence.

### **3.10 MAO-PM0-2.10: Verification**

#### **3.10.1 MAO-PM0-2.10.1: Requirements Verification**

##### **MAO-PM0-2.10.1.1: Verification type**

###### **REQUIREMENT**

Four methods of verification shall be applied to verify that the performance requirements of the Morfeo-Main Structure , and auxiliary equipment are fulfilled:

###### Verification by design

Verification by Design consists of using approved records or evidence (e.g. design documents and reports, technical descriptions, engineering drawings) that unambiguously show that the requirement is met.

###### Verification by analysis

Verification by Analysis consists of performing theoretical or empirical evaluation using techniques such as systematic and statistical design analysis, modelling and computational simulation.

###### Verification by Inspection

Verification by inspection consists of visual determination of physical characteristics (such as constructional features, hardware conformance to document drawing or workmanship requirements, physical conditions, software source code conformance with coding standards).

###### Verification by Test

Verification by test consists of measuring product performance and functions under representative conditions, or under conditions that can be clearly traced to operational ones. It includes the analysis of data derived from the test.

*Note:*

NA

##### **MAO-PM0-2.10.1.2: Verification tags**

###### **REQUIREMENT**

The contractor shall define the verification methods, to be approved by consortium, and as a minimum shall follow the verification tags D/A/I/T provided with each requirement.

*Note:*



NA

### **3.10.2 MAO-PM0-2.10.2: Analysis and Simulation Requirements**

#### **MAO-PM0-2.10.2.1: Structural analysis guidelines**

##### **REQUIREMENT**

Requirements and recommendations stated in AD8 shall be applied for the structural analysis verification of the Morfeo-Main Structure .

*Note:*

NA

#### **MAO-PM0-2.10.2.2: Stress analysis verification**

##### **REQUIREMENT**

The stress analysis shall cover as a minimum all operational conditions defined by R-MAO-2.1. As a minimum, any load combination required in 2.1.2 shall be considered together with the load combination factors defined in 2.1.3 Additional load combinations shall be verified, if required by the design or specific load conditions. The structural safety requirements (including safety factors) defined in AD8, section 5.11 (Mechanical Safety) shall be met for all the load combinations.

*Note:*

NA

#### **MAO-PM0-2.10.2.3: Quasi static earthquake verification**

##### **REQUIREMENT**

For quasi-static earthquake analyses the acceleration components shall be applied as defined in ESO-191462 section 5.10.2.

*Note:*

NA

#### **MAO-PM0-2.10.2.4: Mechanical failure criterias**

##### **REQUIREMENT**

For each component under design all possible criteria of mechanical failure relevant to the component under examination shall be considered (strength, fatigue, buckling, creeping, etc).

*Note:*

NA



#### **MAO-PM0-2.10.2.5: Budget for manufacturing**

##### **REQUIREMENT**

Manufacturing and assembly tolerances shall be taken into account in the performance budgets analysis.

*Note:*

NA

#### **MAO-PM0-2.10.2.6: Modal analysis**

##### **REQUIREMENT**

Modal analysis of Morfeo-Main Structure shall be performed to calculate the eigenfrequencies, eigenmodes and effective mass contribution of the structure required for the analytical verification of the eigenfrequency requirements specified herein.

*Note:*

NA

#### **3.10.3 MAO-PM0-2.10.3: Lifetime Verification Requirements**

##### **MAO-PM0-2.10.3.1: Witness samples**

##### **REQUIREMENT**

Witness samples for all optical elements in open air shall be procured and made available to consortium such that they can be tested for aging effects etc. The exact number of witness samples shall be agreed by FDR.

*Note:*

NA

#### **3.10.4 MAO-PM0-2.10.4: Reliability Verification Requirements**

##### **MAO-PM0-2.10.4.1: Reliability libraries adoption**

##### **REQUIREMENT**

Where data from reliability libraries (e.g. Bellcore/Telcordia, NPRD-95, MIL-HDBK-217, etc.) for electrical, electro and electro-mechanical components are not available and where a failure of a specific component will be safety-critical (i.e. risk score (s) is high or medium, see AD6), an accelerated reliability testing technique, like the Highly Accelerated Life Tests (HALT), shall be applied to ensure that the quantitative reliability requirements of the Technical Specification and RAM and Safety Analyses are achieved.

The list of components for which an accelerated reliability testing technique is foreseen shall be provided for approval to the consortium.

The accelerated reliability testing technique to be adopted shall be agreed, too.



Note:

NA

#### MAO-PM0-2.10.4.2: End of warranty phase MTBF update

##### REQUIREMENT

At the end of the Warranty Phase of the Morfeo-Main Structure (prior to Final Acceptance) and during the HALT Campaign (if any), the reliability requirement(s) shall be demonstrated by accounting for all unreliability induced failures.

The observed MTBF shall meet the specified MTBF with 90% confidence level (computed Upper MTBF value shall be greater than the required MTBF). The chi-squared test shall be adopted, unless otherwise agreed.

The Upper MTBF value shall be computed using the following formula:

$$MTBF_{upper} = \frac{2 \cdot T}{\chi^2_{(a;b)}}$$

where:

T = Total Time - Total Down Time

$\chi^2_{(a;b)}$  = a-th percentile of the Chi-squared distribution with b degrees of freedom

a = percentile of the Chi-squared distribution = 1-(alfa/2) = 0.95

1-alfa = 0.90 (90% confidence level)

b = degrees of freedom of the Chi-squared distribution = 2\*r

r = Number of unreliability induced failures during the period considered.

Note:

NA

#### MAO-PM0-2.10.4.3: Common Cause Failures consideration

##### REQUIREMENT

Where redundant components are used to achieve the availability and reliability targets, the Contractor shall demonstrate that Common Cause Failures have been taken into account in the RAM Analysis and the risk of their occurrence minimised.

Note:



NA

### 3.10.5 MAO-PM0-2.10.5: Maintainability Verification Requirements

#### MAO-PM0-2.10.5.1: Maintainability testing

##### REQUIREMENT

As part of the overall verification of the Morfeo-Main Structure , and its Auxiliary Equipment, the Consortium shall demonstrate by testing the maintainability of the product. The maintainability demonstration shall verify and validate the following, as a minimum:

- Troubleshooting techniques as detailed in the Maintenance Manual;
- Maintenance tools and equipment;
- MTTR values and maximum allocated time (where applicable), both for corrective and preventive /predictive maintenance actions;
- Corrective, Preventive and Predictive maintenance procedures and instructions;
- Software routines used for maintenance, if applicable.

Note:

NA

#### MAO-PM0-2.10.5.2: End of warranty phase MTTR update

##### REQUIREMENT

At the end of the Warranty Phase of the Product (prior to Final Acceptance) and during the HALT Campaign (if any), the maintainability requirement related to the MTTR value(s) shall be demonstrated by accounting for all unreliability induced failures.

The observed MTTR shall meet the specified MTTR with 90% confidence level (computed Upper MTTR value shall be greater than the required MTTR). The chi-squared test shall be adopted, unless otherwise agreed.

The Upper MTTR value shall be computed using the following formula:

$$MTTR_{upper} = \frac{2 \cdot T}{\chi^2_{(a;b)}}$$

where:

T = Total Down Time



$\chi^2(a;b)$  = a-th percentile of the Chi-squared distribution with b degrees of freedom

a = percentile of the Chi-squared distribution = 1-(alfa/2) = 0.95

1-alfa = 0.90 (90% confidence level)

b = degrees of freedom of the Chi-squared distribution = 2\*r

r = Number of repairs/replacements due of unreliability induced failures during the period considered

Note:

NA

### MAO-PM0-2.10.5.3: MTTR computation for design phase

#### REQUIREMENT

During the Design phase, the predicted MTTR value of the System shall be verified using the following formula:

$$MTTR_{System} = \frac{1}{\lambda} \sum_{i=1}^n \lambda_i \cdot MTTR_i$$

$$\lambda = \sum_{i=1}^n \lambda_i$$

where  $\lambda_i$  is the failure rate of the i-th item to be replaced/repared and n is the number of replaceable/repairable items of the System.

The predicted MTTR value of the System shall be compared with the specified MTTR.

Note:

NA



### 3.10.6 MAO-PM0-2.10.6: Thermal Verification Requirements

#### MAO-PM0-2.10.6.1: Surface temperature verification

##### REQUIREMENT

The requirements on surface temperature shall be verified by:

1. thermal analysis during the design phase
2. test in representative conditions during acceptance testing using
  - a. infrared camera to provide overview and estimates of temperatures
  - b. local temperature measurement with appropriate accuracy for critical cases

Note:

NA

#### MAO-PM0-2.10.6.2: Heat dissipation power verification

##### REQUIREMENT

The requirements related to heat dissipation power shall be verified by:

1. Analysis summarized in the form of a heat dissipation power budget
  - a. during the design phase using as-designed parameters
  - b. at acceptance using as-built configuration and measured parameters (e.g. electrical power consumption)

Note:

NA

### 3.10.7 MAO-PM0-2.10.7: Vibration Verification Requirements

#### MAO-PM0-2.10.7.1: Analysis and testing needs

##### REQUIREMENT

The vibration requirement 2.5.12.1 shall be verified by a combination of analysis and testing. Morfeo-Main Structure team shall identify and characterise all possible vibration sources, and by analysis estimate the interface forces in amplitude and frequency defined in 2.5.12.1.

Note:

NA

#### MAO-PM0-2.10.7.2: Tests constraints

##### REQUIREMENT

The characterization of vibration sources by test shall consider the following:



- Under operational conditions, e.g. mechanical boundary condition, coolers, pumps electronic racks in nominal operation.
- Measurements with duration of at least 30 seconds with sampling of at least 300 Hz shall be performed.
- Each measurement set (same condition) shall be repeated at least ten times and an average over 30 sec shall be constructed.
- A spectral analysis of the measured data (averaged data) shall be performed, e.g. PSD (Power Spectral Density) shall be estimated.

*Note:*

NA

#### **MAO-PM0-2.10.7.3: Analysis and modeling constraints**

##### **REQUIREMENT**

The analysis and modeling shall consider the following conditions:

- The model shall be representative of operational boundary conditions.
- The model shall be representative of the specified frequency range.
- The damping factor of 0.75% shall be assumed. Larger damping values shall be approved by the consortium based on justification from the supplier.

*Note:*

NA

#### **MAO-PM0-2.10.7.4: Post processing**

##### **REQUIREMENT**

The post processing of the measured and estimated values shall consider the following:

- Minimum third-octave bands shall be used for frequency band RMS estimation with frequency bands defined using the standard "Acoustics -- Preferred frequencies" ISO 266:1997: 1000Hz as the central frequency corresponding to the 30th band.
- The RMS in each band shall be estimated from the band-pass filtering of the temporal signal and to be crosschecked with the integral of PSD in the respective bands.

*Note:*

NA

#### **3.10.8 MAO-PM0-2.10.8: Welding Verification Requirements**

##### **MAO-PM0-2.10.8.1: Welding load capability**

##### **REQUIREMENT**



The quality and load capability of weld seams shall be verified according to the processes defined in AD4.

*Note:*

NA

### **3.10.9 MAO-PM0-2.10.9: Bonding Verification Requirements**

#### **MAO-PM0-2.10.9.1: Bonding qualification**

##### **REQUIREMENT**

Any structural bonding or bonding to optical substrates shall be qualified before manufacturing. Qualification shall apply to materials, process, and procedure and provide at least 3-sigma confidence that the complete set of concerned bondings will collectively withstand the critical load combinations within the specified lifetime and environment.

*Note:*

NA

#### **MAO-PM0-2.10.9.2: Bonding test data-pack**

##### **REQUIREMENT**

Test results and test specimens shall be delivered to consortium with the concerned elements of the Morfeo-Main Structure. The test procedure and the design of the test setup, if any, shall also be delivered to the consortium.

*Note:*

NA

#### **MAO-PM0-2.10.9.3: Bonding samples**

##### **REQUIREMENT**

Bonding samples shall be glued in parallel with the bonded parts and delivered with the Morfeo-Main Structure, in quantities sufficient to allow periodic (typically, yearly) destructive tests throughout the lifetime of the Morfeo-Main Structure .

*Note:*

NA

### **3.10.10 MAO-PM0-2.10.10: Workmanship Verification Requirements**

#### **MAO-PM0-2.10.10.1: workmanship verification**

##### **REQUIREMENT**

Proper workmanship shall be verified by in-process and final inspections.



MORFEO MAIN STRUCTURE AND  
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*Note:*

*NA*

***3.10.11 MAO-PM0-2.10.11: EMC and Safety Verification Requirements***

**MAO-PM0-2.10.11.1: EMC test**

***REQUIREMENT***

Verification of EMC-and Safety-related requirements shall be according to AD9 and AD6.

*Note:*

*NA*



## 4 Requirement Verification

Id	Req Type	FDR Verification	ARR Verification
MAO-PM0-2.1.1.4	Requirement	Analysis	Analysis
MAO-PM0-2.1.1.5.2	Requirement	Analysis	Analysis
MAO-PM0-2.1.2.2.1	Requirement	Analysis	Analysis
MAO-PM0-2.1.2.2.3	Requirement	Analysis	Analysis
MAO-PM0-2.1.2.2.4	Requirement	Analysis	Analysis
MAO-PM0-2.1.2.2.5	Requirement	Analysis	Analysis
MAO-PM0-2.1.2.3.5	Requirement	Analysis	Analysis
MAO-PM0-2.1.3.1	Requirement	Analysis	Analysis
MAO-PM0-2.2.2.1	Requirement	Analysis	Analysis
MAO-PM0-2.2.3.1.2	Requirement	Design	Test
MAO-PM0-2.4.1.1.2	Requirement	Design	Design
MAO-PM0-2.4.1.1.3	Requirement	Design	Design
MAO-PM0-2.4.1.1.4	Requirement		
MAO-PM0-2.4.1.1.5	Requirement	Design	Design
MAO-PM0-2.4.1.1.7	Requirement	Design	Inspection
MAO-PM0-2.4.1.1.8	Requirement	Design	Inspection
MAO-PM0-2.4.1.1.9	Requirement	Design	Design
MAO-PM0-2.4.2.1.1	Requirement	Design	Design
MAO-PM0-2.4.2.1.4	Requirement	Design	Inspection
MAO-PM0-2.4.2.1.5	Requirement	Design	Inspection
MAO-PM0-2.4.2.1.7	Requirement	Design	Design
MAO-PM0-2.4.2.2.1	Requirement	Design	Design
MAO-PM0-2.4.2.2.4	Requirement	Design	Inspection
MAO-PM0-2.4.2.2.5	Requirement	Design	Inspection
MAO-PM0-2.4.2.2.7	Requirement	Design	Inspection
MAO-PM0-2.4.2.2.9	Requirement	Design	Inspection
MAO-PM0-2.4.2.2.12	Requirement	Design	Inspection
MAO-PM0-2.4.2.2.13	Requirement	Design	Inspection
MAO-PM0-2.4.2.2.14.1	Requirement	Design	Inspection
MAO-PM0-2.4.2.2.14.2	Requirement	Design	Inspection
MAO-PM0-2.4.2.2.14.3	Requirement	Design	Inspection
MAO-PM0-2.4.2.2.14.4	Requirement	Design	Inspection
MAO-PM0-2.4.2.4.1	Requirement	Design	Inspection
MAO-PM0-2.4.2.4.2	Requirement	Design	Inspection
MAO-PM0-2.4.2.4.3	Requirement	Design	Inspection
MAO-PM0-2.4.2.4.4.2	Requirement	Design	Inspection
MAO-PM0-2.4.2.5.1	Requirement	Design	Inspection



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MAO-PM0-2.4.2.5.3	Requirement	Design	Inspection
MAO-PM0-2.4.2.5.5	Requirement	Design	Inspection
MAO-PM0-2.4.2.5.6	Requirement	Design	Inspection
MAO-PM0-2.4.2.5.7	Requirement	Design	Inspection
MAO-PM0-2.4.2.5.8	Requirement	Design	Inspection
MAO-PM0-2.5.1.1	Requirement	Design	Inspection
MAO-PM0-2.5.1.2	Requirement	Design	Inspection
MAO-PM0-2.5.1.3	Requirement	Design	Inspection
MAO-PM0-2.5.1.4	Requirement	Design	Inspection
MAO-PM0-2.5.1.5	Requirement	Design	Inspection
MAO-PM0-2.5.1.6	Requirement	Design	
MAO-PM0-2.5.2.1.1	Requirement	Design	Inspection
MAO-PM0-2.5.2.2	Requirement	Design	Inspection
MAO-PM0-2.5.2.3	Requirement	Design	Inspection
MAO-PM0-2.5.5.1	Requirement	Design	Inspection Test
MAO-PM0-2.5.6.1	Requirement	Design	Inspection Test
MAO-PM0-2.5.10.1	Requirement	Design	Inspection
MAO-PM0-2.5.11.1	Requirement	Design	Inspection
MAO-PM0-2.5.11.2	Requirement	Design	Inspection
MAO-PM0-2.5.11.3	Requirement	Design	Inspection
MAO-PM0-2.5.11.4	Requirement	Design	Inspection
MAO-PM0-2.5.12.1.1	Requirement	Analysis	Test
MAO-PM0-2.5.12.2.1	Requirement	Analysis	Test
MAO-PM0-2.5.12.2.3	Requirement	Analysis	Test
MAO-PM0-2.5.12.3.1	Requirement	Design	Test
MAO-PM0-2.5.12.3.2	Requirement	Design	Inspection
MAO-PM0-2.5.12.3.3	Requirement	Design	Design
MAO-PM0-2.5.13.1	Requirement	Design	Inspection
MAO-PM0-2.6.1.1	Requirement	Analysis	Analysis
MAO-PM0-2.6.1.2	Requirement	Analysis	Analysis
MAO-PM0-2.6.2.1.1	Requirement	Analysis	Analysis
MAO-PM0-2.6.2.1.2	Requirement	Analysis	Analysis
MAO-PM0-2.6.2.2.3	Requirement	Analysis	Analysis
MAO-PM0-2.6.2.2.6	Requirement	Analysis	Analysis
MAO-PM0-2.6.2.2.7	Requirement	Analysis	Analysis
MAO-PM0-2.6.3.1.1	Requirement	Design	Inspection
MAO-PM0-2.6.3.1.2	Requirement	Design	Inspection



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MAO-PM0-2.6.3.1.6	Requirement	Analysis	Inspection
MAO-PM0-2.6.3.1.7	Requirement	Design	Inspection
MAO-PM0-2.6.3.1.8	Requirement	Design	Inspection
MAO-PM0-2.6.4.1.3	Requirement	Analysis	Analysis
MAO-PM0-2.6.4.1.4	Requirement	Analysis	Analysis
MAO-PM0-2.6.4.1.6	Requirement	Design	Design
MAO-PM0-2.6.4.2.1	Requirement	Analysis	Analysis
MAO-PM0-2.6.4.2.2	Requirement	Analysis	Analysis
MAO-PM0-2.6.4.2.4	Requirement	Analysis	Analysis
MAO-PM0-2.6.4.4.1	Requirement	Design	Inspection
MAO-PM0-2.6.4.4.2	Requirement	Design	Inspection
MAO-PM0-2.6.4.4.3	Requirement	Design	Inspection
MAO-PM0-2.6.4.4.4	Requirement	Design	Inspection
MAO-PM0-2.6.4.4.5	Requirement	Design	Inspection
MAO-PM0-2.6.4.4.6	Requirement	Design	Inspection
MAO-PM0-2.6.5.1	Requirement	Design	Inspection
MAO-PM0-2.7.1	Requirement	Design	Analysis
MAO-PM0-2.7.2	Requirement	Design	Analysis
MAO-PM0-2.7.3	Requirement	Design	Analysis
MAO-PM0-2.7.5	Requirement	Design	Analysis
MAO-PM0-2.7.6	Requirement	Design	Analysis
MAO-PM0-2.7.7	Requirement	Design	Analysis
MAO-PM0-2.7.9	Requirement	Design	Analysis
MAO-PM0-2.7.10	Requirement	Design	Analysis
MAO-PM0-2.7.12	Requirement	Design	Analysis
MAO-PM0-2.7.13	Requirement	Design	Analysis
MAO-PM0-2.8.1.1	Requirement	Design	Inspection
MAO-PM0-2.8.2.1	Requirement	Design	Inspection
MAO-PM0-2.10.1.1	Requirement	Design	Design
MAO-PM0-2.10.1.2	Requirement	Design	Design
MAO-PM0-2.10.2.1	Requirement	Analysis	Analysis
MAO-PM0-2.10.2.2	Requirement	Analysis	Analysis
MAO-PM0-2.10.2.3	Requirement	Analysis	Analysis
MAO-PM0-2.10.2.4	Requirement	Analysis	Analysis
MAO-PM0-2.10.2.5	Requirement	Analysis	Analysis
MAO-PM0-2.10.2.6	Requirement	Analysis	Analysis
MAO-PM0-2.10.3.1	Requirement	Analysis	Analysis
MAO-PM0-2.10.4.1	Requirement	Design	Test



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<b>MAO-PM0-2.10.4.3</b>	Requirement	Analysis	Analysis
<b>MAO-PM0-2.10.5.1</b>	Requirement	Analysis	Analysis
<b>MAO-PM0-2.10.5.2</b>	Requirement	Analysis	Analysis
<b>MAO-PM0-2.10.5.3</b>	Requirement	Analysis	Analysis
<b>MAO-PM0-2.10.6.1</b>	Requirement	Analysis	Analysis
<b>MAO-PM0-2.10.6.2</b>	Requirement	Analysis	Analysis
<b>MAO-PM0-2.10.7.1</b>	Requirement	Analysis	Analysis
<b>MAO-PM0-2.10.7.2</b>	Requirement		Test
<b>MAO-PM0-2.10.7.3</b>	Requirement	Analysis	
<b>MAO-PM0-2.10.7.4</b>	Requirement	Analysis	Analysis
<b>MAO-PM0-2.10.8.1</b>	Requirement	Analysis	Analysis
<b>MAO-PM0-2.10.9.1</b>	Requirement		Test
<b>MAO-PM0-2.10.9.2</b>	Requirement		Analysis
<b>MAO-PM0-2.10.9.3</b>	Requirement		Test
<b>MAO-PM0-2.10.10.1</b>	Requirement		Test
<b>MAO-PM0-2.10.11.1</b>	Requirement		Inspection