Programme: **ELT**

Project: **ELT MCAO Construction – MORFEO**

DMs Common Requirements

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07/02/2023	all	first draft

Contents

1 Related Documents

1.1 Applicable Documents

MAO-PD0-1.6 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.

AD18 ESO-044295 Electrical and Electronic Design Standards v:4

AD13 Execution of steel structures and aluminium structures; EN 1090

AD15 Standard Components and Guidelines for Cooling Circuits; ESO-254314 Version 6

AD19 ESO-193497 SAF-GEN-MAN-3444 ESO Safety Conformity Assessment Procedure, issue 5

AD20 ESO-192984 ESO Mechanical Standards, issue 2

AD21 ESO-191462 ESO Engineering Analysis Standard, issue 2

1.2 Reference Documents

RD1 ESO PDM Document Types and Definitions Number ESO-231062 Version 1

RD2 Systems Engineering General Requirements ECSS-EST-10C Version 3

RD3 General Definitions and Basic Conventions Related to Interfaces ESO-193459 Version 2

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 two MORFEO Deformable Mirrors, one concave and one convex of one metre size class.

2.2 Naming Convention

Requirements are identified with a requirement tag following the format [MAO-PD0-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
I-PXX/PD0	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
PD0	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
PSO	MORFEO Software subsystem
PT0	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

3 Common Requirement

3.1 Environmental Conditions

3.1.1 MAO-PD0-2.1.1: Nominal Operating Conditions

MAO-PD0-2.1.1.1: info operational condition definition

INFO

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

MAO-PD0-2.1.1.2: info functional condition definition

INFO

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

MAO-PD0-2.1.1.3: 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-Deformable Mirrors during their lifetime. Morfeo-Deformable Mirrors shall survive such events and shall be able to restart operation after their occurrence:
a) No damage of Morfeo-Deformable Mirrors 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-PD0-2.1.1.4: 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-PD0-2.1.1.5: Nasmyth Instruments

MAO-PD0-2.1.1.5.1: Nasmyth nominal Operating conditions

INFO

The Nominal Operating Conditions for Morfeo-Deformable Mirrors are provided in the Table below:

	Operational	Functional	Survival
Air density	0.87kg/m^3 (Median)		0.92kg/m^3
Air Pressure	712mbar ± 50mbar		N/A
Air Temperature	0°C to +15°C	-5°C to +20°C	-10°C to +25°C
Air temperature gradient at night time See also #1246 - #1248	-0.55°C/h to +0.5°C/h	-1.0°C/h to +1.4°C/h	-10°C/h to +10°C/h (over 30 min) -5°C/h to +5°C/h (over 1h)
Relative Humidity range	5% to 80%		3% to 100% with condensation
Average wind speed	<2 m/s	<3 m/s	<16 m/s
Sky temperature (relevant for radiative heat transfer computation)	See #1254		
Ozone Concentration	<180 µg/m^3		
Dust and Sand	ISO 7.2 (median) and ISO 8 (90% percentile), according to EN ISO 14644-1: 1999		
Aggressive atmosphere	NO ≤ 3ppb, NO_2 ≤ 3ppb, SO_2 ≤ 3ppb		
Vibration and Acoustic Noise	See Sec 7.6 of AD3		
Accelerations	See Sec 3.2.2 of AD3		
	I-INS/ELT-71	I-INS/ELT-72	I-INS/ELT-72
Earthquake (expressed in $\{X_{AZ}, Y_{AZ}, Z_{AZ}\}$) in g	N/A		As defined in #1244

this requirement is refined by **MAO-PD0-1.1.2 of** E-MAO-PD0-INA-SPE-003

3.1.2 MAO-PD0-2.1.2: Specific Conditions

MAO-PD0-2.1.2.1: definition of specific operating condition

INFO

The Specific Operating Conditions apply to:

- Morfeo-Deformable Mirrors (Re-)assembly at the Observatory
- Morfeo-Deformable Mirrors Integration
- Maintenance
- Transport and Storage

3.1.2.1 MAO-PD0-2.1.2.2: Conditions Applicable to (Re)-Assembly, Integration and Maintenance

MAO-PD0-2.1.2.2.1: 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-PD0-2.1.2.2.2: Reassembly Integration and Maintenance condition

INFO

	Typical	Functional
Gravity orientation (Zc wrt vertical*)	<1 deg	NA
Air pressure	712mbar ± 50mbar	NA
Air temperature	0°C to +15°C Inside the telescope dome	NA
	+15°C to +21°C Inside the instrument Assembly Area	NA
Earthquake	none	±1.3 g quasi-static in any direction

3.1.2.2 MAO-PD0-2.1.2.3: Conditions Applicable to Transport and Storage

MAO-PD0-2.1.2.3.1: definition of transport operating condition 1

INFO

Transport Conditions are those to which Morfeo-Deformable Mirrors 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-PD0-2.1.2.3.2: definition of transport operating condition 2

INFO

	Typical	Functional
Gravity orientation (wrt Zc axis)	As specified in packing requirements	NA
Air pressure	570mbar to 1045mbar	NA
Air temperature	-15°C to +45°C	-33°C to +85°C (*)
Rain	None	10 cm/h with a droplet size of 0.5 to 4.5mm and a wind velocity of 18 m/s
Relative Humidity range	3% to 100% condensing	NA
Blowing Dust and Sand	Particle size 74 to 1000 micrometers, mostly 74 to 350 micrometers Particle concentration: 1.0 g/m^3 Wind speed 18 to 30 m/s	NA
Shipping vibration loads	As defined by PSD in #879	NA
Quasi-static accelerations	As defined in #1250	NA
Salt concentration	5% ± 1%	20%
Mechanical shocks	None	Drop height 20cm
Earthquake	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).
#879 is replaced by MAO-PDo-2.1.2.3.4
#1250 is replaced by MAO-PDo-2.1.2.3.6

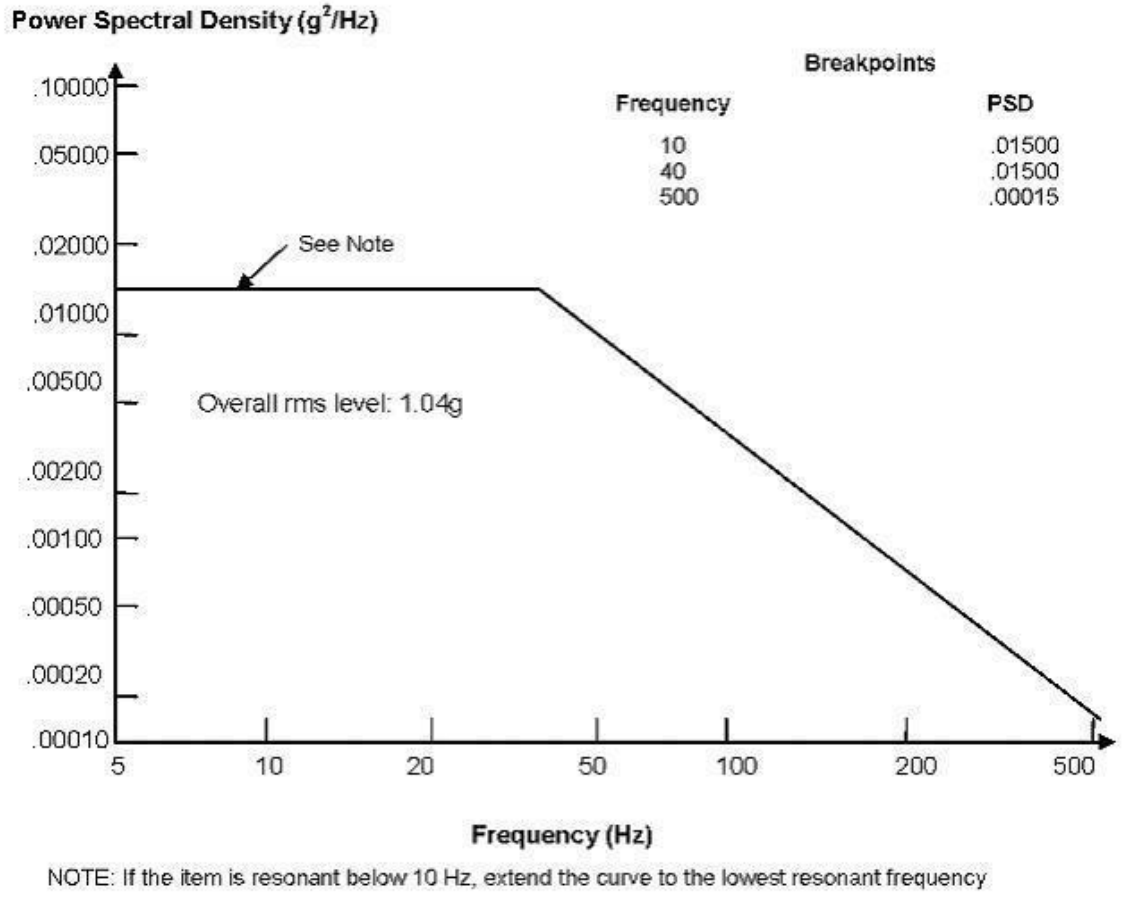
MAO-PD0-2.1.2.3.3: definition of transport operating condition 3

INFO

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

MAO-PD0-2.1.2.3.4: 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-PD0-2.1.2.3.5: Applicability of transport and storage condition

REQUIREMENT

The conditions defined in 2.1.2.3.2 and 2.1.2.3.3 shall apply when transporting and storing Morfeo-Deformable Mirrors .

Note:

NA

MAO-PD0-2.1.2.3.6: Transport quasi static acceleration

REQUIREMENT

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		
	In the direction of travel	Sideways	Vertical
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

Quasi-static acceleration during transport

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-PD0-2.1.3: Load Combination Factors

MAO-PD0-2.1.3.1: 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-PD0-2.1.3.2: load combination factors definition

INFO

				Load combination factor	
Load combination	**Load Category**	**Section**	**Permanent load**	**Survival temperature**	**Maximum acceleration (earthquake, shock)**
LC1	Operational Conditions	4.1 Nominal Operating Conditions	1.0 x O (1)		
LC2	Survival/Accidental	4.1 Nominal Operating Conditions	1.0 x O (1)	1.0	
LC3	Survival/Accidental	4.1 Nominal Operating Conditions	1.0 x O (1)		1.0
LC4	Survival/Accidental	4.2.1 Conditions applicable to assembly	As per section 4.2.1		1.0
LC5	Survival/Accidental	4.2.1 Conditions applicable to integration and alignment into the telescope	As per section 4.2.1		1.0
LC6	Survival/Accidental	4.2.2 Transport	As per section 4.2.2	1.0	
LC7 (Shock Load)	Survival/Accidental	4.2.2 Transport	As per section 4.2.2	0.7	1.0
LC8 (Earthquake)	Survival/Accidental	4.2.2 Storage	As per section 4.2.2		1.0

(1) *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 [INFO-INS-690] in the column "Operational".

3.2 MAO-PD0-2.2: Physical, Functional and Performance Requirements

3.2.1 MAO-PD0-2.2.4: Operational Requirements

MAO-PD0-2.2.4.12: remote operability of the instrument

REQUIREMENT

Operation and monitoring of Morfeo-Deformable Mirrors shall be possible remotely and shall not require the presence of humans at, or near, the operation site.

Note:

NA

3.4 MAO-PD0-2.4: Access and Handling

3.4.1 MAO-PD0-2.4.1: Access

3.4.1.1 MAO-PD0-2.4.1.1: Nasmyth Platforms

MAO-PD0-2.4.1.1.1: Nasmith accessibility

INFO

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

MAO-PD0-2.4.1.1.2: Size and mass of loads (stairs)

INFO

Size and mass of loads intended for transport via the elevator will be issued at beginning of phase C

MAO-PD0-2.4.1.1.3: Size and mass of loads (elevator)

INFO

Size and mass of loads intended for transport via the stairs will be issued at beginning of phase C

MAO-PD0-2.4.1.1.4: Extra loads (crane)

INFO

Loads that can neither be transported via elevator nor via stairs shall be handled with a crane. details will be issued at beginning of phase C

MAO-PD0-2.4.1.1.5: Restriction of operation Accessibility

REQUIREMENT

Access to the Nasmyth Morfeo-Deformable Mirrors shall be for the following purposes:

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

Note:

NA

MAO-PD0-2.4.1.1.6: Access and maintainability requirement

REQUIREMENT

The access provided by Morfeo-Deformable Mirrors within its design volume shall be consistent with the maintainability requirements given in MAO-PD0-2.6.4 Maintenance Requirements

Note:
NA

3.4.2 MAO-PD0-2.4.2: Handling

3.4.2.1 MAO-PD0-2.4.2.1: General

MAO-PD0-2.4.2.1.1: Integration facility specifications

INFO

Specifications of the on site facilities and equipment will be issued at beginning of phase C

MAO-PD0-2.4.2.2: Instrument Arrival and Integration

INFO

Specifications for the Arrival and Integration will be issued at beginning of phase C

3.4.2.2 MAO-PD0-2.4.2.4: Storage

MAO-PD0-2.4.2.4.1: Needs of separate storage stand

REQUIREMENT

A separate storage stand or base shall be provided for Morfeo-Deformable Mirrors 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-Deformable Mirrors .
Note:
NA

MAO-PD0-2.4.2.4.2: Carriages certification

REQUIREMENT

Morfeo-Deformable Mirrors carriages shall be certified for compliance with applicable safety regulations by an approved agency (such as TÜV or equivalent).
Note:
NA

MAO-PD0-2.4.2.4.3: Protecting cover needs

REQUIREMENT

If Morfeo-Deformable Mirrors are not otherwise protected from dust ingress and mechanical damage when dismounted from the telescope shall be provided with protective cover(s).
Note:
NA

3.4.2.3 MAO-PD0-2.4.2.5: Tools

MAO-PD0-2.4.2.5.1: Special tools delivery

REQUIREMENT

If special tools or equipment other than the one provided by the consortium is needed for the Morfeo-Deformable Mirrors , its handling, integration, maintenance, transportation and/or modification, then such tools shall be delivered together with Morfeo-Deformable Mirrors and become property of the observatory.

Note:

NA

MAO-PD0-2.4.2.5.2: Documentation required for tools

REQUIREMENT

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

Note:

NA

MAO-PD0-2.4.2.5.3: Certification of the lifting tools

REQUIREMENT

Lifting tools shall come with a proper certification (as defined in SAF-GEN-MAN-3444) that is still valid for at least one year from the time when it is handed over to ESO.

Note:

NA

MAO-PD0-2.4.2.5.5: 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-PD0-2.4.2.5.6: 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-PD0-2.4.2.5.7: 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-PD0-2.4.2.5.8: Transport containers

REQUIREMENT

Transport containers for Line Replaceable Units (LRUs) or other Morfeo-Deformable Mirrors 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-PD0-2.5: Design and Construction

3.5.1 MAO-PD0-2.5.1: Optomechanical

MAO-PD0-2.5.1.1: surface blackening

REQUIREMENT

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

Note:

NA

MAO-PD0-2.5.1.2: Cleanability of external optical surface

REQUIREMENT

External optical surfaces shall be cleanable.

Note:

NA

MAO-PD0-2.5.1.3: 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-Deformable Mirrors or to the telescope, in particular if such parts or equipment are unprotected.

Note:

NA

MAO-PD0-2.5.1.4: 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-PD0-2.5.1.5: prevent liquid trapping

REQUIREMENT

The design of Morfeo-Deformable Mirrors and its sub-systems shall ensure that, for all permitted orientations of the Morfeo-Deformable Mirrors , liquids do not become trapped. An exception to this is under survival conditions (MAO-PD0-2.1.1.3).

Note:

NA

MAO-PD0-2.5.1.6: Washing compatibility of item fixed to mirrors

REQUIREMENT

Items fixed to mirrors during washing (removal of reflective coating) 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

MAO-PD0-2.5.1.7: Compatibility for recoating

REQUIREMENT

Mirrors that require recoating over the lifetime of the Morfeo-Deformable Mirrors , and any item permanently mounted onto them, shall be compatible with vacuum coating by evaporation and by sputtering. 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

MAO-PD0-2.5.1.8: Lubricants cleanability

REQUIREMENT

Lubricants may be applied onto uncoated optical substrates for transport only (e.g. to reduce friction against supports). It shall be possible to remove such lubricants by using alcohol and clean wipes.

Note:

NA

3.5.2 MAO-PD0-2.5.2: Mechanical

3.5.2.1 MAO-PD0-2.5.2.1: Welding

MAO-PD0-2.5.2.1.1: 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 AD13 shall be applied.

Note:

NA

MAO-PD0-2.5.2.2: General mechanical requirements

REQUIREMENT

Morfeo-Deformable Mirrors shall conform to ESO-192984.

Note:

NA

3.5.3 MAO-PD0-2.5.3: Cooling

MAO-PD0-2.5.3.1: Cooling reference document

INFO

The instruments' cooling system shall use and follow the “Standard Components and Guidelines for the Cooling Circuits” (AD15).
(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-PD0-2.5.5: Electric and Electronic

MAO-PD0-2.5.5.1: Electrical bonding

REQUIREMENT

Morfeo-Deformable Mirrors shall be electrically bonded. The bonding shall be compliant with ESO-044295.

Note:

NA

MAO-PD0-2.5.5.3: General electrical requirements

REQUIREMENT

Morfeo-Deformable Mirrors shall conform to ESO-044295.

Note:

NA

MAO-PD0-2.5.5.4: Safety Power

REQUIREMENT

Safety power will remain active for a period of at least six (6) hours.
In the case of a prolonged power failure period, instruments relying on safety power shall therefore use the Safety power to place critical equipment in a safe state to avoid the safety power being depleted.
The time to complete this exercise shall not exceed 6 hours.

Note:

NA

3.5.5 MAO-PD0-2.5.6: Electromagnetic Compatibility

MAO-PD0-2.5.6.1: General electromagnetic requirements

REQUIREMENT

Morfeo-Deformable Mirrors shall conform to the electromagnetic compatibility requirements specified in ESO-044295.

Note:

NA

3.5.6 MAO-PD0-2.5.10: Interchangeability

MAO-PD0-2.5.10.1: 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-PD0-2.5.11: Workmanship

MAO-PD0-2.5.11.1: 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-PD0-2.5.11.2: verified procedures applicability

REQUIREMENT

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

Note:

NA

MAO-PD0-2.5.11.3: Inspection in different phases

REQUIREMENT

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

Note:

NA

MAO-PD0-2.5.11.4: 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-PD0-2.5.12: Induced Environment

3.5.8.1 MAO-PD0-2.5.12.3: Contamination and Pollution Requirements

MAO-PD0-2.5.12.3.1: Surface emissivity

REQUIREMENT

Instruments 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-PD0-2.5.12.3.2: 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-PD0-2.5.12.3.3: 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-PD0-2.5.13: Site Adaptation

MAO-PD0-2.5.13.1: 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-PD0-2.6: Lifetime and Reliability, Availability and Maintainability (RAM)

3.6.1 MAO-PD0-2.6.1: Lifetime

MAO-PD0-2.6.1.2: 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 as planned, but within the limits defined by Maintenance requirement. Similarly for parts having a lifetime shorter than the lifetime of Morfeo-Deformable Mirrors as a whole, it can be assumed that overhauls will be performed as planned, but within the limits of Design for Reliability and Maintainability Requirements

Note:

NA

3.6.2 MAO-PD0-2.6.2: Reliability

3.6.2.1 MAO-PD0-2.6.2.1: Failure Definition

MAO-PD0-2.6.2.1.1: Severity definition

REQUIREMENT

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

Severity 3	The occurrence of a functional failure of the Instrument that will cause if not rectified, directly or indirectly, a loss of science observation time or corrective maintenance action that cannot be deferred
Severity 2	The occurrence of a functional failure or of the Instrument that will cause if not rectified, directly or indirectly, a performance degradation of science observation
Severity 1	The occurrence of a functional failure of the Instrument that does not belong to category with severity 3 or 2

Definition of Severity

Note:
NA

MAO-PD0-2.6.2.1.2: 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-PD0-2.6.2.1.1).

Note:
NA

MAO-PD0-2.6.2.1.3: 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-PD0-2.6.2.2: Reliability Requirements

MAO-PD0-2.6.2.2.3: Clock time

REQUIREMENT

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

Note:
NA

MAO-PD0-2.6.2.2.6: 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-PD0-2.6.2.2.7: Activity of provider +consortium

REQUIREMENT

The provider and the Consortium shall jointly:
- identify those items of the Morfeo-Deformable Mirrors 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-Deformable Mirrors
- work together to estimate MTBF, MCMT and MTTR for critical components, mechanisms or sub-assemblies and model these data to obtain an overall Morfeo-Deformable Mirrors availability which meets the top-down availability allocation for Morfeo-Deformable Mirrors
.

Note:
NA

3.6.3 MAO-PD0-2.6.3: Maintainability

3.6.3.1 MAO-PD0-2.6.3.1: General

MAO-PD0-2.6.3.1.1: 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-PD0-2.6.3.1.2: 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-PD0-2.6.3.1.3: Use of non standard tools

REQUIREMENT

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

Note:

NA

MAO-PD0-2.6.3.1.4: 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-PD0-2.6.3.1.5: 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-PD0-2.6.3.1.6: LRU final destination

INFO

After substitution, failed LRU's may be discarded, replaced or repaired at the Telescope (in-situ), at the consortium premises or at the factory following the prescriptions that shall be given by the Consortium in the Maintenance Manual.

MAO-PD0-2.6.3.1.7: list of LRU

REQUIREMENT

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

Note:

NA

MAO-PD0-2.6.3.1.8: In situ maintenance operations

REQUIREMENT

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

Note:

NA

MAO-PD0-2.6.3.1.9: in situ operations on LRU

REQUIREMENT

As a goal all LRU shall be replaceable in situ.

Note:

NA

3.6.3.2 MAO-PD0-2.6.3.2: Test and Maintenance Software

MAO-PD0-2.6.3.2.1: Test and Maintenance Software delivery

REQUIREMENT

For each Morfeo-Deformable Mirrors test and maintenance software shall be provided.

Note:

NA

MAO-PD0-2.6.3.2.2: identification of failures

REQUIREMENT

In case of system failure, this software shall allow identification of the subsystem level at which the failure happened.

Note:

NA

3.6.4 MAO-PD0-2.6.4: Maintenance Requirements

3.6.4.1 MAO-PD0-2.6.4.1: Corrective Maintenance

MAO-PD0-2.6.4.1.1: 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-PD0-2.6.4.1.2: MCMT reference time

REQUIREMENT

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

Note:

NA

MAO-PD0-2.6.4.1.3: 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.

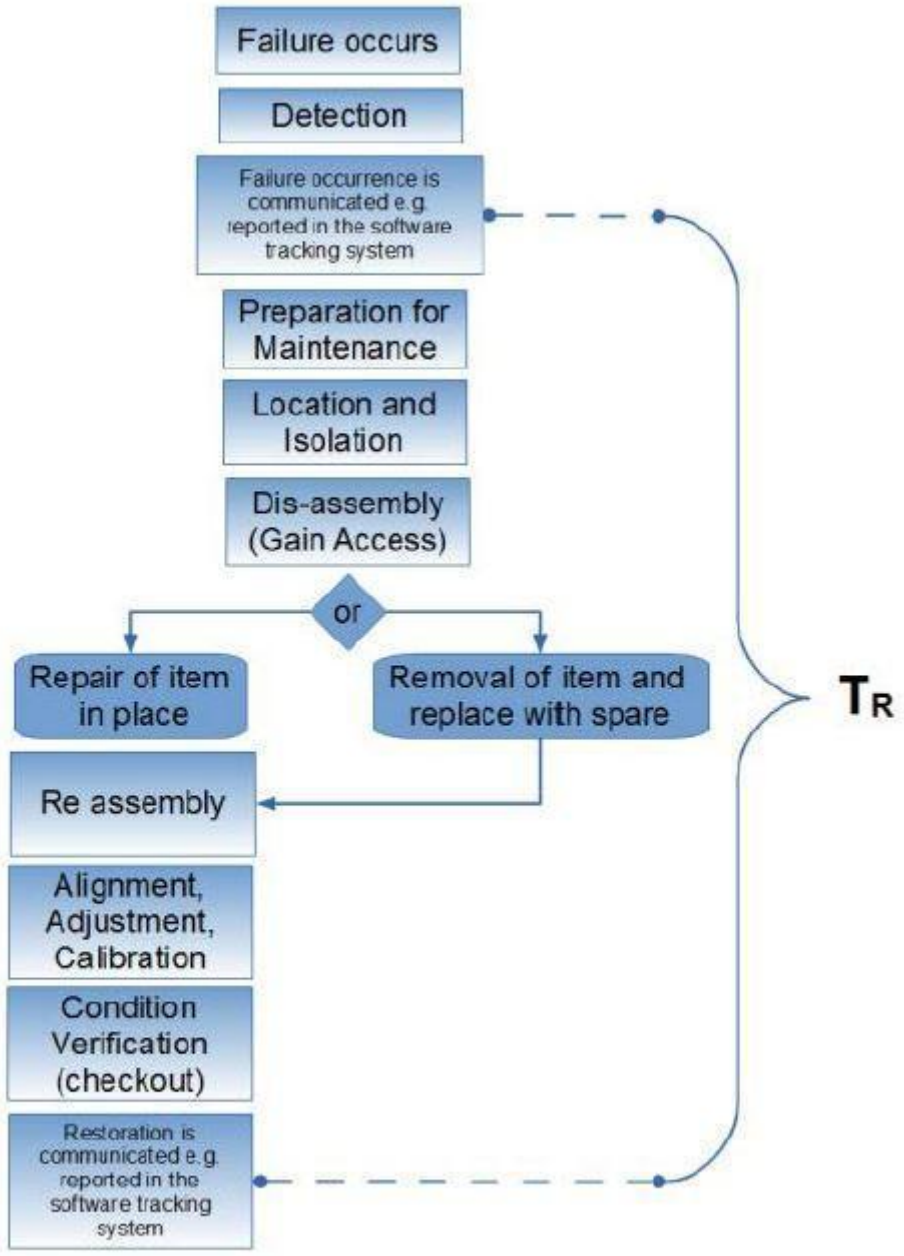
Note:

NA

MAO-PD0-2.6.4.1.4: 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-PD0-2.6.4.1.5: 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-Deformable Mirrors .

Note:

NA

MAO-PD0-2.6.4.1.6: TR computation 2

REQUIREMENT

For the computation of MCMT and MTTR it shall be assumed that instruments cannot be transported in a cooled-down state for safety reasons. Hence, time for potentially necessary additional warm-up and cool-down cycles shall be considered.

Note:

NA

3.6.4.2 MAO-PD0-2.6.4.2: Preventive/Predictive Maintenance

MAO-PD0-2.6.4.2.1: actions limitations

REQUIREMENT

For Morfeo-Deformable Mirrors 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-PD0-2.6.4.2.2: 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-PD0-2.6.4.2.3: 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-PD0-2.6.4.3: Overhaul Maintenance Requirements

MAO-PD0-2.6.4.3.1: Overhaul planning

INFO

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

3.6.4.4 MAO-PD0-2.6.4.4: Design for Reliability and Maintainability Requirements

MAO-PD0-2.6.4.4.1: Marking requirement

REQUIREMENT

All Morfeo-Deformable Mirrors 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-PD0-2.6.4.4.2: Morfeo-Deformable Mirrors 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-Deformable Mirrors ;
- 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-PD0-2.6.4.4.3: Morfeo-Deformable Mirrors design guidelines

REQUIREMENT

The design for maintainability of Morfeo-Deformable Mirrors 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-PD0-2.6.4.4.4: 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-PD0-2.6.4.4.5: 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

3.6.5 MAO-PD0-2.6.5: Computerised maintenance management system

MAO-PD0-2.6.5.1: Compatibility with CMMS

REQUIREMENT

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

Note:

NA

MAO-PD0-2.6.5.2: 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-PD0-2.7: Safety

MAO-PD0-2.7.1: EU directives applicability

REQUIREMENT

Morfeo-Deformable Mirrors 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-PD0-2.7.2: 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 SAF-GEN-MAN-3444 and ESO-044295.

Note:

NA

MAO-PD0-2.7.3: Hazard analysis and risk assessment

REQUIREMENT

A hazard analysis and risk assessment shall be conducted according to the principles noted down in SAF-GEN-MAN-3444. 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-PD0-2.7.4: 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-PD0-2.7.5: 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-PD0-2.7.6: undesirable hazards

REQUIREMENT

None of these events shall lead to an unacceptable or undesirable hazard as defined in SAF-GEN-MAN-3444. This includes the mechanical limitation of stroke of all moving parts.

Note:

NA

MAO-PD0-2.7.7: 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 SAF-GEN-MAN-3444).

Note:

NA

MAO-PD0-2.7.9: 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-PD0-2.7.10: 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-PD0-2.7.11: 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-Deformable Mirrors -specific safety rules that are part of the function of an Morfeo-Deformable Mirrors '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-PD0-2.7.12: Morfeo-Deformable Mirrors ILS

REQUIREMENT

Morfeo-Deformable Mirrors 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-PD0-2.7.13: 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-PD0-2.8: Preparation for Delivery

3.8.1 MAO-PD0-2.8.1: Cleaning

MAO-PD0-2.8.1.1: cleaning before packing

REQUIREMENT

Morfeo-Deformable Mirrors 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-PD0-2.8.2: Packaging and Transport

MAO-PD0-2.8.2.1: Packing datapack

REQUIREMENT

Morfeo-Deformable Mirrors components shall be packed with its accompanying documentation and samples, including as-build documents and handling procedures.
Note:
NA

MAO-PD0-2.8.2.2: desert transportation

INFO

Morfeo-Deformable Mirrors 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-PD0-2.8.2.3: Packing specification definition

INFO

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

MAO-PD0-2.8.2.4: land and sea

INFO

Transport containers should allow land, sea and air freight.

MAO-PD0-2.8.2.5: containers norms

INFO

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

MAO-PD0-2.8.2.6: minimum volume loss

INFO

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

MAO-PD0-2.8.2.7: special transport

INFO

Special transport conditions should be avoided.

MAO-PD0-2.8.2.8: 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-PD0-2.8.2.9: 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-PD0-2.9: Precedence

MAO-PD0-2.9.1: 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-PD0-2.9.2: integrity Morfeo-Deformable Mirrors 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-Deformable Mirrors , the latter shall take precedence.

3.10 MAO-PD0-2.10: Verification

3.10.1 MAO-PD0-2.10.1: Requirements Verification

MAO-PD0-2.10.1.1: Verification type

REQUIREMENT

Four methods of verification shall be applied to verify that the performance requirements of the Morfeo-Deformable Mirrors , 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-PD0-2.10.1.2: 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-PD0-2.10.2: Analysis and Simulation Requirements

MAO-PD0-2.10.2.1: Structural analysis guidelines

REQUIREMENT

Requirements and recommendations stated in ESO-191462 shall be applied for the structural analysis verification of the Morfeo-Deformable Mirrors .

Note:

NA

MAO-PD0-2.10.2.2: Stress analysis verification

REQUIREMENT

The stress analysis shall cover as a minimum all operational conditions defined by R-PD0-2.1. 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 ESO-191462, section 5.11 (Mechanical Safety) shall be met for all the load combinations.

Note:

NA

MAO-PD0-2.10.2.3: 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-PD0-2.10.2.4: 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-PD0-2.10.2.5: Budget for manufacturing

REQUIREMENT

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

Note:

NA

MAO-PD0-2.10.2.7: Modal analysis

REQUIREMENT

Modal analysis of Morfeo-Deformable Mirrors 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-PD0-2.10.3: Lifetime Verification Requirements

MAO-PD0-2.10.3.1: 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-PD0-2.10.4: Reliability Verification Requirements

MAO-PD0-2.10.4.1: 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 SAF-GEN-MAN-3444), 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-PD0-2.10.4.2: End of warranty phase MTBF update

REQUIREMENT

At the end of the Warranty Phase of the Morfeo-Deformable Mirrors (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-PD0-2.10.4.3: 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-PD0-2.10.5: Maintainability Verification Requirements

MAO-PD0-2.10.5.1: Maintainability testing

REQUIREMENT

As part of the overall verification of the Morfeo-Deformable Mirrors , 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-PD0-2.10.5.2: 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-PD0-2.10.5.3: 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 λ_i is the failure rate of the i-th item to be replaced/repaired 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-PD0-2.10.6: Thermal Verification Requirements

MAO-PD0-2.10.6.1: 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-PD0-2.10.6.2: 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-PD0-2.10.7: Vibration Verification Requirements

MAO-PD0-2.10.7.1: Analysis and testing needs

REQUIREMENT

The vibration requirement 2.5.12.1 shall be verified by a combination of analysis and testing. Morfeo-Deformable Mirrors 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-PD0-2.10.7.2: 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-PD0-2.10.7.3: 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-PD0-2.10.7.4: 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-PD0-2.10.8: Welding Verification Requirements

MAO-PD0-2.10.8.1: Welding load capability

REQUIREMENT

The quality and load capability of weld seams shall be verified according to the processes defined in AD13.

Note:

NA

3.10.9 MAO-PD0-2.10.9: Bonding Verification Requirements

MAO-PD0-2.10.9.1: 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-PD0-2.10.9.2: Bonding test data-pack

REQUIREMENT

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

Note:
NA

MAO-PD0-2.10.9.3: Bonding samples

REQUIREMENT

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

Note:
NA

3.10.10 MAO-PD0-2.10.10: Workmanship Verification Requirements

MAO-PD0-2.10.10.1: workmanship verification

REQUIREMENT

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

Note:
NA

3.10.11 MAO-PD0-2.10.11: EMC and Safety Verification Requirements

MAO-PD0-2.10.11.1: EMC test

REQUIREMENT

Verification of EMC- and Safety-related requirements shall be according to ESO-044295.

Note:
NA

4 Requirement Verification

ID requirement	FDR Verification	ARR Verification
MAO-PD0-2.1.1.4	Analysis	Analysis
MAO-PD0-2.1.2.2.1	Analysis	Analysis
MAO-PD0-2.1.2.3.5	Similarity	Analysis
MAO-PD0-2.1.2.3.6	Analysis	Analysis
MAO-PD0-2.1.3.1	Similarity	Analysis
MAO-PD0-2.2.4.12	Design	Inspection
MAO-PD0-2.3.1	Design	Inspection
MAO-PD0-2.4.1.1.5	Design	Design
MAO-PD0-2.4.1.1.6	Design	Design
MAO-PD0-2.4.2.4.1	Design	Inspection
MAO-PD0-2.4.2.4.2	Design	Inspection
MAO-PD0-2.4.2.4.3	Design	Inspection
MAO-PD0-2.4.2.5.1	Design	Inspection
MAO-PD0-2.4.2.5.2	Design	Inspection
MAO-PD0-2.4.2.5.3	Design	Inspection
MAO-PD0-2.4.2.5.5	Design	Inspection
MAO-PD0-2.4.2.5.6	Design	Inspection
MAO-PD0-2.4.2.5.7	Design	Inspection
MAO-PD0-2.4.2.5.8	Design	Inspection
MAO-PD0-2.5.1.1	Design	Inspection
MAO-PD0-2.5.1.2	Design	Inspection
MAO-PD0-2.5.1.3	Design	Inspection
MAO-PD0-2.5.1.4	Design	Inspection
MAO-PD0-2.5.1.5	Design	Inspection
MAO-PD0-2.5.1.6	Design	Inspection
MAO-PD0-2.5.1.7	Design	Inspection
MAO-PD0-2.5.1.8	Design	Inspection
MAO-PD0-2.5.2.1.1	Design	Inspection
MAO-PD0-2.5.2.2	Design	Inspection
MAO-PD0-2.5.5.1	Design	Inspection
MAO-PD0-2.5.5.3	Design Analysis	Inspection Test
MAO-PD0-2.5.5.4	Design Analysis	Inspection Test

ID requirement	FDR Verification	ARR Verification
MAO-PD0-2.5.6		
MAO-PD0-2.5.6.1	Design Analysis	Inspection Test
MAO-PD0-2.5.10.1	Design	Inspection
MAO-PD0-2.5.11.1	Design	Inspection
MAO-PD0-2.5.11.2	Design	Inspection
MAO-PD0-2.5.11.3	Design	Inspection
MAO-PD0-2.5.11.4	Design	Inspection
MAO-PD0-2.5.12.3.1	Design	Test
MAO-PD0-2.5.12.3.2	Design	Inspection
MAO-PD0-2.5.12.3.3	Design	Design
MAO-PD0-2.5.13	Design	Design
MAO-PD0-2.6.1.2	Design Analysis	Design Analysis
MAO-PD0-2.6.2.1.1	Analysis	Analysis
MAO-PD0-2.6.2.1.2	Analysis	Analysis
MAO-PD0-2.6.2.2.3	Analysis	Analysis
MAO-PD0-2.6.2.2.6	Analysis	Analysis
MAO-PD0-2.6.2.2.7	Analysis	Analysis
MAO-PD0-2.6.3.1.1	Design	Inspection
MAO-PD0-2.6.3.1.2	Design	Inspection
MAO-PD0-2.6.3.1.3	Design	Inspection
MAO-PD0-2.6.3.1.4	Analysis	Analysis
MAO-PD0-2.6.3.1.7	Analysis	Analysis
MAO-PD0-2.6.3.1.8		Design
MAO-PD0-2.6.3.1.9	Analysis	Analysis
MAO-PD0-2.6.3.2.1	Design	Inspection
MAO-PD0-2.6.3.2.2		Test
MAO-PD0-2.6.4.1.2	Design	Analysis
MAO-PD0-2.6.4.1.3	Design	Design
MAO-PD0-2.6.4.1.4	Design	Design
MAO-PD0-2.6.4.1.5	Design	Test
MAO-PD0-2.6.4.1.6	Design	Design
MAO-PD0-2.6.4.2.1	Design	Test
MAO-PD0-2.6.4.2.2	Design	Test
MAO-PD0-2.6.4.2.3	Design	Design

ID requirement	FDR Verification	ARR Verification
MAO-PD0-2.6.4.4.1	Design	Inspection
MAO-PD0-2.6.4.4.2	Design	Analysis
MAO-PD0-2.6.4.4.3	Design	Analysis
MAO-PD0-2.6.4.4.4	Design	Analysis
MAO-PD0-2.6.4.4.5	Design	Analysis
MAO-PD0-2.6.5.1		Inspection
MAO-PD0-2.7.1	Design	Analysis
MAO-PD0-2.7.2	Design	Analysis
MAO-PD0-2.7.3	Design	Analysis
MAO-PD0-2.7.5	Design	Analysis
MAO-PD0-2.7.6	Design	Analysis
MAO-PD0-2.7.7	Design	Analysis
MAO-PD0-2.7.9	Design	Analysis
MAO-PD0-2.7.10	Design	Analysis
MAO-PD0-2.7.12	Design	Analysis
MAO-PD0-2.7.13	Design	Analysis
MAO-PD0-2.8.1.1		Inspection
MAO-PD0-2.8.2.1		Inspection
MAO-PD0-2.10.1.1	Design	Design
MAO-PD0-2.10.1.2	Design	Design
MAO-PD0-2.10.2.1	Analysis	Analysis
MAO-PD0-2.10.2.2	Analysis	Analysis
MAO-PD0-2.10.2.3	Analysis	Analysis
MAO-PD0-2.10.2.4	Analysis	Analysis
MAO-PD0-2.10.2.5	Analysis	Analysis
MAO-PD0-2.10.2.7	Analysis	Analysis
MAO-PD0-2.10.3.1		Inspection
MAO-PD0-2.10.4.1		Test
MAO-PD0-2.10.4.2	Analysis	Analysis
MAO-PD0-2.10.4.3	Analysis	Analysis
MAO-PD0-2.10.5.1		Test
MAO-PD0-2.10.5.2	Analysis	Test
MAO-PD0-2.10.5.3	Analysis	Analysis
MAO-PD0-2.10.6.1	Analysis	Test
MAO-PD0-2.10.6.2	Analysis	Analysis
MAO-PD0-2.10.7.1	Analysis	Test

ID requirement	FDR Verification	ARR Verification
MAO-PD0-2.10.7.2		Test
MAO-PD0-2.10.7.3	Analysis	
MAO-PD0-2.10.7.4	Analysis	Analysis
MAO-PD0-2.10.8.1		Test
MAO-PD0-2.10.9.1		Test
MAO-PD0-2.10.9.2		Test
MAO-PD0-2.10.9.3		Test
MAO-PD0-2.10.10.1		Inspection
MAO-PD0-2.10.11.1		Test

FDR Verification	ARR Verification