



Programme: **ELT**

Project: **ELT MCAO Construction – MORFEO**

# MORFEO MAIT HTs-Seq Technical Specifications

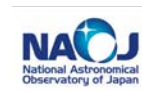
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## Change Record from previous version

Date	Affected Section(s)	Changes / Reason / Remarks
2025-10-10	All	First issue
2026-01-29	Sec. 5 "Handling Tools" pag. 34	In " <i>MAO-SM0-1.1: Handling tools General Requirements</i> " added the sentence: "Deviation to the following requirements shall be discussed and agreed with the MORFEO consortium."
2026-01-29	Sec. 5 "Handling Tools" pag. 36	Added " <i>MAO-SM0-1.1.20</i> ": "All the HTs shall allow installation/dis-installation of the corresponding Opto-mech, inside the MSS, within 2 hours."
2026-01-29	Sec. 6 "Support Equipment" pag. 83	In " <i>MAO-SM0-1.2: Support Equipments General Requirements</i> " added the sentence: "Deviation to the following requirements shall be discussed and agreed with the MORFEO consortium."
2026-01-29	Sec. 6 "Support Equipment" pag. 83	In " <i>MAO-SM0-1.2.9</i> " added the sentence: "Depending on the operating scenario (most probably just in the BIH), sectioning of some SEq might be mandatory, to allow its installation on the bench."



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2026-01-29	Sec. 6 "Support Equipment" pag. 83	Added "MAO-SM0-1.2.13": All the Support Equipments that will be handled using a crane shall foresee connection eyebolts. Their position shall be identified in a way to have the support equipment balanced. A possible concept for the eyebolts positioning is depicted in Sec. 6.7."
2026-01-29	Sec. 6 "Support Equipment" pag. 84	Added "MAO-SM0-1.2.14": All the SEq shall be installed/dis-installed within 30 minutes."
2026-01-29	Sec. 6.7	Added Sec. 6.7 "Handling of the SEq"
2026-03-11	Issue 01	Final version for calft



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# 1. Related Documents

## 1.1 Applicable Documents

The following applicable documents form a part of the present document to the extent specified herein.

- AD1 E-MAO-SE0-INA-SPE-006 MORFEO main structure and handling tools common requirements
- AD2 E-MAO-SE0-INA-SPE-007 Nasmyth interface requirements for morfeo main structure subsystem and handling tools
- AD3 E-MAO-000-INA-PLA-003 MAORY Product and Quality Assurance Plan, issue 3
- AD6 CAD 135139 Nasmyth Platform Interfaces
- ~~AD7 E-MAO-SE0-INA-SPE-006 MORFEO main structure and handling tools common requirements~~
- AD8 E-MAO-PFK-ICD-DWG-001\_01 Corrective plate Morfeo interface drawing
- AD9 E-MAO-PFA-ICD-DWG-001\_03 M6M Volume Interface drawing
- AD10 E-MAO-PFB-ICD-DWG-001\_03 M7M Volume Interface drawing
- AD11 E-MAO-PFC-ICD-DWG-001\_03 M8M Volume Interface drawing
- AD12 E-MAO-PFE-ICD-DWG-001\_03 M11M Volume Interface drawing
- AD13 E-MAO-PFF-ICD-DWG-001\_03 M12M interface drawing
- AD14 E-MAO-PFD-ICD-DWG-001\_03 DICHROIC interface drawing
- AD15 E-MAO-PFG-ICD-DWG-001\_03 LGSO-FM1 interface drawing
- AD16 E-MAO-PFI-ICD-DWG-001\_03 LGSO-FM3 interface drawing
- AD17 E-MAO-PFJ-ICD-DWG-001\_01 CUFM interface drawing
- AD18 E-MAO-PFH-ICD-DWG-001\_03 LGSO Volume and Optical Design
- AD19 E-MAO-PDA-ICD-DWG-001\_01 M9M interface drawing
- AD20 E-MAO-PDB-ICD-DWG-001\_01 M10M interface drawing
- AD21 E-MAO-PUA-INA-ICD-DWG-001\_01 MORFEO Calibration Unit Optomechanical System - PUA (supply) volume
- AD22 E-MAO-PL0-00-00-00-ADP-ICD-001\_10 LGS WFS Interface Drawing



- AD23 E-MAO-000-00-00-00-00-MOD-03\_03 MORFEO System dynamic volume.stp
- AD24 E-MAO-000-00-00-00-00-MOD-10\_01 MORFEO Functional Integrated Geometry Assembly
- AD25 ESO-193497 SAF-GEN-MAN-3444 ESO Safety Conformity Assessment Procedure, issue 5
- AD26 ESO-192984 ESO Mechanical Standards, issue 2
- AD27 ESO-191462 ESO Engineering Analysis Standard, issue 2
- AD28 E-MAO-000-INA-SOW-012\_01 Morfeo Main Structure (MS) and AIV tools SOW
- AD29 PE-G09 - MORFEO\_20260209

## 1.2 Reference Documents

The following documents, of the exact version shown herein, are listed as background references only. They are not to be construed as a binding complement to the present document.

- RD1 ESO PDM Document Types and Definitions  
Number ESO-231062 Version 1
- ~~RD2 Systems Engineering General Requirements  
ECSS-EST-10G Version 3~~
- RD3 MAORY Management Plan  
E-MAO-000-INA-PLA-001 Version 04
- RD4 MAORY System Overview  
E-MAO-000-INA-DER-001 Version 01
- RD5 MAORY System MAIT Plan  
E-MAO-000-INA-PLA-010 Version 01
- RD6 MAORY On-site AIV Plan  
E-MAO-000-INA-PLA-015 Version 01D1
- RD7 Donut: Measuring Optical Aberrations from a Single Extrafocal Image  
PASP 118: 1165-1175, 2006, Tokovinin & Heathcote
- RD8 MAORY System Optical Design and Analysis Report  
E-MAO-SF0-INA-DER-001 Version 01



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RD9 MAORY LGS WFS MAIT Plan Version 1.0  
E-MAO-PL0-IPA-PLA-015\_01



## 2. Introduction

### 1.1 Scope

The scope of this document is to give the technical specifications for the Handling Tools (HTs in the following) and of the Support Equipment (SEq in the following) to be used for the installation and dis-installation of the various opto-mechanical sub-systems of the instrument MORFEO, which stands for Multi-conjugate adaptive Optics Relay For ELT Observation, and it is one of the first light instruments of the European Extremely Large Telescope (ELT).

The MORFEO instrument is designed and developed by an international consortium composed by INAF (Istituto Nazionale di AstroFisica, Italy), CNRS/INSU (Centre National de la Recherche Scientifique/ Institut National des Sciences de l'Univers, France), NUIG (National University of Ireland Galway, Ireland), NRC (National Research Council, Canada), Kyoto University (Japan), NAOJ (National Astronomical Observatory of Japan), the University of Osaka (Japan) and ESO (European Southern Observatory, Europe).

The final destination of MORFEO is at Cerro Armazones, in Chile, where ESO is building the ELT.

The assembly/dis-assembly operations of the MORFEO opto-mechanical sub-systems will be carried on in three different locations:

- BIH (Bologna Integration Hall): a large laboratory of INAF, located in Bologna (Italy), where the overall instrument will be installed and tested before being shipped to Chile
- IAA (Integration and Assembly Area): a large laboratory of ESO, located at Cerro Armazones (Chile) in the ELT telescope basement, where the overall instrument will be re-installed and tested after being shipped to Chile
- the Nasmyth platform of the telescope, where the instrument will be finally installed for its operations on-sky

Further to the 3 locations just mentioned (where MORFEO and its sub-systems will be installed/un-installed), at Armazones in Chile the unpacking of the HTs/SEq (and, more generally, of whatever sub-system/component that will have to be taken inside the IAA) will happen in the entrance hall, which is a large room directly connected to the IAA through a large gate/door.

In the following sections, the three locations and the entrance hall will be briefly described, and the support equipment available for each of them will be also listed and described (such as overhead cranes, fork-lifts, trans pallets, scissor lifts, trolley for heavy loads transportation, ...).

The selected contractor shall thus make the final design and the manufacturing of all the HTs and SEq that will be described hereafter.

Since the selected contractor will also be responsible of the design and manufacturing of the MORFEO Main Support Structure (MSS), further to the HTs and SEq design and manufacturing, a procedure for the installation of each opto-mechanical sub-systems (making use of the HTs and SEq) shall also be devised and proposed. We also point out that every opto-mechanical subsystem that will be handled through the HTs will have



dummies (provided by the companies that will design and manufacture the sub-system) with volumes, geometries, centre of gravity and interfaces (both toward the MSS and toward the HTs) fully representative of the sub-system itself. Such dummies will be used to perform installation test for each opto-mechanical subsystem at the contractor premises, to check both the HTs/Seq and the installation/dis-installation procedure functionality. Such test will be part of the final acceptance procedure concerning the HTs/Seq.

The MORFEO project is undergoing its final design phase, that will finish with a Final Design Review carried on by ESO, which is now tentatively scheduled for the beginning of year 2027. The contractor will then initially be in charge of performing the final design of the HTs/Seq, delivering the step files and final executive drawings for all of them. Furthermore, the contractor will also deliver the installation procedure for each opto-mechanical sub-system in a dedicated comprehensive document, that will be part of the FDR data-package of MORFEO. For this reason, the HTs/Seq design and the related drawings/documentation shall be delivered to INAF at least 2 months prior to the FDR data-package delivery date, to allow internal double-checking and design/document validation.

Should the FDR be positively concluded, the contractor will oversee the HTs/Seq manufacturing too.

Details concerning how the offers shall be prepared are given in the “Disciplinare di gara” but we anticipate here that, for the reasons just explained, the contract will be divided in two phases (design phase and manufacturing phase) and, consequently, the bidder shall provide one offer for each of the 2 phases. The details concerning the deliverables and the related timelines can be found in the SoW and in the mentioned Applicable Documents (ADXXX).

Finally, a preliminary study phase of MORFEO and of the MSS and HTs/Seq have been already carried out. Such phase ended in February 2023. with the positive conclusion of the Preliminary Design Review (PDR). We thus have a preliminary design of the HTs/Seq, and conceptual procedures making use of them, for the installation of each opto-mechanical sub-systems on the MORFEO main support structure, that will be provided to the bidders as a possible solution to be further developed and finalized.

Concerning the design of the HTs/Seq, the bidding company is free to propose alternative solutions wrt the conceptual ones studied by the MORFEO team. We suggest anyhow to consider as much as possible the conceptual solutions that we are proposing as the baseline, performing for the FDR their final design study, to minimize design cost and delivery time.

## 1.2 Definitions, Acronyms and Abbreviations

AD	Applicable Document
ADP	Acceptance Data Package
AO	Adaptive Optics
AIT	Assembly Integration Test
AIV	Assembly Integration Verification



BIH	Bologna Integration Hall
BoM	Bill of Material
CA	Clear Aperture
CBS	Cost Breakdown Structure
CMP	Configuration Management Plan
CoG	Centre of Gravity
Col	Co-Investigator
CP	Corrective Plate
CV	Curriculum Vitae
CNRS	Centre National de la Recherche Scientifique
DoF	Degree of Freedom
ELT	European Extremely Large Telescope
EFC	Executive Funding Committee
ESO	European Southern Observatory
DASF	Dichroic Assembly Support Frame
DM	Deformable Mirror
DRD	Document Requirements Definition
FDR	Final Design Review
FM	Folding Mirror
FoV	Field of View
FTE	Full Time Equivalent
GTO	Guaranteed Time Observing allocation
HT	Handling Tool
HW	Hardware
IAA	Instrumentation Assembly Area
ICDR	Instrument Critical Design Review
IECR	Instrument End of Commissioning Review
IFP	Input Focal Plane
INAF	Istituto Nazionale di AstroFisica
ICH	Instrument Control Hardware
ICS	Instrument Control Software
INSU	Institut National des Sciences de l'Univers



IORR	Instrument Operations Readiness Review
IPAG	Institut de Planétologie et d'Astrophysique de Grenoble
IPDR	Instrument Preliminary Design Review
ISQR	Instrument System Qualification Review
ISRR	Instrument System Requirements Review
KO	Kick Off
LGS	Laser Guide Stars
LGSO	LGS Objective
LOR	Low Order and Reference
LoS	Line of Sight
LT	Laser Tracker
LVDT	Linear Variable Displacement Transducer
MAD	Multi conjugate Adaptive optics Demonstrator
MAIT	Manufacturing Assembly Integration and Test
MORFEO	Multiconjugate adaptive Optics For ELT Observations
MC	Monte Carlo
MCAO	Multi Conjugate Adaptive Optics
MOA	MORFEO Optical Alignment
MES	MICADO Emulating Structure
MICADO	Multi-AO Imaging Camera for Deep Observations
MoU	Memorandum of Understanding
MRB	Material Review Board
MS	Motorized Stage
MSS	Main Support Structure
MSQR	MORFEO System Qualification Review
MTA	Milestone Trend Analysis
N/A	Not Applicable
NCR	Non Conformity Report
NGS	Natural Guide Star
NIP	Nasmith Interface Plate
NUIG	School of Physics at the National University of Ireland Galway
OA	Optical Alignment



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
OFP	Output Focal Plane
PA	Product Assurance
PAC	Preliminary Acceptance Review in Chile
PAE	Preliminary Acceptance Europe
PAP	Product Assurance Plan
PDM	Product Data Management
PDR	Preliminary Design Review
PFS	Pre Focal Station
PI	Principal Investigator
MPI	MICADO Pupil Imager
PM	Project Manager
PMP	Project Management Plan
PSF	Point Spread Function
PT	Product Tree
PTT	Piston Tip Tilt
PtoV	Peak to Valley
QE	Quantum Efficiency
RAMS	Reliability, Availability, Maintainability, Safety
RD	Reference Document
RMS	Root Mean Square
RON	Read Out Noise
RR	Retro Reflector
RTC	Real-Time Computer
SAT	System Architect Team
SCAO	Single-conjugate Adaptive Optics
SEq	Support Equipment



SET	System Engineering Team
SMR	Spherically Mounted Retroreflector
SNR	Signal to Noise Ratio
SOW	Statement of Work
SQR	System Qualification Review
SR	Strehl Ratio
SRR	System Requirements Review
SW	Software
TAC	Test and Alignment Camera
TAT	Technical Advisor Team
TBC	To Be Confirmed
TBD	To Be Defined
TBH	To Be Hired
TBW	To Be Written
TCS	Telescope Control Software
TRA	Technology Readiness Assessment
TRL	Technology Readiness Level
TRR	Test Readiness Review
TTF	Tip Tilt & Focus
VCD	Verification Control Document
VLT	Very Large Telescope
WBS	Work Breakdown Structure
WFS	Wavefront Sensor
WP	Work Package
WRT	With Respect To
WS	WorkShop
YPR	Yaw Pitch Roll

RD10



## 3. Overview

The project history, the MORFEO consortium and the instrument overview are described in detail in RD3 and RD4. In this section we just briefly recall the main characteristics of the instrument and of the consortium, with the aim of clarifying the framework in which the MAIV process will be carried out.

### 1.3 Project overview

The MORFEO instrument description given here is based on the design developed for the PDR.

#### 1.3.1 Project description

ELT (Extremely Large Telescope) is the world's largest telescope (39m diameter) under construction by ESO (<https://elt.eso.org/>) at Cerro Armazones in Chile. ELT is considered worldwide to be one of the highest priorities in ground-based astronomy. MORFEO (<http://www.morfeo.oabo.inaf.it/>), is a first-generation ELT instrument, and will help compensating for the distortion of light caused by the atmospheric turbulence present in the Earth's atmosphere. MORFEO is a Multi-Conjugate Adaptive Optics (MCAO) module that will allow spatially uniform adaptive optics compensation over a large field of view (about 1 arcmin<sup>2</sup>) with high sky coverage. Wavefront sensing is performed by six Laser Guide Stars (LGS) and three Natural Guide Stars (NGS), for the measurement of high and low-order wavefront perturbations respectively.

The main function of MORFEO is thus to relay the light beam from the ELT focal plane to the client instrument while compensating the effects of the atmospheric turbulence and other disturbances affecting the wavefront coming from the scientific sources of interest.

MORFEO will be installed on the ELT Nasmyth platform. It feeds two focal stations: the gravity invariant port of MICADO and the lateral port of HARMONY.

The next figure shows the functional block diagram of the instrument.

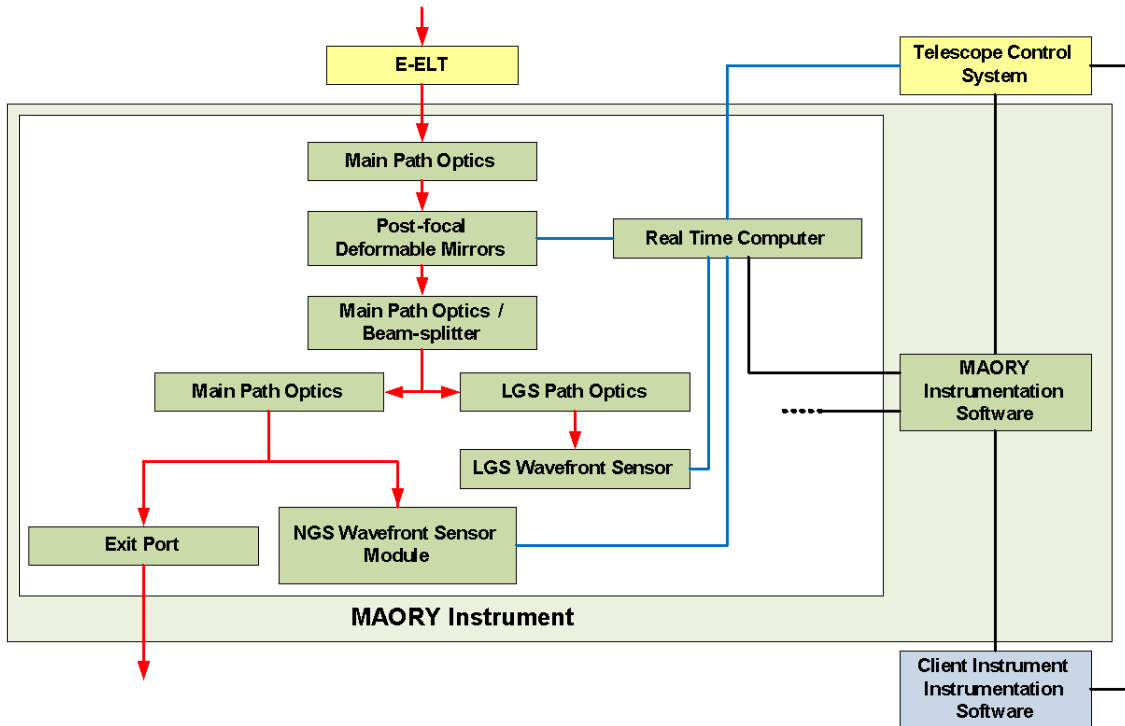


Figure 1: MORFEO Instrument functional block diagram. Red arrows: light path. Blue lines: real-time signals. Black lines: non real-time signals. The black dotted line departing from the MORFEO Instrumentation Software block indicates that this block has connections with other sub-systems which are not shown in this diagram for simplicity.

### 1.3.2 The MORFEO consortium

The MORFEO instrument is designed and developed by an international consortium composed by INAF (Istituto Nazionale di AstroFisica, Italy), CNRS/INSU (Centre National de la Recherche Scientifique/ Institut National des Sciences de l'Univers, France), NUIG (National University of Ireland Galway, Ireland), NRC (National Research Council, Canada), Kyoto University (Japan), NAOJ (National Astronomical Observatory of Japan), the University of Osaka (Japan) and ESO (European Southern Observatory, Europe).

The lead Institute is INAF. The local institutes within the consortium provide logistic support to the project and the necessary work-power.

All the member institutes provide support to the System Engineering team and to the MAIV team.

The INAF institutes involved in the development of MORFEO in Italy are the following:

- INAF OAS (Bologna), providing the MORFEO PI, PM; INAF OAS also provides the Bologna Assembly Hall (BAH), where MORFEO will be integrated in Europe, and support to the ICH, RTC and MAIV activities.



- INAF OAA (Arcetri - Firenze), providing Adaptive Optics System Engineering and management, RTC WP management, DM WP management and procurement, Simulation SW WP management and procurement and NGS WFS WP management and procurement.
- INAF OAAB (Abruzzo – Teramo), providing Calibration Unit WP management and procurement.
- INAF OAB (Brera - Milano), providing System Engineering WP management, Thermal Control System WP management and procurement, Opto-mechanics WP management and procurement and support to the Optical Design WP.
- INAF OACN (Capodimonte - Napoli), providing the Main Support Structure WP management and procurement and the ICH WP management and procurement.
- INAF OACT (Catania), providing support to the Optical Design WP.
- INAF OAPD (Padova), providing PA WP management, Optical Design WP management, MAIV WP management, ICS WP management and procurement, RTC WP support and procurement and Science WP management.

## 1.4 Instrument Overview

As already mentioned, MORFEO is a wide field adaptive optics system, that will serve the MICADO camera and the HARMONY instrument. MORFEO will take advantage of the ELT M4 adaptive mirror, which will deliver a partially corrected wavefront to the instrument.

MORFEO has to provide, as already mentioned, two adaptive optics modes to support MICADO:

- MCAO mode, in which three deformable mirrors are conjugated to different altitudes in the atmosphere; one of these deformable mirrors is the telescope M4;
- SCAO mode, in which wavefront compensation is performed using M4 only.

The MCAO mode of MORFEO is based on the use of 6 LGS. Natural guide star wavefront sensors (3 in the baseline design) are also required to complement LGS measurements.

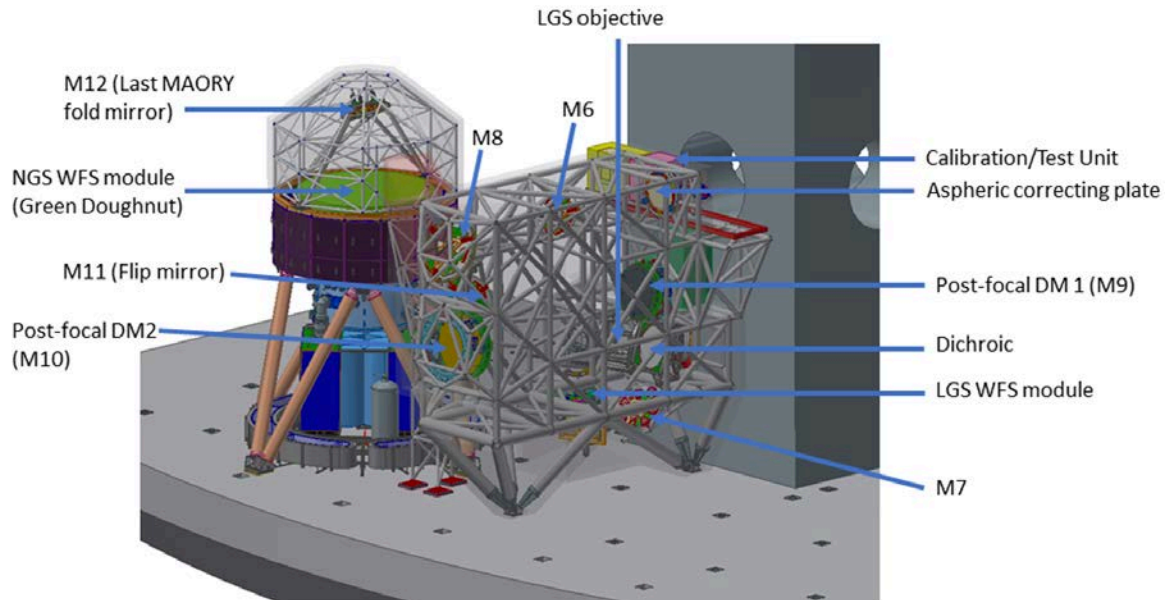


Figure 2: a 3-D view of the MORFEO instrument (the thermal cover is shown in transparency) installed on the Nasmyth platform with MICADO

The NGS wavefront sensor and the last MORFEO folding mirror (M12) are hosted in the same structure, the so-called Green Doughnut (GD), located above the MICADO instrument.

The MORFEO main structure, holding all the opto-mechanics of the bench and the main sub-systems, is based on a latticework tower made of standard structural steel truss-beam shaped pipes, welded/bolted with different section properties. The truss is connected to the Nasmyth platform through 10 legs that merge into 3 points. The overall design has been constrained to be able to fit with the three legs concept, in order to null the distortion induced by the Nasmyth displacements out of a rigid body motion.

In Figure 2: a 3-D view of the MORFEO instrument (the thermal cover is shown in transparency) installed on the Nasmyth platform with MICADO there is a view of the MORFEO instrument, with the main sub-systems highlighted. A thermal cover will maintain the instrument temperature stable within a certain range, and the main hardware subsystems indicated in the figure are complemented by the electronics at system and sub-systems level, instrument control software and real time computer.

## 1.5 MORFEO MAIT overview

Since MICADO will be installed at the ELT before MORFEO, the final instrument performance of MORFEO + MICADO can only be assessed at ELT level. Furthermore, all the final interfaces and the “instrument to telescope alignment” can be only performed at ELT level too.

Therefore, a test/verification strategy has been developed based on:

- partial performance and functional test at MORFEO sub-systems level



- even though the MICADO camera will not be available, the alignment procedure will be performed considering the instrument performance throughout the whole FoV, to minimize the risk of more conventional on-axis alignment strategy. MICADO will be simulated by using a test camera moving over the full FoV.
- overall instrument test to characterize the instrument performance on and off-axis in a wide variety of situations
- an “instrument to telescope” alignment procedure defined accordingly the guidelines defined by ESO, which will be partially reproduced and tested also in the BIH, by checking the capability to adjust the MORFEO MSS within the expected range and accuracy

We also recall the baseline assembly and alignment strategy, which has been presented at the trade-off review, consisting in the following main steps:

1. Main Support Structure (MSS) population with all the opto-mechanics and references for the LT alignment
2. Laser tracker alignment for all of them to their nominal position (wrt Input Focal Plane (IFP) SMRs), within a reasonable accuracy
3. Fine tuning of the WFE acting on M10/DM2 tip/tilt and focus
4. Fine tuning of pupil and exit focal plane position by tip-tilting the last two flat mirrors, M11 and M12

If necessary, the last two steps will be repeated iteratively, since the alignment of DM2 will affect the position of the pupil and of the exit focal plane. No active corrections are necessary to the optics up to M10/DM2, simplifying the AIV procedure.

To these 4 steps, we add the following items:

5. Pupil and focal plane alignment within the LGS WFS
6. MORFEO to PFS alignment test
7. MORFEO testing phase

Concerning the alignment strategy just presented, it has to be emphasized that the MORFEO optical design allows for loose alignment tolerances of all the optics but M10/DM2, the focus and TT of which are the only compensators permitting to fine tune the final optical quality of the wavefront delivered by the system.



## 1.6 MORFEO MAIT Items Nomenclature

Table 1 Univocal MORFEO items code and nomenclature used through the current document.

Univocal Item code	Nomenclature used in the MAIT document	Notes
E-MAO-PFK	Schmidt-Plate	
E-MAO-PFA	M6 Assembly	
E-MAO-PFB	M7 Assembly	
E-MAO-PFC	M8 Assembly	
E-MAO-PDA	DM1 Assembly	
E-MAO -PDB	DM2 Assembly	
E-MAO-PFD	Dichroic Assembly	
E-MAO-PFE	M11 Assembly	
E-MAO-PFF	M12 Assembly	
E-MAO-PFG	LGS Fold Mirror 1 Assembly	
E-MAO-PFH	LGS Objective	
E-MAO-PFI	LGS Fold Mirror 3 Assembly	
E-MAO-PFJ	CU Folding Mirror Assembly	
E-MAO-PFL	M9 Dummy Assembly	
E-MAO-PFM	M10 Dummy Assembly	
E-MAO-PN0	LOR WFS Module	
E-MAO-PT0	Thermal Unit	
E-MAO-PU0	Calibration Unit	



## 4. Facilities

In this section, we describe the facilities which are available both in Europe and in Chile for the overall MORFEO AIT operations. For the sake of clarity:

- we call Facility (Fac) a permanent installation, such as an assembly hall, a laboratory, a clean room, a workshop
- we call Handling Tool (HT) whatever device (which may be permanent like an overhead travelling crane or movable such as a jib crane or a trans-pallet or a cherry picker) useful to handle/move/position equipment, which are sometimes commercial products; they are described in Sec.4.
- we call Support Equipment (SEq) whatever handling tool which must be designed and realized on purpose to achieve a certain AIT task, such as an auxiliary mirror to be used for analysing the beam in auto-collimation during the alignment. They are described in Sec.5.

### 4.1 Europe

#### 4.1.1 Institute, Location, Premises

The integration facility is located in Bologna (Bologna Integration Hall, BIH), located in the northern part of Italy, at the premises of INAF-OAS, located in the building of the CNR/INAF Research Area next door, at the address *via Piero Gobetti n. 101, Bologna*. The building is located 10-15 minutes away from a major highway, and is also reachable within 30 minutes walking from the railway station or 10-15 minutes by public transport from the city centre or within 15 minutes of taxi from the Bologna international airport.

An **important issue to be taken into account** when reaching the laboratory, above all for goods shipping, is that at about 500m of distance from the lab the road is going below a bridge where the maximum height allowed for a truck is 4.95m on one side and 5.17m on the CNR side.

#### 4.1.2 Bologna Integration Hall (BIH)

The BIH main integration hall is shown in Figure 3, where the main integration hall, the entrance gates, the external parking area, the technical room (in red colour, hosting the pumps for the air conditioning system and the switches panel of the electric plant) and the control room (in green colour, hosting possibly all the necessary HW to be used during the AIT, such as computers and controllers of needed support equipment, the dimensions of which are 4.4x1.5m) are visible. The technical room is physically separated from the rest of the building to allow relative movements of the two structures in case of earthquake.

The main integration hall is currently hosting most of the facilities needed for the AIT operations, like sufficient access to power, cooling water, liquid nitrogen, UPS line for sensitive equipment.



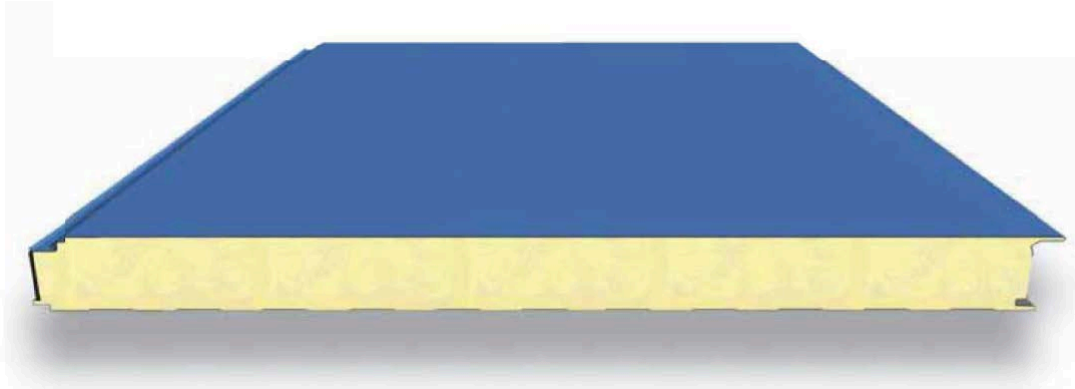


Figure 4: an example of the panel used for the internal lab insulation

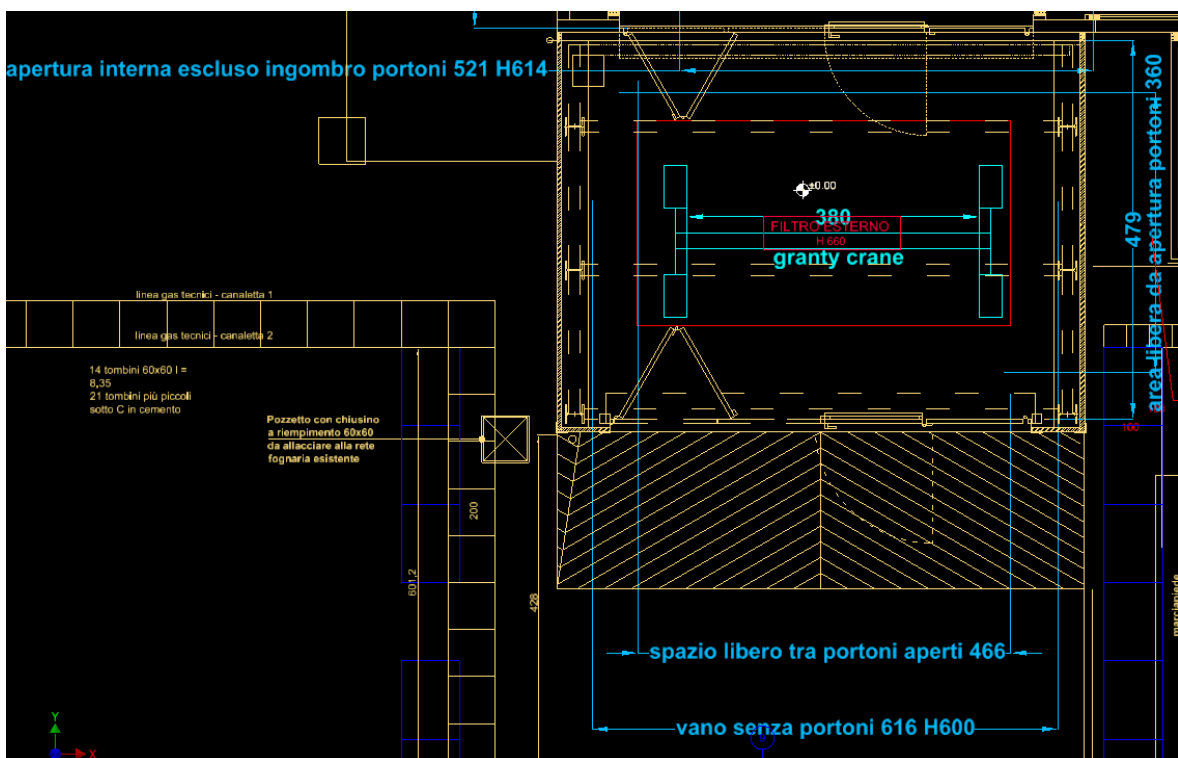


Figure 5: The BIH entrance, characterized by two gates opening as shown in the drawing; In case of need the door panels may be removed

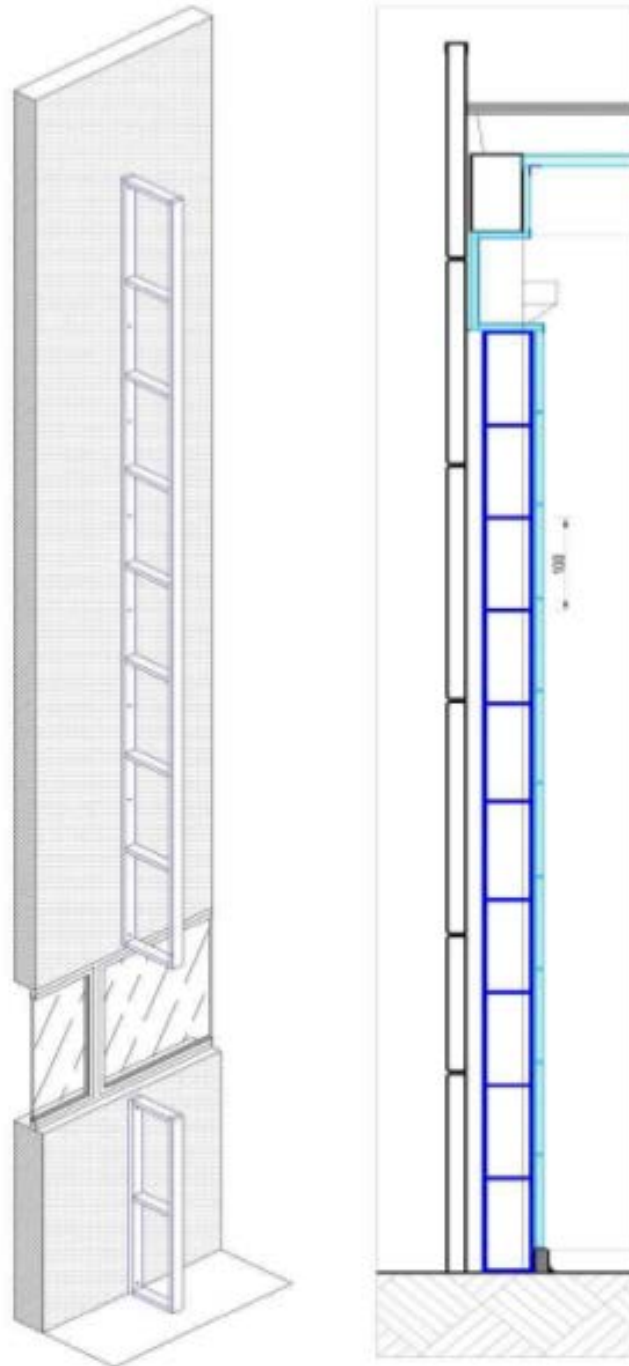


Figure 7: an example of how the insulating panels are kept in position; external windows will be replicated in the inner part of the structure, as shown in the left image. All the windows will have remotely controlled curtains to allow creating a dark environment when needed for test purposes.



#### 4.1.2.2 Crane

The main integration is equipped with an overhead crane (bridge crane) with a max load capacity of 3.2T.

The useful height below the crane hoist is 10.6m

The overall movement range of the crane hoist is shown in AD29

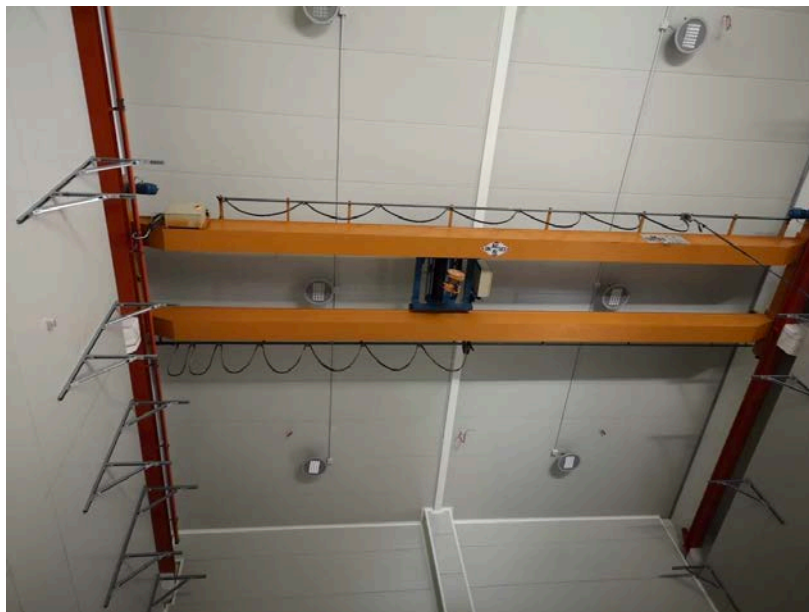


Figure 8: the BIH overhead crane (3.2T maximum load capacity)

#### 4.1.3 Handling devices

In the following, there is the list of handling tools available at the facility:

- A couple of manual trans-pallet
- One motorized forklift
- One cherry-picker
- Three scissor-lift
- One portable bridge crane (to be used in the entrance hall for un-packing operations)
- A few trolleys



- Transporter similar to the ESO one

Every handling device has the CE certification.

#### 4.1.4 Cleanliness

The laboratory ventilation has the purpose to maintain the temperature and humidity conditions foreseen, and to maintain the requested cleanliness class 100000 (ISO 8 following ISO 14644-1). The latter requires a number of total air recirculation corresponding to 10-20 overall lab air volume, which correspond in this case to 20000m<sup>3</sup>/h (being the lab volume 1800m<sup>3</sup>). The air will be properly filtered with the following sequence: pre-filtering with G4 efficiency filters, high-efficiency filtering with F7 filters and then final filters stadium with H12 filters with a global efficiency equal to 99.5%.

#### 4.1.5 Storage

A dedicated storage area has still to be identified, and we are also evaluating temporary storage solutions, as the one presented in Figure 9.



Figure 9: temporary storage facilities (from CDU presentation at the AIV WS)

## 4.2 Chile

### 4.2.1 Location

Cerro Armazones is a mountain at an altitude of about 3046 metres in the central part of Chile's Atacama Desert, about 130 kilometres south of the town of Antofagasta and about 20 kilometres from Cerro Paranal

### 4.2.2 Entrance Hall

This is the area within the Auxiliary Building of the E-ELT Dome at Armazones where instruments will be unloaded after transportation and prepared before moving them into the clean IAA and the dome areas. Everything described in this section is coming from AD2, from which we extrapolate the main characteristics of the Entrance Hall, which are:

- The clear cross-section of the access between the outside world and the Entrance Hall shall measure at least 10m x 7.5m (wxh).



- The Entrance Hall shall be, as a minimum, 32mx10mx8m (lxwxh) in size.
- The Entrance Hall shall be equipped with an overhead travelling crane which covers the whole specified area except for the last 2.5m from the walls.
- The Entrance Hall crane shall provide two crabs with a single hook, each with a capacity of 10 tonnes, and a hoist height from the floor to 7m above floor level.
- Parallel and also independent operation of both crabs and hooks shall be possible.
- The crane shall have a load indication with a minimum accuracy of 2% of the maximum load with remote readout.
- The lateral speed shall be adjustable from 9mm/sec to 80mm/sec and will allow a minimum step of 2mm.
- The vertical speed shall be adjustable from 1mm/sec to 50mm/sec and will allow a minimum step of 0.5mm.

Services of the Entrance Hall will be:

- The Entrance Hall shall be equipped with Service Connection Points Parts A2-B-C
- The Entrance Hall shall be equipped with a hot and cold water supply
- The Entrance Hall shall be equipped with a drainage connection.
- The Entrance Hall shall be equipped with two standard compressed air supply points.
- The Entrance Hall shall be equipped with 15x 230V (16A) electrical sockets.
- The Entrance Hall shall be equipped with 8x RJ45 outlets.
- The illumination level of the Entrance Hall shall be 500 Lux.

### **4.2.3 Instrumentation Assembly Area (IAA)**

This is the area within the Auxiliary Building of the E-ELT Dome at Armazones where an instrument can be assembled and test before integration on the Telescope. This area includes:

- instrument assembly area
- instrument assembly area auxiliary room



- instrument electronics maintenance area

The auxiliary room will house the instrument control electronics and test equipment during integration and test.

Also in this case, everything described in this section is coming from AD2, from which we extrapolate the main characteristics of the IAA, which are:

- The Instrumentation Assembly Area shall be connected to the Entrance Hall via an access path having a clear cross-section of at least 10x7.5m (wxh).
- The Instrumentation Assembly Area shall be connected to the Instrument Assembly Area Auxiliary Room via an access path having a clear cross-section of at least 2x2.5m (wxh).
- The Instrumentation Assembly Area shall be connected to the Instrument Electronics Maintenance Area via an access path having a clear cross-section of at least 2x2.5m (wxh).
- The volume available to instruments within the Instrumentation Assembly Area shall be, as a minimum, 22x10x8m (lxwxh) in size.
- The floor of the Instrumentation Assembly Area shall be capable of transiting a forklift class FL6 as according to section 6.3 of EN 1991-1-1:2002 Eurocode 1
- The floor loading capacity of the Instrumentation Assembly Area shall be classed as Category E2 as according to section 6.3 of EN 1991-1-1:2002 Eurocode 1
- The instrument assembly area shall be equipped to reach ISO class 8 (100,000) cleanliness.
- The Instrumentation Assembly Area Auxiliary Room shall be, as a minimum, 6x5x3m (wxlxh) in size.
- The Instrumentation Electronics Maintenance Area shall have a floor area of at least 30 square metres.

Handling Equipment available in the IAA are:

- The Instrumentation Assembly Area shall be equipped with an overhead travelling crane which covers the whole specified area except for the last 2.5m from the walls.
- The Instrumentation Assembly Area crane shall provide a bridge crane with two hooks, each with a capacity of 12 tonnes, and a hoist height from the floor to 8.8m above floor level.



- The lateral speed shall be adjustable from 9mm/sec to 80mm/sec and will allow a minimum step of 2mm.
- The vertical speed shall be adjustable from 1mm/sec to 50mm/sec and will allow a minimum step of 0.5mm.

Services of the IAA are:

- The Instrumentation Assembly Area shall be equipped with 2 Service Connection Points Parts A2-B-C
- The Instrumentation Assembly Area shall be equipped with a supply of cryogenic fluids
- The Instrumentation Assembly Area shall be equipped with a hot and cold water supply and drainage connection.
- The Instrumentation Assembly Area shall be equipped with two standard compressed air supply points.
- The Instrumentation Assembly Area shall be equipped with 15 x 230V (16A) electrical sockets, 5 x 230V (16A) Safety Power Sockets and 5 x 400V (32A/phase) electrical sockets.
- The Instrumentation Assembly Area shall be equipped with 2x telephone sockets.
- The Instrumentation Assembly Area shall be equipped with 8x RJ45 outlets.
- The illumination level of the Instrumentation Assembly Area shall be 750 Lux.

The Instrumentation Electronics Maintenance Area shall be equipped with a Service Connection Point Parts A2-B-C



## 5. Handling Tools

Table 2 gives a complete overview of all Handling Tools in the univocal device code that are needed during the system AIT

Table 2: list of the handling tools to be used during MORFEO AIT

Handling Device code	Description	Notes
SM0-HT-PFK	Schmidt-Plate Assembly and Maintenance Handling Tool	Helmet and safety shoes required
SM0-HT-PFA	M6M Assembly and Maintenance Handling Tool	Helmet and safety shoes required
SM0-HT-PFB	M7M Assembly and Maintenance Handling Tool	Helmet and safety shoes required
SM0-HT-PFC	M8M Assembly and Maintenance Handling Tool	Helmet and safety shoes required
SM0-HT-PDA	M9M/DM1 Assembly and Maintenance Handling Tool	Helmet and safety shoes required
SM0-HT-PDB	M10M/DM2 Assembly and Maintenance Handling Tool	Helmet and safety shoes required
SM0-HT-PFD_CRANE	Dichroic Assembly and Maintenance Handling Tool to lift up the dichroic	Helmet and safety shoes required
SM0-HT-PFD_BENCH	Dichroic Assembly and Maintenance Handling Tool to make the dichroic sliding into the MSS and to finely position it against its interface points on MSS.	Helmet and safety shoes required
SM0-HT-PFE	M11M Assembly and Maintenance Handling Tool	Helmet and safety shoes required
SM0-HT-PFG_CRANE	LGS Fold Mirror 1 Assembly and Maintenance Handling Tool to lift up the mirror	Helmet and safety shoes required
SM0-HT-PFG_BENCH	LGS Fold Mirror 1 Assembly and Maintenance Handling Tool to make the mirror sliding into the MSS and to finely position it against its interface points on MSS.	Helmet and safety shoes required
SM0-HT-PFH_CRANE	LGS-Objective Assembly and Maintenance Handling Tool to lift it up	Helmet and safety shoes required
SM0-HT-PFH_BENCH	LGS-Objective Assembly and Maintenance Handling Tool to make it sliding into the MSS and to finely position it against its interface points on MSS.	Helmet and safety shoes required
SM0-HT-PFL	LGS Fold Mirror 3 Assembly and Maintenance Handling Tool to lift up the mirror	Helmet and safety shoes required
SM0-PFF_HT	M12M Assembly and Maintenance Handling Tool	Helmet and safety shoes required



	CU Assembly and Maintenance Handling Tool to make the CU sliding into the MSS and to finely position it against its interface points on MSS.	
SM0-HT-XXX	CU folding mirror Assembly and Maintenance Handling Tool to lift it up.	

### MAO-SM0-1.1: Handling tools General Requirements

Deviation to the following requirements shall be discussed and agreed with the MORFEO consortium.

As **general requirements**, every Handling Tool (HT) shall be designed and manufactured in a way that:

**MAO-SM0-1.1.1.** It must allow to safely install/un-install the related transported opto-mechanical sub-system on the MSS. Each opto-mechanical sub-system will be specified through a 3D volume characterized by a weight, a centre of mass and defined interfaces toward the HT and the MSS. After the installation of the opto-mechanics, the HT has to be removed and safely stored.

**MAO-SM0-1.1.2.** *[info]* The call for tenders concerning many opto-mechanical sub-systems are on-going. This is why, in the previous item, we clarified that we will provide representative volumes for each opto-mechanics. As soon as the interfaces between the sub-systems and the HTs will be frozen and/or step files will be available, they will be provided to the contractor.

**MAO-SM0-1.1.3.** To allow such installation/un-installation of the various opto-mechanical sub-systems using the HTs, some operations might be needed on the MSS, such as:

- temporary removal of one of some top/lateral beam/bars of the MSS, in a way to create an access (opening) to allow the HT to reach the desired location inside the MSS.
- Installation of SEq (such as ladders, elevators “scissor lift like”, platforms, ...) to allow reaching the location where the opto-mechanics have to be connected and/or disconnected to the MSS and the HT has to be disconnected and/or connected to the opto-mechanics.

As specified in Sec. 1.1, since the selected contractor will also be responsible of the design and manufacturing of the MORFEO Main Support Structure (MSS), further to the HTs design, possible SEq needed for the opto-mechanics installation have to be designed/proposed and a procedure for the installation of each opto-mechanical sub-systems (making use of the HTs and SEq) shall also be devised and proposed. Such procedure shall describe also the needed preparatory operations to be done at MSS level.

**MAO-SM0-1.1.4.** All the sub-systems that will be transported by the HTs are delicate and fragile opto-electro-mechanical components. The procedures that will have to be conceived for their installation shall thus take this fact into account,

**MAO-SM0-1.1.5.** The operating scenarios for the HTs usage are 3:



- a. The Bologna Integration Hall (BIH)
- b. The Armazones Integration and Assembly Area (IAA)
- c. The telescope Nasmyth platform

**MAO-SM0-1.1.6.** Whenever possible, the same HT shall be used for the 3 locations just described. Should the operating conditions be different in one of the identified location (for example the maximum available height for the overhead hook), a different HT/installation procedure may be required for the same sub-system for that particular location.

**MAO-SM0-1.1.7.** Its dimensions shall fit in the provided and applicable insertion/extraction volume

**MAO-SM0-1.1.8.** Its interfaces shall be compliant with the provided and applicable interfaces both toward the sub-system that it must carry and toward the overhead crane or, anyhow, the device that will be used to move the HT

**MAO-SM0-1.1.9.** If needed, removable counterweights shall be used to balance the HT both when it is moved alone and when it is moved carrying the sub-system. The HT (connected to a crane) shall be balanced with no counterweights installed without the LOAD (no opto-mechanical sub-system connected to the HT). This means that:

- a. The counterweights shall be in position (connected/installed on the HT) in the configuration in which the HT is moved carrying the sub-system (HT with load)
- b. They shall instead be removed when the HT will be moved alone (HT with no load)
- c. The maximum weight of each counterweight should allow their safe removal by a single person, working also in not ideal accessibility conditions. We would suggest not to exceed 5-6 kg for each counterweight

**MAO-SM0-1.1.10.** They shall be designed in a way to minimize shifts of their centre of gravity in the 2 configurations WITH and WITHOUT load

**MAO-SM0-1.1.11.** Possibly, they shall be designed in a single piece. Alternatively, they may be designed in parts to be assembled but, after the first assembly and certification, they shall not be disassembled, not even for their shipping. This requirement is to avoid its re-certification at each assembly occurrence.

**MAO-SM0-1.1.12.** They must be equipped with a manual balancing fine tuning mechanism (that we implemented, on our conceptual designs, on the hoisting holes), to allow proper balancing in the configuration "HT with load". Such operation will be, in principle, done the first time that the LOAD will be applied. Once the balancing in the LOAD HT configuration will be done, a locking system should ensure that such position can be kept for the successive uses of the HT. The locking system shall not be permanent, giving the possibility to re-adjust the balancing if needed.

**MAO-SM0-1.1.13.** The HTs must be equipped with a manual lockable way to fine tune the tip-tilt of the opto-mechanical sub-systems that has to be handled/installed. Also in this case, such operation will be, in principle, done the



first time that the opto-mechanical sub-system will be installed. Once the fine tuning of the tip-tilt of the opto-mechanical sub-system will be done at the first occurrence, the locking system should ensure that such position can be kept for the successive uses of the HT. The locking system shall not be permanent, giving the possibility to re-adjust the tip-tilt if needed.

**MAO-SM0-1.1.14.** They shall be equipped with a re-usable storage/transport box that, concerning the material, must be compliant with the laws applicable to EU and Chile. The transport load to which the boxes will be subject during the shipping are specified in AD1. In the same document also the shipping environmental conditions are specified.

**MAO-SM0-1.1.15.** Concerning the loads to be considered for each HT, please, consider that they will be used in a seismic area, and thus each HT shall be designed and manufactured to account for a larger load than the sub-system real load. The driving load depends on the operating scenarios, and thus different loads shall be considered for different locations. In AD1 we specify the different environmental conditions. As a general rule, for the HTs that will be used for all the foreseen locations/operating scenarios, the most stringent driving load shall be applied.

**MAO-SM0-1.1.16.** In general, all the applicable environmental conditions that must be considered for the HTs/SEq design and manufacturing are specified in AD1.

**MAO-SM0-1.1.17.** All the HTs must have the CE certification.

**MAO-SM0-1.1.18.** The lifetime of all the HTs shall be equivalent, or larger, than the MORFEO lifetime

**MAO-SM0-1.1.19.** All the HTs shall comply with AD25 and AD26

**MAO-SM0-1.1.20.** All the HTs shall allow installation/dis-installation of the corresponding Opto-mech, inside the MSS, within 2 hours.

In the following sections we will report, for each HT, the specific requirements, and we will describe the PDR design, performed by INAF, of the various HTs.

We will start with M6M HT, that will be described in more detail than the other HTs, to give a possibly comprehensive idea of the concept which is behind the design of all the handling tools.

For nearly all of them, our preliminary design is considering that the HT will be moved using the overhead cranes of the various locations (BIH, Entrance Hall, IAA, Nasmyth platform) where it will be used.

The contractor shall always assume that the various opto-mechanical sub-systems will be picked-up/parked from/on a HT similar to a stand keeping it with the right orientation (i.e., the same orientation w.r.t. gravity the opte-mechanical sub-system will have when mounted into MORFEO).



## 5.1 M6M HT (SM0-HT-PFA)

### 5.1.1 Purpose and functionality: M6M HT technical specifications

The SM0-HT-PFA must allow to safely install/un-install M6M on the MSS for assembly and maintenance purposes. The HT shall possibly be the same in all the locations where it will be used (BIH, Entrance Hall, IAA, Nasmyth platform). Should this not be possible, an additional HT shall be designed for that purpose.

M6M will be represented through a 3D volume characterized by a weight, a centre of mass and defined interfaces toward the HT and the MSS. After the installation of M6M, the HT has to be removed and safely stored.

If needed, counterweights shall be added, to have the HT properly balanced in the LOAD configuration, as specified in 9)a.

Since it will be used in a seismic area, the design must consider a load increased according to what specified in AD1. Since the HTs that will be used for all the foreseen locations/operating scenarios, the most stringent driving load shall be applied. Should this not be possible, the HTs shall be designed according to the driving load specific indications for the location where it will be used.

All the general requirements described in Sec. 4 “HANDLING TOOLS” are applicable.

Applicable and reference documents are the following:

- AD doc concerning the available volumes inside the MSS: AD24
- AD doc concerning the volume and interfaces of the opto-mech: AD9 and AD24
- RD docs (MAIT/AIV plans) concerning the procedures for the installation in the various locations: RD5 and RD6

### 5.1.2 Deliverables

Phase 1: executive drawings, step files and detailed and comprehensive procedure for M6M installation/dis-installation in the various locations

Phase 2: HT manufactured, test report, user and maintenance manual, storage box

### 5.1.3 Additional information: M6M HT suggested design

The proposed design described here assumes the MSS and M6M HT PDR design.

#### 4.1.3.1 Description

M6M HT proposed design has the following characteristics:

- It is a C-shape handling (see Figure 10), designed to install the M6M opto-mechanical unit onto the Main Support Structure (MSS) from above, using a crane. The C shape allows to interface/connect the crane hook along the projection of the barycentre of M6M + handling tool (which means LOAD HT configuration).
- The handling system interface flange includes three interface connection points to the opto-mechanical unit M6M, located on its front side (opposite to the interface



side facing the main structure). These interfaces consist of clearance holes for TBD screws (e.g., M8). The fixing screws on the HT side are designed to remain captive within the handling system, even when fully disengaged from the opto-mech, thus avoiding accidental falls. See Figure 11 and Figure 12 for details.

- The handling is designed to keep the mirror with an orientation very close to the one it will have when mounted into MSS. 3 threaded rods screwed to the fixed part of the handling and pushing on the movable part allow to fine adjust the tip-tilt of M6 during the installation phase (see Figure 13 and Figure 14). One of the threaded rods is inserted in a small pit in the movable part, to prevent rotation of the mirror around its optical axis (see Figure 15).
- The position of the crane hook hoisting hole with the handling can be finely adjusted as it is mounted on a rail, actuated by an endless screw. Such an adjustment will be used to fine-tune the position of the hoisting ring in the LOAD HT configuration, as specified in 12). Once the best position is identified, the hoist ring can be securely locked in place.
- Movable masses/counterweights connected to the handling will be used, to have the HT balanced also in the NO-LOAD configuration, as specified in 9). Thus, the system provides the option to manually adjust the center of mass by adding, removing, or relocating modular balancing weights. Each weight module is designed to be manually handled ( $\leq 8$  kg), and multiple units can be used to reach the correct balancing. Weights cannot slide out un-expectedly, thanks to a safety bolt. This feature is especially critical during the release phase, when the opto-mech is detached from the handling system, to maintain balance and prevent swinging.
- The handling can be interfaced to M6M with the mirror protecting cover in place, in a way to protect it as much as possible during the

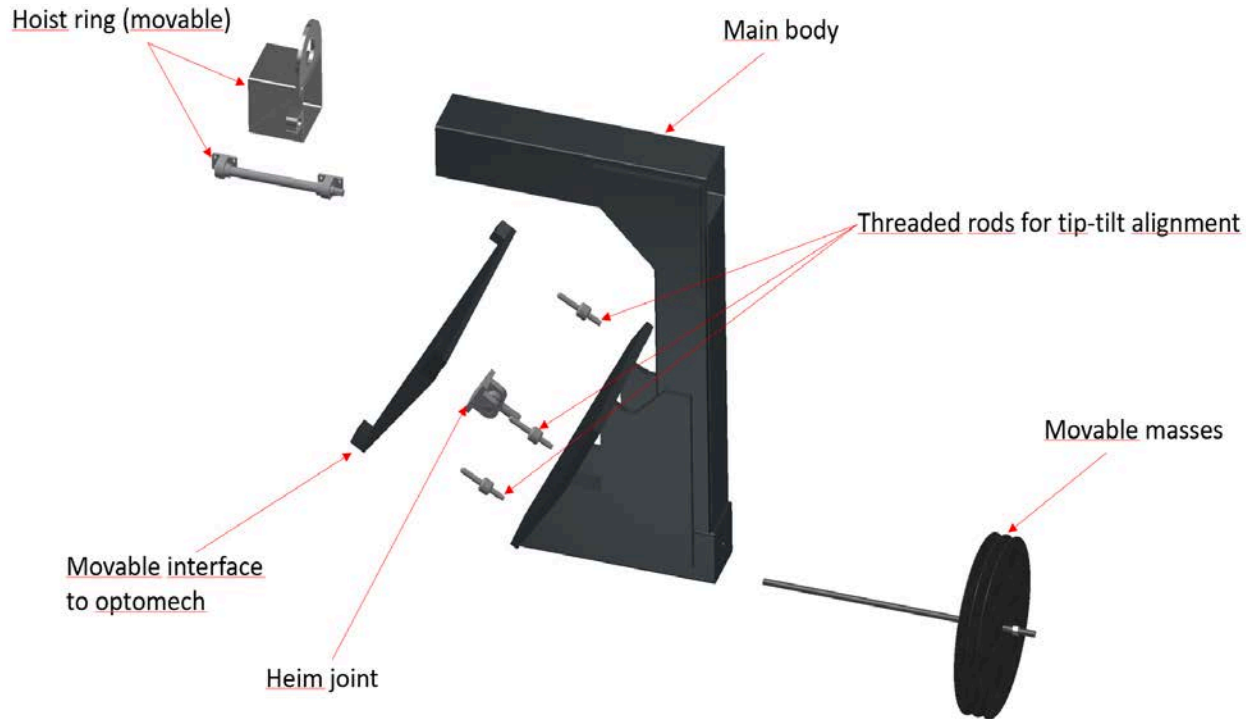
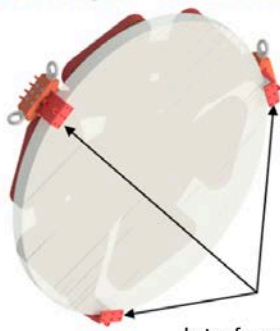


Figure 10: exploded view of M6M HT

**M6M opto-mechanics**



Interfaces to M6M HT  
(threaded holes)

Interfaces to M6M  
opto-mechanics

Hoist ring (movable)

**M6M HT**

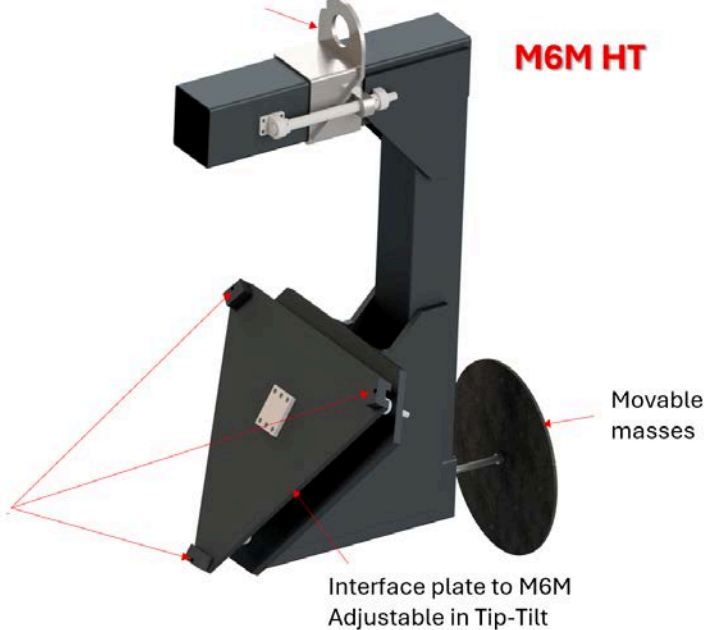


Figure 11: The C-shaped HT for M6M installation. The interface between M6M and the handling is between the 3 branches embracing M6M and the 3 connection pads of the handling. The handling is equipped with a hook hoisting connection point having the



possibility to slide, in order to have it precisely aligned with the barycentre of the system when M6 is connected.

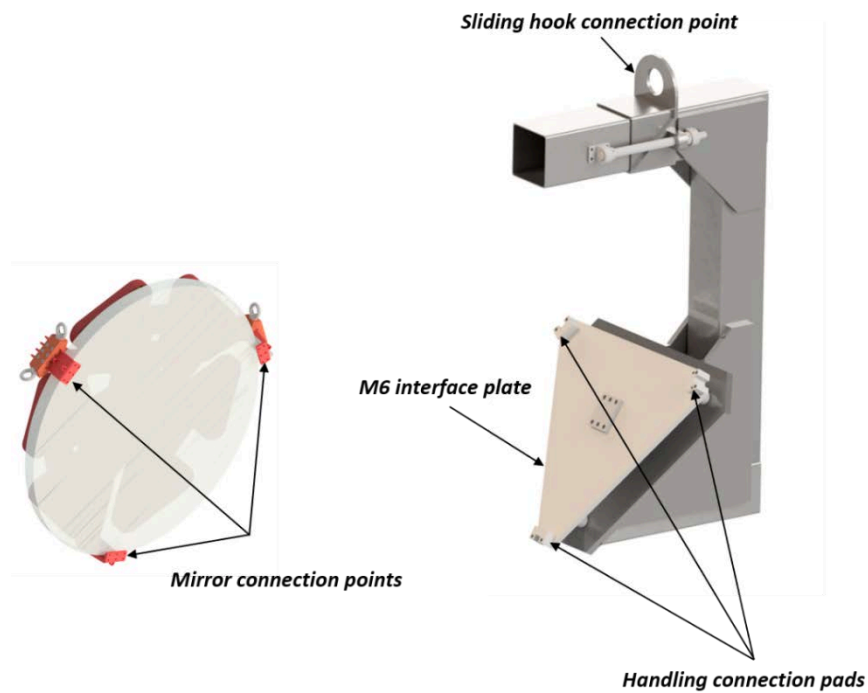


Figure 12: C-shaped handling for M6M installation. The interface between M6M and the handling is between the 3 branches embracing M6M and the 3 connection pads of the handling. The handling is equipped with a hook hoisting connection point having the possibility to slide, in order to have it precisely aligned with the barycentre of the system when M6 is connected.

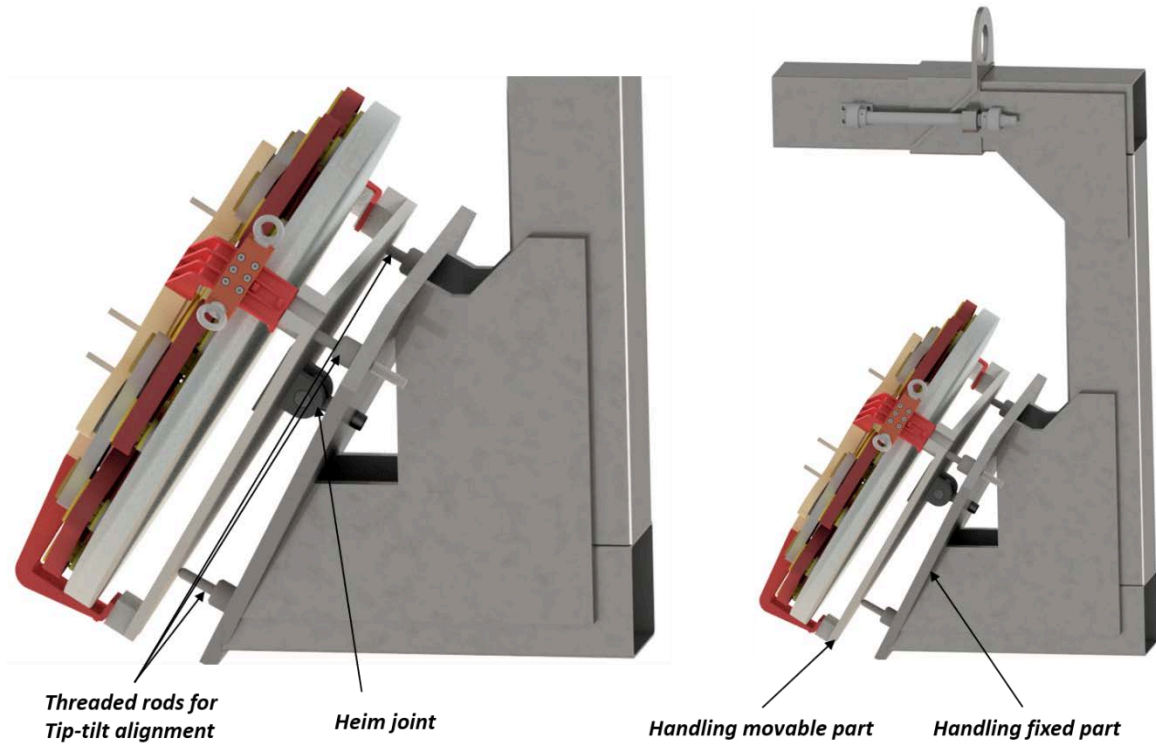


Figure 13: the handling allows to fine adjust tip-tilt of the mirror before installation, thanks to a heim joint and 3 threaded rods (or screws) pushing against the movable part of the handling.

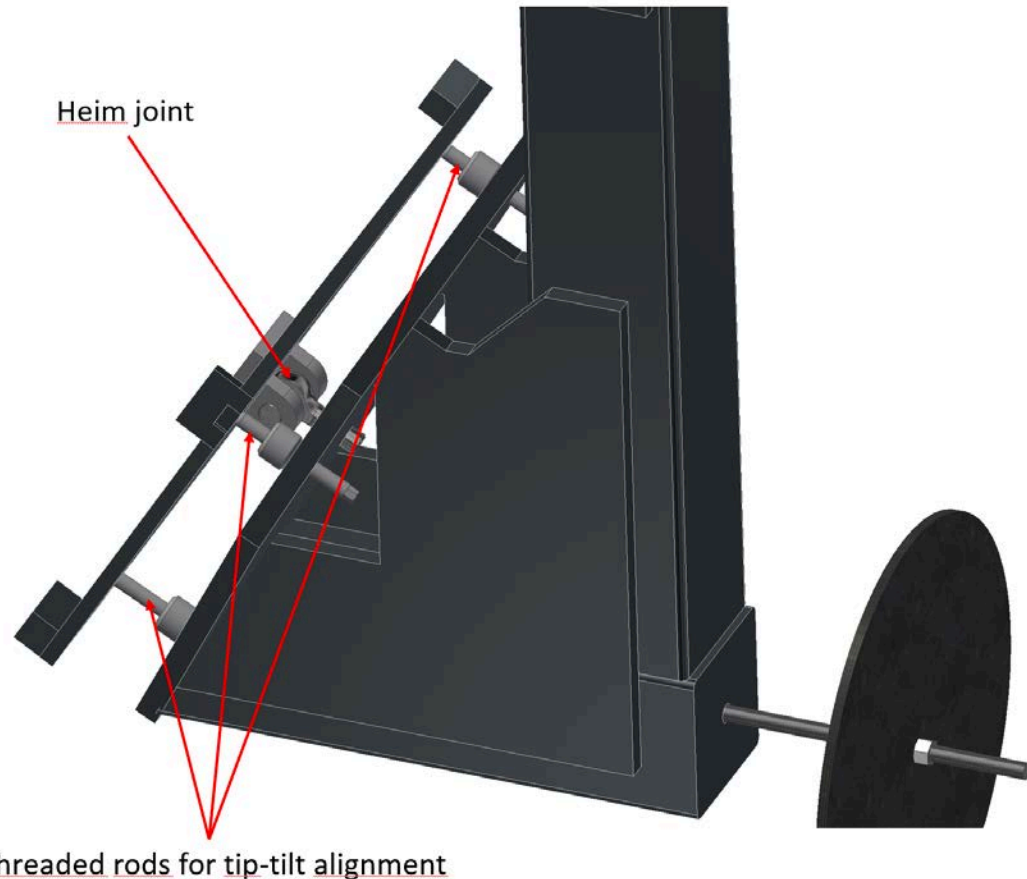


Figure 14: the handling allows to fine adjust tip-tilt of the mirror before installation, thanks to a heim joint and 3 threaded rods (or screws) pushing against the movable part of the handling.

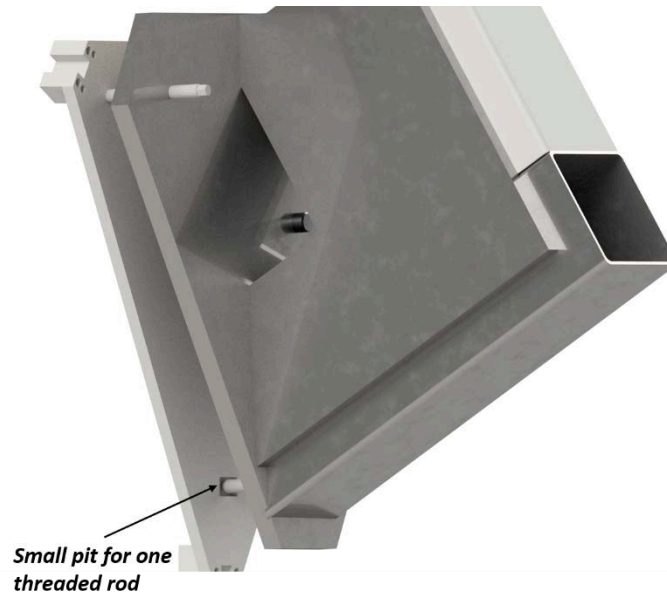


Figure 15: one of the threaded rods allowing tip-tilting of the handling movable part is inserted into a small pit in the movable part, to prevent its rotation around the mirror optical axis.

#### **4.1.3.2 Way to be operated/procedure**

The SM0-HT-PFA must be operated in the following way:

- The cover of M6 must be installed
- A minimum of 2 persons plus the crane operator are necessary for the SM0-HT-PFA handling/movement
- The internal ladders, platform, SEq and security harnesses to access M6 on the MSS must be in place
- The hoist point on SM0-HT-PFA has to be connected to the crane hook, then the HT approaches M6 (kept on a stand with the same orientation it will have when installed on the MSS) and connects to the fixation points on the mirror opto-mech. Some bars positioned on M6 branches can be used to ease and guide SM0-HT-PFA approach to M6.

#### **4.1.3.3 Special tools needed**

Normal mechanical workshop tools.

#### **4.1.3.4 AIT phase when needed**

The SM0-HT-PFA is needed for the assembly operations in the BIH in Bologna and in the IAA in Chile and in the Nasmyth platform for maintenance in Chile.



#### **4.1.3.5 Deliverable and lifetime**

- The SM0-HT-PFA is a deliverable both to Bologna and to Chile, where it has to be stored to be used for maintenance.
- The lifetime of the HT shall be equivalent, or larger, than the MORFEO lifetime

#### **4.1.3.6 Hazard and Safety issues**

The SM0-HT-PFA must be operated in the following way:

- The cover of M6 must be installed
- A minimum of 2 persons plus the crane operator are necessary for the SM0-HT-PFA handling/movement
- The scaffolding or security harnesses to access M6 on the bench must be in place
- The platform allowing to reach M6 area on the bench structure must be in place
- Operators shall wear the helmet, safety gloves and safety shoes
- Every operator shall wear safety shoes, safety gloves and helmet
- When operating on the platform, the harness safely secured is mandatory for each operator

No Major Hazards have been identified, but mirror destruction in case of mishandling

#### **4.1.3.7 BIH M6M Installation procedure**

##### **Purpose and functionality**

M6 is installed on the MSS

**HTs/Seq needed:** BIH Bridge crane, M6M HT SM0-HT-PFA, internal platforms and/or internal elevator

**Success Criteria:** M6 properly installed

**Duration:** 1 day (goal few hours)

**Prerequisites:**

##### **Procedure**

This procedure is described also in RD5

Its position into MORFEO main structure suggests installing this mirror from the top. This can be performed by removing the yellow beam shown in Figure 18 and the thermal cover panel on top of it. In this way we create an access at the top of the main structure wide enough to insert M6 using a C-shaped handling. Care has to be given to the space needed by the counterweight system, that was not foreseen at the PDR (see Figure 16).

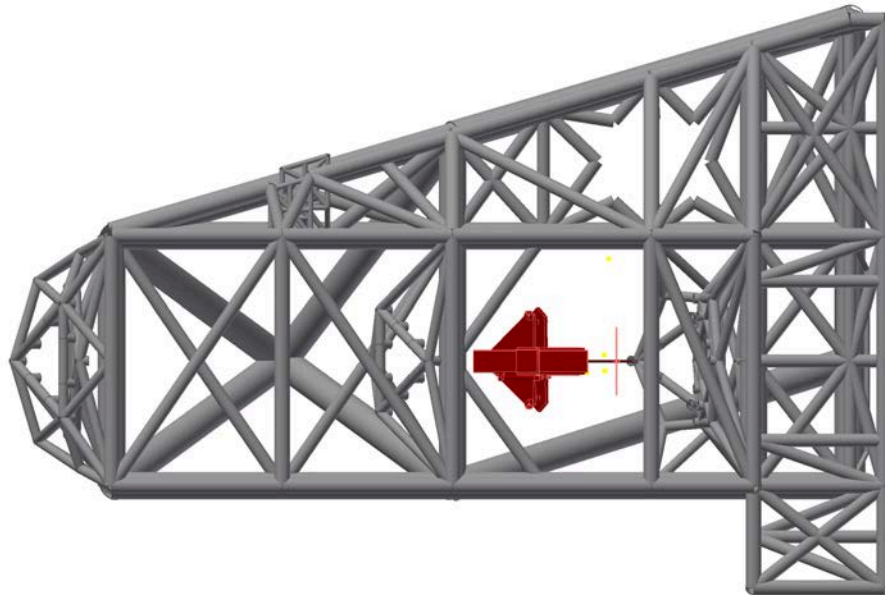


Figure 16: the M6M HT seen from the top, with its counterweight system (right end side of the red HT)

The handling is designed to naturally pick M6M with the same orientation it will have when mounted into the MSS, and the interface plate has tip-tilt adjustment to fine tune such position.

By using the overhead crane, the HT with M6M is inserted from the top, as it is shown in Figure 17.

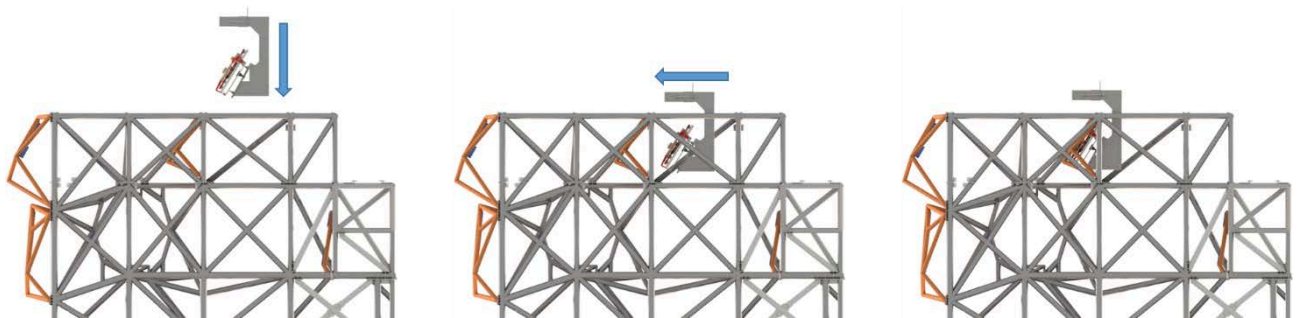


Figure 17: installation of M6 inside MORFEO main structure. The hoisting point is always above the top part of MORFEO main structure, so to avoid interferences between the crane wire rope and the beams of the main structure.

Once M6M is inside the MSS, two people (one at the front and one at the back of M6M inside the MSS) are necessary to secure the mirror to its supporting structure and to release the handling (see Figure 18 and Figure 19). Access to that location is provided by a modular system of internal ladders that can be mounted/dismounted inside the MSS at the occurrence (see Figure 19).

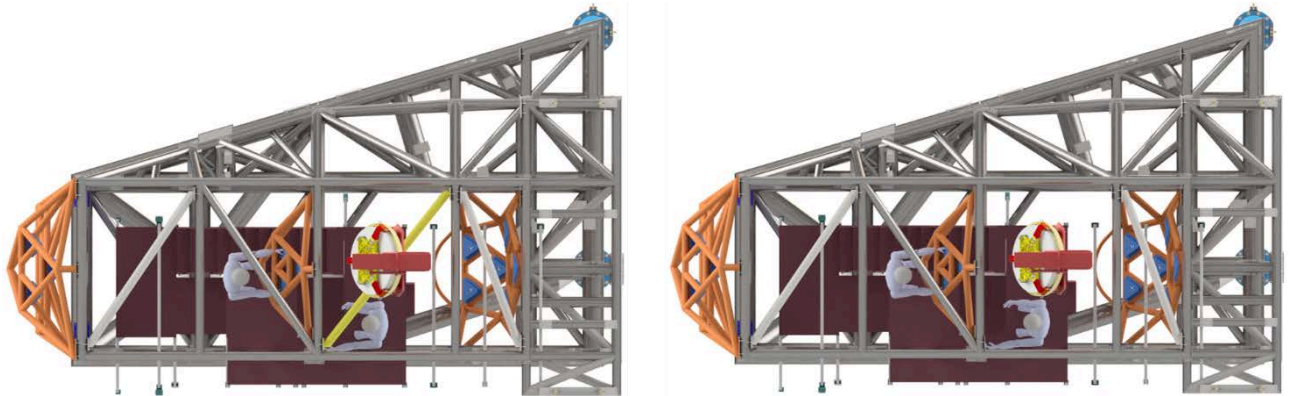


Figure 18: yellow beams shall be removed to allow handling accessing into MORFEO main structure.

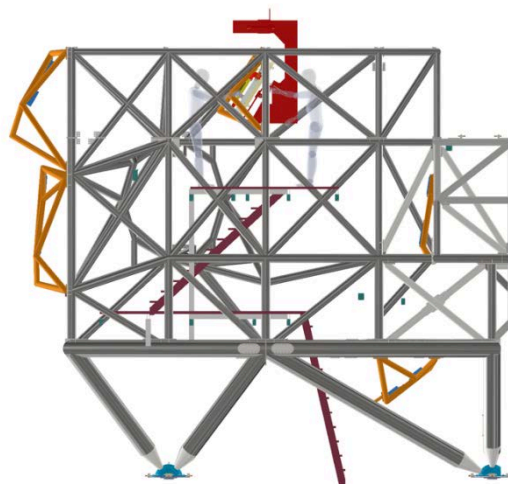


Figure 19: Internal ladders (in garnet) to reach the M6 position

The platform solution has been presented at the PDR, but it has a drawback, consisting in the time needed to install and un-install it. At the beginning of the FDR phase we did study an alternative solution, foreseen to use an elevator permanently installed inside MORFEO, which can move on rails, when it is completely retracted, in 2-3 different positions, allowing to reach several opto-mechanical sub-systems. As it is shown in Figure 20, in the case of M6M an operator can reach both the area of the interface with the MSS (to install M6M on that) and, on the opposite side of the mirror, the area of the interface with the HT, to remove the counterweights and then release the HT from M6M, allowing the HT itself to be taken out from the MSS without any load to be safely stored in his box.

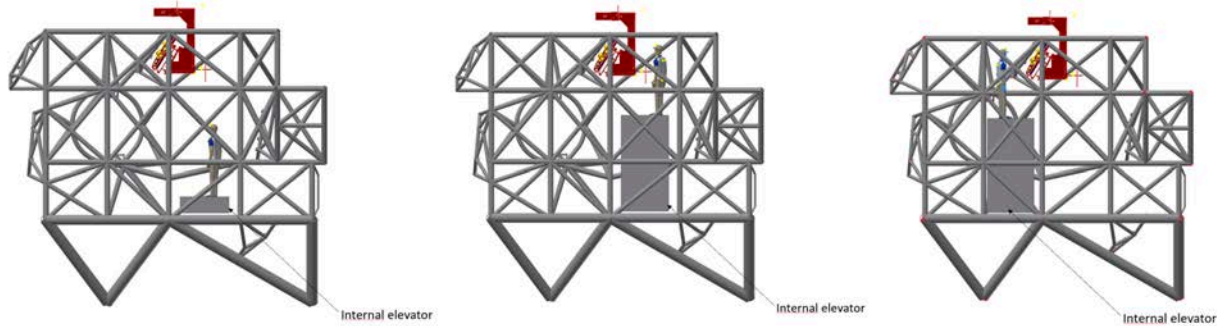


Figure 20: a conceptual view of the internal elevator, which can slide on rails when it is in the low position.

In Figure 21 we report the necessary space for the M6M installation, given the PDR design of the MSS and of the M6M HT. Height constraint is imposed by the maximum height of the crane hook at the 3 locations where MORFEO will be installed, constraints in the other directions are imposed by the current design of the Main Structure.

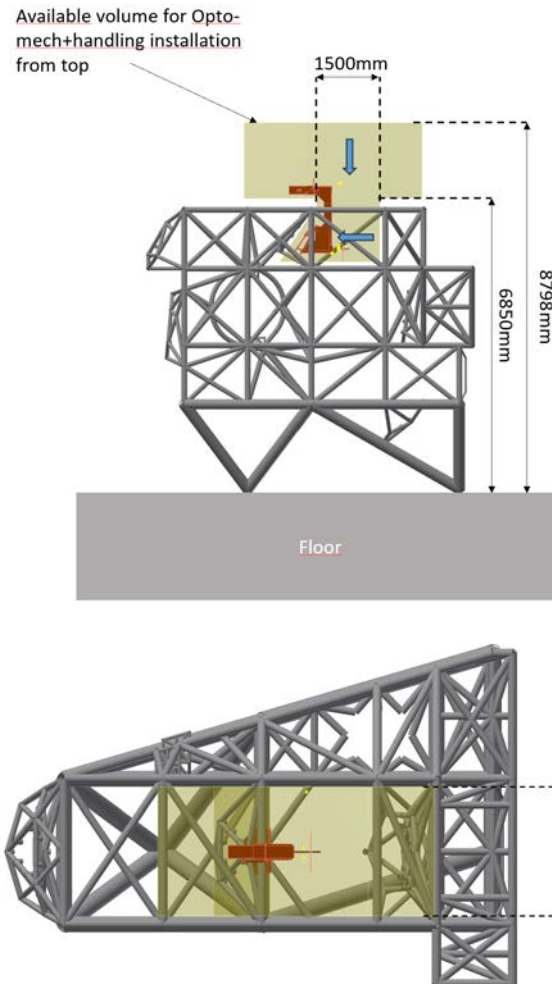


Figure 21: on the left side, we report the necessary height for the M6M installation with the current design of the M6M HT and with the current MSS design. On the right side, we report the currently available width with the MSS PDR design.

The M6M dis-installation procedure is pretty much the reverse procedure of what just described for its installation.

As reported in Sec.3 in all the 3 locations the same HT can be used to install/un-install M6M, due to the available height of the overhead crane lifting hook.

**Notes:** The pre-requisites here are more due to the procedure sequence and to the necessity/wish to install just one main subsystem at a time

#### **4.1.3.8 IAA M6M installation procedure**

Same procedure described in 4.1.3.7 due to the available height of the overhead crane lifting hook.



#### **4.1.3.9 Nasmyth M6M installation procedure**

Same procedure described in 4.1.3.7 due to the available height of the overhead crane lifting hook.

## **5.2 M7M HT (SM0-HT-PFB)**

### **5.2.1 Purpose and functionality: M7M HT technical specifications**

The SM0-HT-PFB must allow to safely install/un-install M7M on the MSS for assembly and maintenance purposes. The HT shall possibly be the same in all the locations where it will be used (BIH, Entrance Hall, IAA, Nasmyth platform). Should this not be possible, an additional HT shall be designed for that purpose.

M7M will be represented through a 3D volume characterized by a weight, a centre of mass and defined interfaces toward the HT and the MSS. After the installation of M7M, the HT has to be removed and safely stored.

If needed, counterweights shall be added, to have the HT properly balanced in the LOAD configuration, as specified in 9)a.

Since it will be used in a seismic area, the design must consider a load increased according to what specified in AD1. Since the HTs that will be used for all the foreseen locations/operating scenarios, the most stringent driving load shall be applied. Should this not be possible, the HTs shall be designed according to the driving load specific indications for the location where it will be used.

All the general requirements described in Sec. 4 "HANDLING TOOLS" are applicable.

Applicable and reference documents are the following:

- AD doc concerning the available volumes inside the MSS: AD24
- AD doc concerning the volume and interfaces of the opto-mech: AD10 and AD24
- RD docs (MAIT/AIV plans) concerning the procedures for the installation in the various locations: RD5 and RD6

### **5.2.2 Deliverables**

Phase 1: executive drawings, step files and detailed and comprehensive procedure for M7M installation/dis-installation in the various locations

Phase 2: HT manufactured, test report, user and maintenance manual, storage box

### **5.2.3 Additional information: M7M HT suggested design**

The proposed design described here assumes the MSS and M7M HT PDR design.

#### **5.2.3.1 Description**

It is a quite stubby C-shaped handling. This handling shape allows to interface the crane hook along the projection of the barycentre of M7 + handling. In the PDR design the position of the crane hook hoisting hole cannot be adjusted, but instead we require also for the M7M HT a fine-tuning mechanism, as requested in 12).

To keep the system balanced both when M7 is connected and not, a system of sliding counterweights will also be used. These are installed on a M30 threaded rod passing



through the middle of the long beam of the handling. Two nuts allow to tune the position of the masses on the rod, shifting accordingly the barycentre of the system.

The rest of the handling is conceptually identical to what described for M6, with the only obvious exception of the handling total dimensions and mirror interface.

At M7 side, the C-shaped handling is constituted by 2 main parts: a fixed part and a movable one. The latter is physically screwed to the 3 branches embracing M7 through six M8 screws (2 per branch), and it is interfaced to the handling fixed part through a heim joint, that allows adjusting its position in 3 DoFs.

The handling can be interfaced to M7 with the mirror protecting cover in place.

3 threaded rods screwed to the fixed part of the handling and pushing on the movable part allow to fine adjust the tip-tilt of M7 during the installation phase. One of the threaded rods is inserted in a small pit in the movable part, to prevent rotation of the mirror around its optical axis.

The handling is designed to keep the mirror with an orientation very close to the one it will have when mounted into MSS. This allows to perform only small mirror position adjustment at the moment of interfacing M7 to its supporting structure inside the MSS.

Figure 22: C-shaped handling for M7 installation. The interface between M7 and the handling is between the 3 branches embracing M7 and the 3 connection pads of the handling. The handling is equipped with a fixed hoist ring and movable counterweight to tune the position of the barycentre.

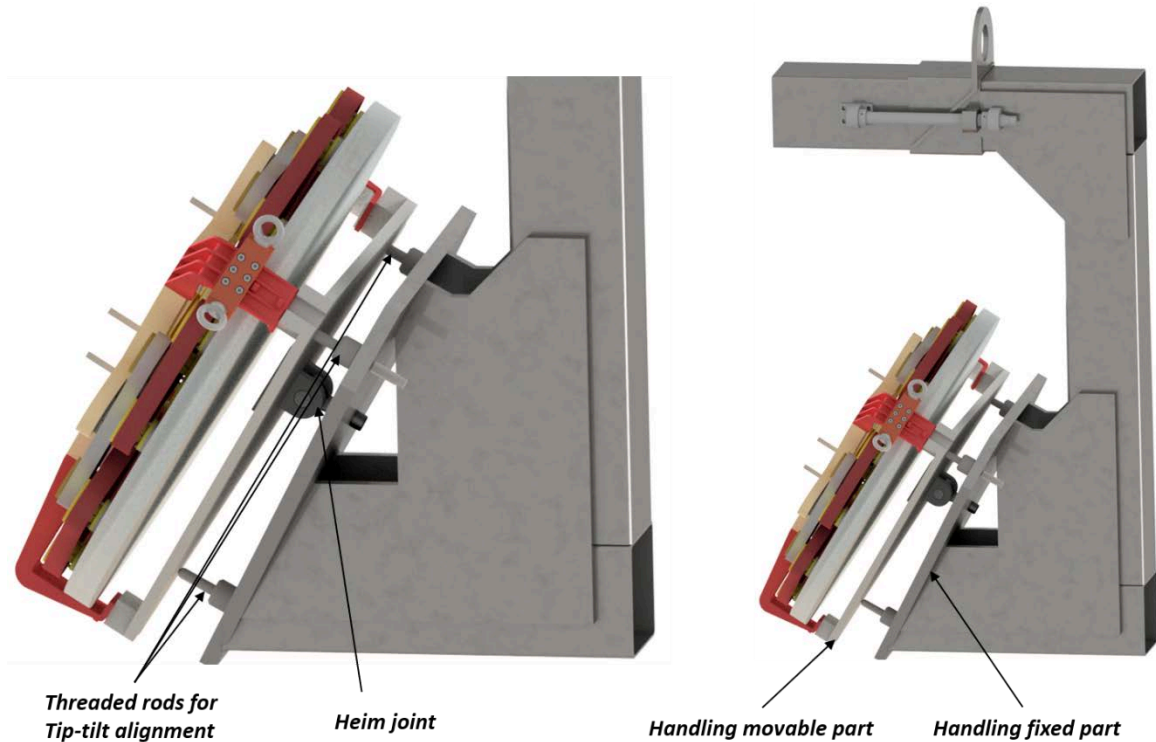


Figure 23: the handling allows to fine adjust tip-tilt of the mirror before installation, thanks to a heim joint and 3 threaded rods pushing against the movable part of the handling.

### 5.2.3.2 Way to be operated/procedure

The SM0-HT-PFB must be operated in the following way:

- The cover of M7 must be installed
- A minimum of 2 persons plus the crane operator are necessary for the SM0-HT-PFB handling/movement
- The hoist point on SM0-HT-PFB has to be connected to the crane hook, then the HT approaches M7 (kept on a stand with the same orientation it will have when installed on the MSS) and connects to the fixation points on the mirror opto-mech. Some bars positioned on M7 branches can be used to guide SM0-HT-PFB when approaching M7.

### 5.2.3.3 Special tools needed

Normal mechanical workshop tools.



#### **5.2.3.4 AIT phase when needed**

The SM0-HT-PFB is needed for the assembly operations in Bologna and in Chile and in the Nasmyth platform for maintenance in Chile.

#### **5.2.3.5 Deliverable and lifetime**

The SM0-HT-PFB is a deliverable to Chile, where it has to be stored to be used for maintenance and its lifetime shall be equivalent, or larger, than the MORFEO lifetime.

#### **5.2.3.6 Hazard and Safety issues**

The SM0-HT-PFB must be operated in the following way:

- The cover of M7 must be installed
- A minimum of 2 persons plus the crane operator are necessary for the SM0-HT-PFB handling/movement
- Operators shall wear the helmet, safety gloves and safety shoes
- Every operator shall wear safety shoes, safety gloves and helmet
- When operating on the platform, the harness safely secured is mandatory for each operator
- The crane shall always hold all the weight, also during the shift of the counterweights

No Major Hazards have been identified, but mirror destruction in case of mis-handling

#### **5.2.3.7 BIH M7M Installation Procedure**

##### **Purpose and functionality**

M7 is installed on the MSS; its position is adjusted by acting on its TT and focus manual adjustments using the BIH LTs against M7 reference SMRS.

**HTs/Seq needed:** BIH Bridge crane, Dedicated HT

**Success Criteria:** M7 properly installed and in the nominal position given by the BIH LTs

**Duration:** 1 day (goal few hours)

**Prerequisites:** CP installation (**Note:** The pre-requisites here are more due to the procedure sequence and to the necessity/wish to install just one main subsystem at a time)

##### **Procedure:**

Due to its location, at the bottom part of MORFEO main structure, a C-shaped handling with the hoist ring above the top of the MSS is not an optimal solution as it would result in a very long handling.

Still the installation can be done from the top, using the same access used for M6. The handling is still C-shaped, even though the short sides of the C must be really short, as



the whole handling must enter into the MSS. For this reason, it is not possible to locate the hoist ring along the projection of the barycenter of M7 + handling, thus a counterweight is required. The counterweight constitutes of some metal disk inserted in a threaded rod fixed to the long side of the C-shaped handling. Two nuts allow to move the counterweight along the threaded rod, in order to adjust its position when M7 is removed.

Other than this, the concept of the M7 handling is the same shown for M6, thus the handling is physically connected to the 3 branches embracing M7 by using M8 screws.

The mirror is then lowered all the way down the MSS and brought in position. Being in a quite low position (highest interface point with its supporting structure being less than 1.8 meter from the ground), the operator does not need any special SEq to fix M7 to its interface points nor to disengage the handling from M7, while a small portable ladder might be needed to move the counterweight before releasing the handling.

When M7 is secured to its supporting structure and the handling, after rebalancing, is disengaged, it is extracted from the top of MSS.

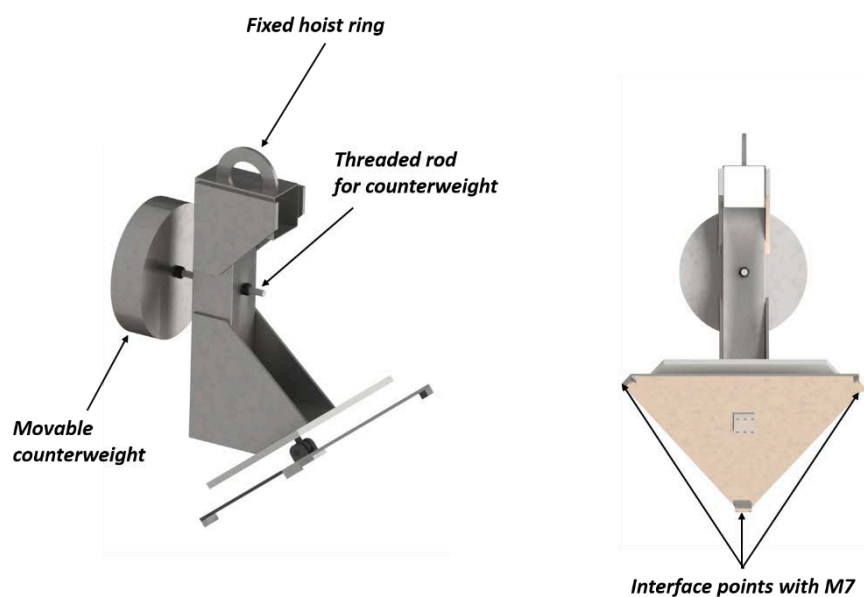


Figure 24: the C-shaped handling for M7 installation.

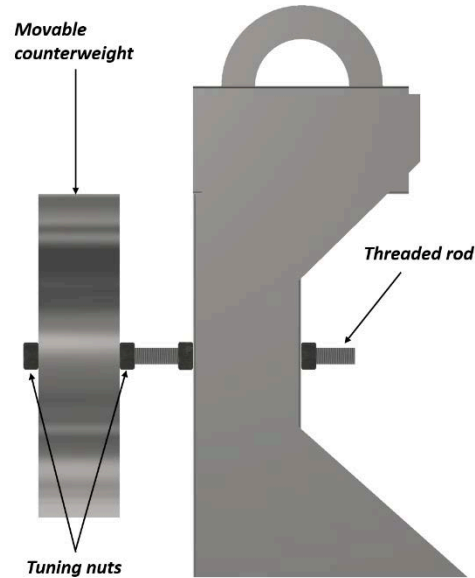


Figure 25: Two nuts allow to tune the position of the counterweight on the threaded rod.

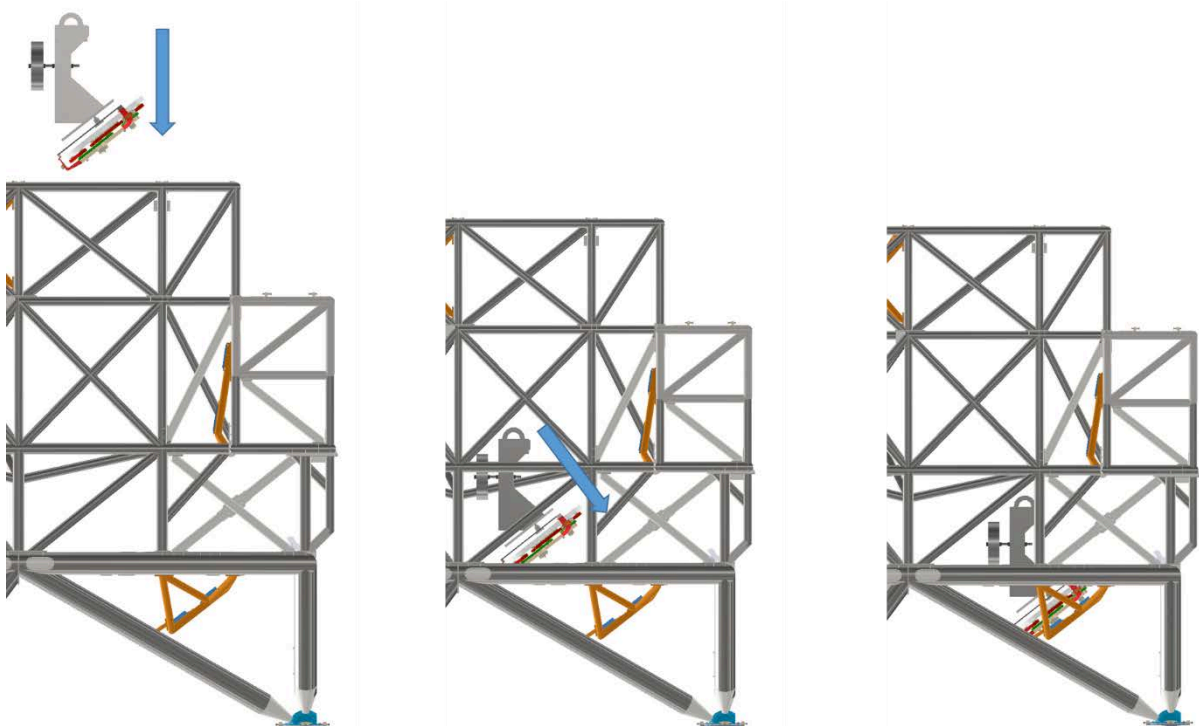


Figure 26: installation of M7 inside MORFEO main structure. To avoid a very long handling, the hoist ring during the installation is inside the MSS. This poses handling dimensioning constraints and the use of counterweights.

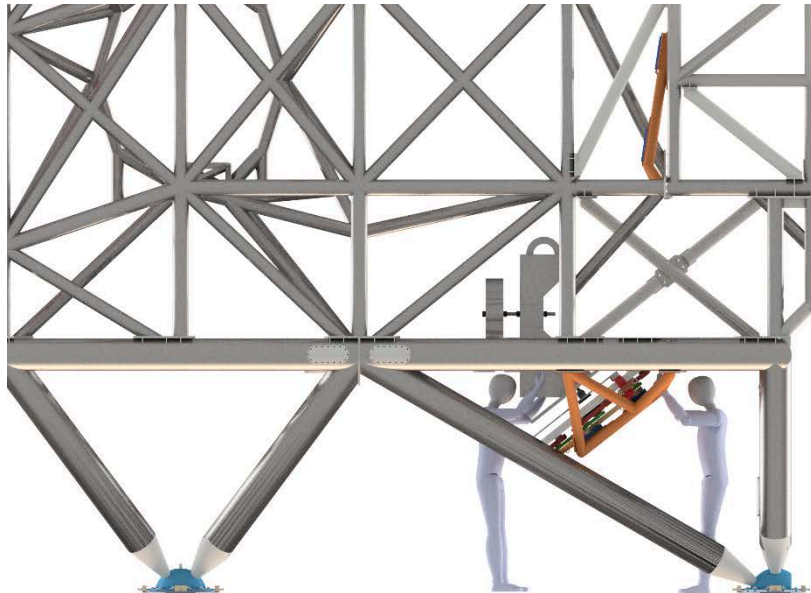


Figure 27: persons standing on the ground can easily secure M7 to its supporting structure and remove the handling. Fine tuning of the counterweight position might require a small ladder.

#### **5.2.3.8 IAA M7M Installation Procedure**

Same procedure described in Sec. 4.2.3.7 due to the available height of the overhead crane lifting hook.

#### **5.2.3.9 Nasmyth M7M Installation Procedure**

Same procedure described in Sec. 4.2.3.7 due to the available height of the overhead crane lifting hook.

### **5.3 M8M, M9M, M10M, M11M, Dichroic, 1<sup>st</sup> folding mirror LGSO HTs (SM0-HT-PFC, SM0-HT-PDA, SM0-HT-PDB, SM0-HT-PFE, SM0-HT-PFD\_CRANE, SM0-HT-PFG\_CRANE)**

#### **5.3.1 Purpose and functionality: M8M, M9M, M10M, M11M, Dichroic, LGSO FM1 HT technical specifications**

These handling are conceptually all the same, and very similar to the handling shown for M6, differing only for their overall dimensions. They have the purpose to perform the assembly of M8, M9, M10, M11M, the dichroic and 1<sup>st</sup> folding mirror LGSO in the MSS. They are equipped with a sliding hoisting point to balance the overall system with LOAD.

They must allow to safely install/un-install M8M, M9M, M10M, M11M, the dichroic and the LGSO FM1 on the MSS for assembly and maintenance purposes. The HTs shall possibly be the same in all the locations where they will be used (BIH, Entrance Hall, IAA, Nasmyth platform). Should this not be possible, additional HT shall be designed for that purpose.



The related opto-mechanical sub-systems will be represented through 3D volumes characterized by a weight, a centre of mass and defined interfaces toward the HT and the MSS. After the installation of the various opto-mechanical sub-systems, the HTs have to be removed and safely stored.

If needed, counterweights shall be added, to have the HTs properly balanced in the LOAD configuration, as specified in 9)a.

Since they will be used in a seismic area, the design must consider a load increased according to what specified in AD1. Since the HTs that will be used for all the foreseen locations/operating scenarios, the most stringent driving load shall be applied. Should this not be possible, each HT shall be designed according to the driving load specific indications for the location where it will be used.

All the general requirements described in Sec. 4 “HANDLING TOOLS” are applicable.

Applicable and reference documents are the following:

- RD doc concerning the available volumes inside the MSS: AD24
- AD doc concerning the volume and interfaces of the opto-mech: AD11, AD19, AD20, AD12, AD14, AD15 and AD24
- RD docs (MAIT/AIV plans) concerning the procedures for the installation in the various locations: RD5 and RD6

### **5.3.2 Deliverables**

Phase 1: executive drawings, step files and detailed and comprehensive procedure for installation/dis-installation in the various locations of M8, M9, M10, M11, Dichroic, LGSO HTs

Phase 2: HTs manufactured, test report, user and maintenance manual, storage box for M8M, M9M, M10M, Dichroic, LGSO HTs

### **5.3.3 Additional information: HT suggested design concerning M8M, M9M, M10M, M11M Dichroic, LGSO HTs**

The proposed design described here assumes the MSS and PDR design of the HTs concerning the opto-mechanical sub-systems M8, M9, M10, M11, Dichroic, LGSO HTs

#### **5.3.3.1 Description**

- They are all C-shaped handlings, designed to install the M8, M9, M10, M11, Dichroic, LGSO opto-mechanical units onto the Main Support Structure (MSS) from above, using a crane.
- The handling shape allows to interface the crane hook along the projection of the barycentre of the mirror + handling.
- The position of the crane hook hoisting hole with the handling can be finely adjusted as it is mounted on a rail, actuated by an endless screw. Such an adjustment will be used to fine-tune the position of the hoisting ring in the LOAD HT configuration, as specified in 12). Once the best position is identified, the hoist ring can be securely locked in place.



- Movable masses/counterweights connected to the handling are also be used, to have the HT balanced also in the NO-LOAD configuration, as specified in 9). Thus, the system provides the option to manually adjust the centre of mass by adding, removing, or relocating modular balancing weights. Each weight module is designed to be manually handled ( $\leq 8$  kg), and multiple units can be used to reach the correct balancing. Weights cannot slide out un-expectedly, thanks to a safety bolt. This feature is especially critical during the release phase, when the opto-mech is detached from the handling system, to maintain balance and prevent swinging.
- At mirror side, the C-shaped handling is constituted by 2 main parts: a fixed part and a movable one. The latter is physically screwed to the 3 branches embracing M8 through six M8 screws (2 per branch), and it is interfaced to the handling fixed part through a heim joint, that allows adjusting its position in 3 DoFs.
- The handling can be interfaced to the mirrors with the mirror protecting cover in place.
- 3 threaded rods screwed to the fixed part of the handling and pushing on the movable part allow to fine adjust the tip-tilt of the mirrors during the installation phase. One of the threaded rods is inserted in a small pit in the movable part, to prevent rotation of the mirror around its optical axis.
- The handlings are designed to keep the mirrors with an orientation very close to the one they will have when mounted into MSS. This allows to perform only small mirror position adjustment at the moment of interfacing the mirrors to their supporting structure inside the MSS.

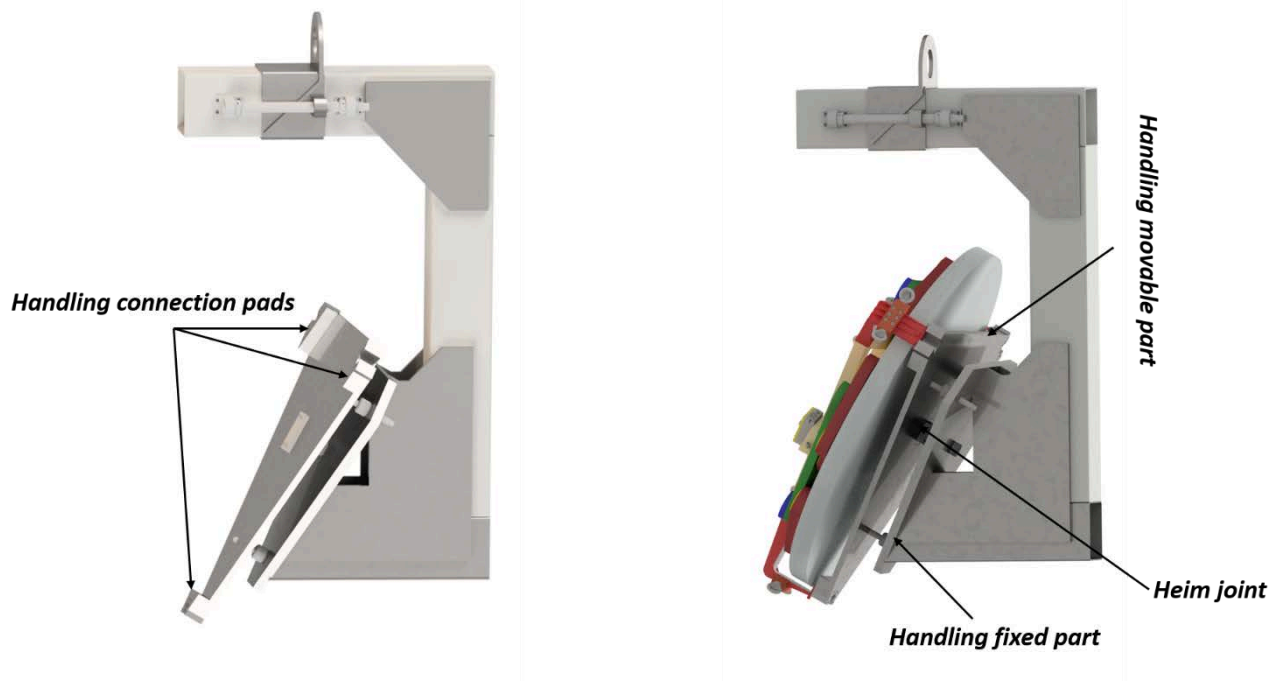


Figure 28: C-shaped handling for M8 installation. The interface between M8 and the handling is between the 3 branches embracing M8 and the 3 connection pads of the handling. The handling is equipped with a hook hoisting connection point having the possibility to slide, in order to have it aligned with the barycentre of the system both when M8 is connected and disconnected.

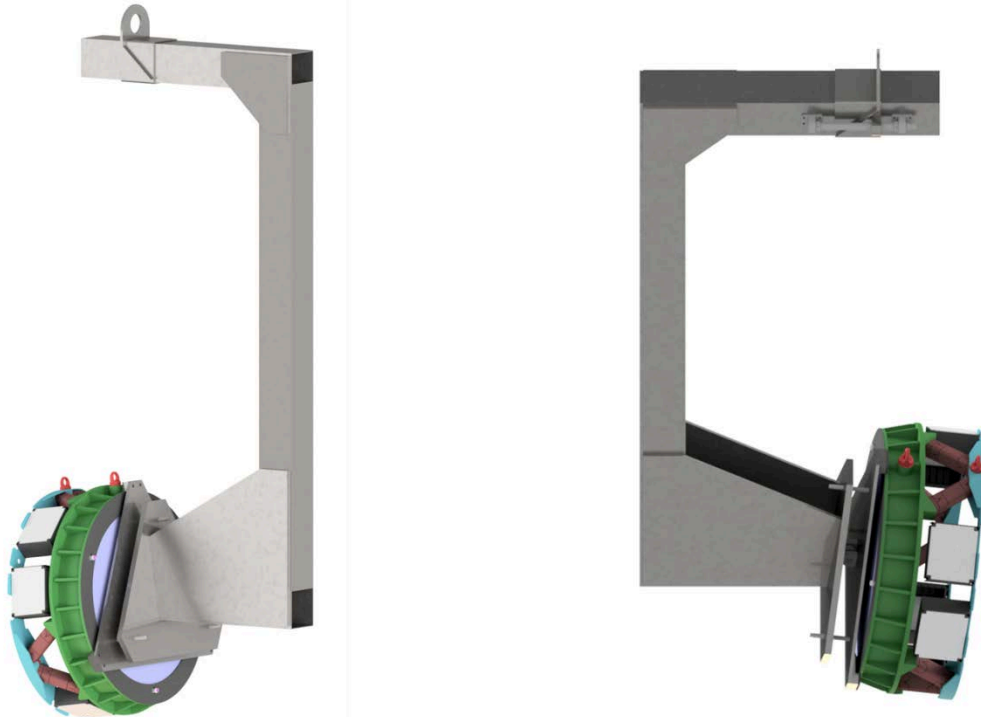


Figure 29: C-shaped handling for M9 installation. The interface between M9 and the handling is between the 3 pads at the front flange (in green) and the 3 connection pads of the handling. The handling is equipped with a hook hoisting connection point having the possibility to slide, in order to have it aligned with the barycentre of the system both when M9 is connected and disconnected.

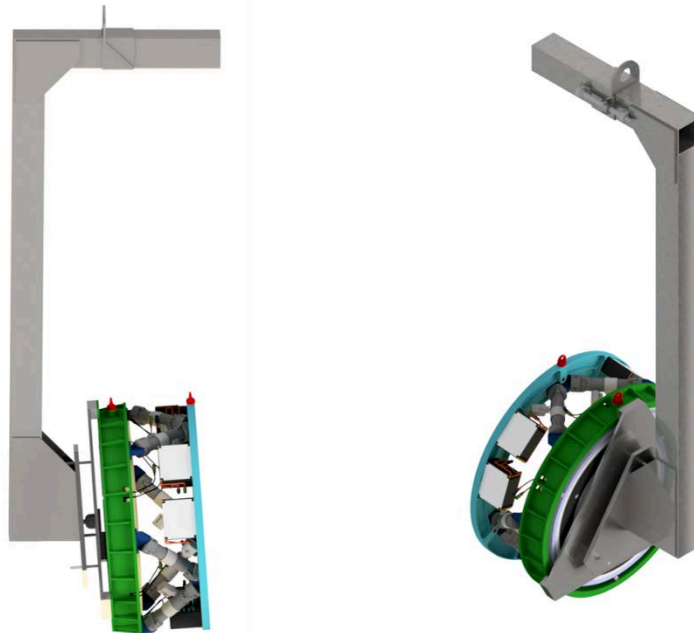


Figure 30: C-shaped handling for M10 installation. The interface between M10 and the handling is between the 3 pads at the front flange (in green) and the 3 connection pads of the handling. The handling is equipped with a hook hoisting connection point having the possibility to slide, in order to have it aligned with the barycentre of the system both when M9 is connected and disconnected.

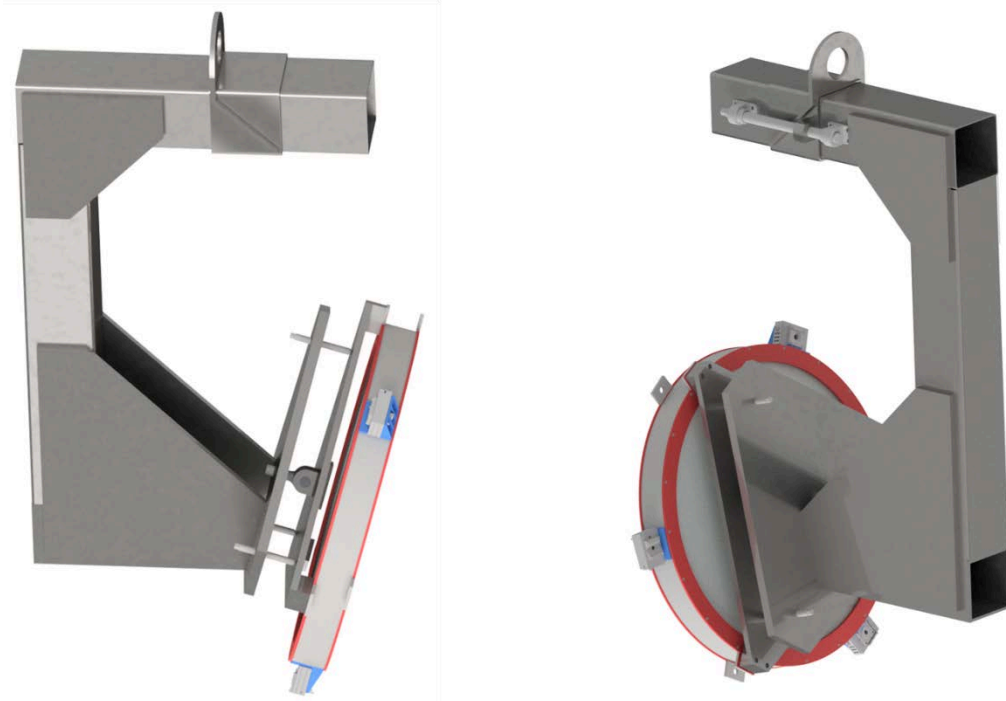


Figure 31: C-shaped handling for dichroic installation. The interface between dichroic and the handling is between the 3 pads at the front flange and the 3 connection pads of the handling. The handling is equipped with a hook hoisting connection point having the possibility to slide, in order to have it aligned with the barycentre of the system both when the dichroic is connected and disconnected.



**1° folding mirror LGSO fixing screws**

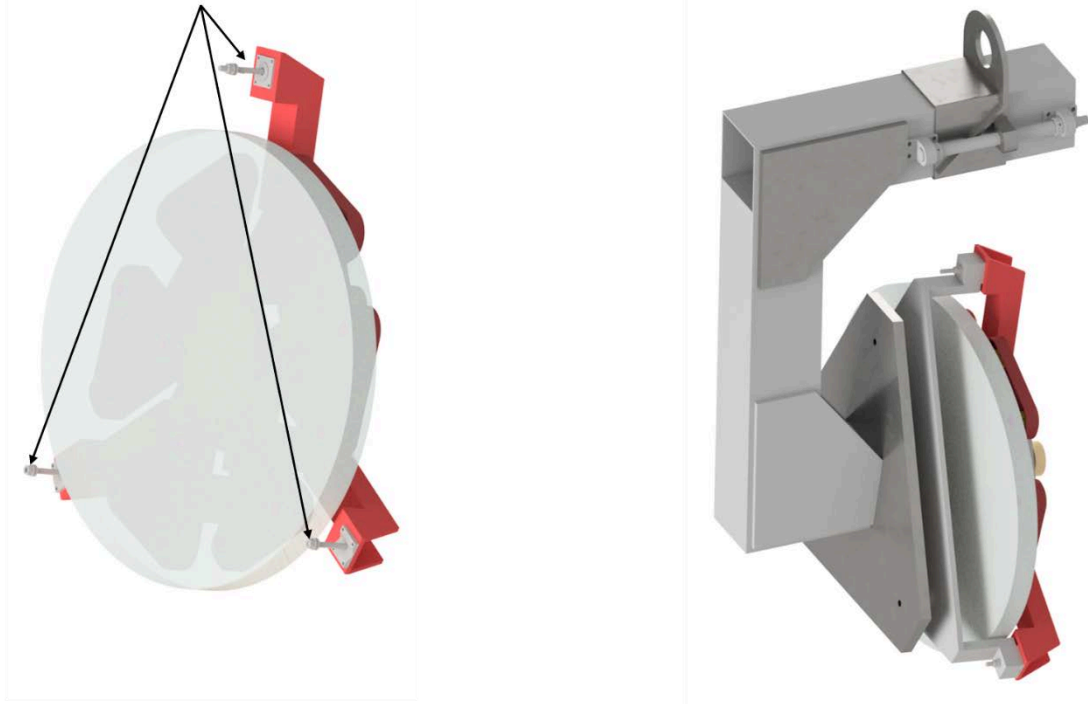


Figure 32: C-shaped handling for 1<sup>st</sup> folding mirror LGSO installation. The interface between the mirror and the handling is between the 3 branches, which are also the interface of the mirror to its supporting structure inside the MSS, and the 3 connection pads of the handling. The handling is equipped with a hook hoisting connection point having the possibility to slide, in order to have it aligned with the barycentre of the system both when the mirror is connected and disconnected.

**5.3.3.2 Way to be operated/procedure**

All these handlings must be operated in the following way:

- The cover of the corresponding mirrors must be installed
- A minimum of 2 persons plus the crane operator are necessary for mirror installation inside the MSS
- The internal ladders, platform and security harnesses to access mirrors in the MSS must be in place
- The hoist point on the handlings has to be connected to the crane hook, then the HT approaches the opto-mechanical unit (kept on a stand with the same orientation it will have when installed on the MSS) and connects to the fixation



points on the mirror opto-mech. Some bars positioned on the opto-mech branches can be used to ease and guide the handlings approaching the relative mirrors.

#### **5.3.3.3 Special tools needed**

Normal mechanical workshop tools.

#### **5.3.3.4 AIT phase when needed**

SM0-HT-PFC, SM0-HT-PDA, SM0-HT-PDB, SM0-HT-PFD\_CRANE, SM0-HT-PFE and SM0-HT-PFG\_CRANE are needed for the assembly operations in Bologna and in Chile and in the Nasmyth platform for maintenance in Chile.

#### **5.3.3.5 Deliverable and lifetime**

SM0-HT-PFC, SM0-HT-PDA, SM0-HT-PDB, SM0-HT-PFD\_CRANE, SM0-HT-PFE and SM0-HT-PFG\_CRANE are deliverables to Chile, where they have to be stored to be used for maintenance and its lifetime shall be equivalent, or larger, than the MORFEO lifetime.

#### **5.3.3.6 Hazard and Safety issues**

The handlings must be operated in the following way:

- The mirror protection covers must be installed
- A minimum of 2 persons plus the crane operator are necessary for the mirror installation in the MSS
- The temporary platform/scissor lift and internal ladders allowing to reach the mirrors area inside and outside the MSS must be in place
- Operators shall wear the helmet, safety gloves and safety shoes
- Every operator shall wear safety shoes, safety gloves and helmet
- When operating on the platform, the harness safely secured is mandatory for each operator

No Major Hazards have been identified, but mirrors destruction in case of mis-handling

#### **5.3.3.7 BIH Installation Procedure**

The installation procedure in the BIH for M8, M9, M10, M11M, Dichroic, LGSO using the HTs PDR proposed design are described in RD5.

#### **5.3.3.8 IAA Installation Procedure**

The installation procedure in the IAA for M8, M9, M10, M11M Dichroic, LGSO using the HTs PDR proposed design are described in RD6.

#### **5.3.3.9 Nasmyth Installation Procedure**

The installation procedure in Nasmyth for M8, M9, M10, M11M, Dichroic, LGSO will be, most probably, identical to the BIH



## 5.4 Corrective Plate HT (SM0-HT-PFK)

### 5.4.1 Purpose and functionality: Corrective Plate HT technical specifications

The SM0-HT-PFK must allow to safely install/un-install the Corrective Plate (CP) on the MSS for assembly and maintenance purposes. The HT shall possibly be the same in all the locations where it will be used (BIH, Entrance Hall, IAA, Nasmyth platform). Should this not be possible, an additional HT shall be designed for that purpose.

The CP will be represented through a 3D volume characterized by a weight, a centre of mass and defined interfaces toward the HT and the MSS. After the installation of the CP, the HT has to be removed and safely stored.

If needed, counterweights shall be added, to have the HT properly balanced in the LOAD configuration, as specified in 9)a.

Since it will be used in a seismic area, the design must consider a load increased according to what specified in AD1. Since the HTs that will be used for all the foreseen locations/operating scenarios, the most stringent driving load shall be applied. Should this not be possible, the HTs shall be designed according to the driving load specific indications for the location where it will be used.

All the general requirements described in Sec. 4 “HANDLING TOOLS” are applicable.

Applicable and reference documents are the following:

- AD doc concerning the available volumes inside the MSS: AD24
- AD doc concerning the volume and interfaces of the opto-mech: AD8 and AD24
- RD docs (MAIT/AIV plans) concerning the procedures for the installation in the various locations: RD5 and RD6

### 5.4.2 Deliverables

Phase 1: executive drawings, step files and detailed and comprehensive procedure for the CP installation/dis-installation in the various locations

Phase 2: HT manufactured, test report, user and maintenance manual, storage box

### 5.4.3 Additional information: CP HT suggested design

The proposed design described here assumes the MSS and CP HT PDR design.

#### 5.4.3.1 Description

- It is basically a simplified and light-weighted C-shaped handling, designed to install the CP opto-mechanical unit onto the Main Support Structure (MSS) from above, using a crane.
- The handling shape allows to interface the crane hook along the projection of the barycentre of the CP + handling.
- The position of the crane hook hoisting hole with the handling can be finely adjusted as it is mounted on a rail, actuated by an endless screw. Such an adjustment will be used to fine-tune the position of the hoisting ring in the LOAD HT configuration, as



specified in 12). Once the best position is identified, the hoist ring can be securely locked in place.

- Movable masses/counterweights connected to the handling may also be used, to have the HT balanced in all the configuration (LOAD and NO-LOAD), as specified in 9). Thus, the system provides the option to manually adjust the centre of mass by adding, removing, or relocating modular balancing weights. Each weight module is designed to be manually handled ( $\leq 8$  kg), and multiple units can be used to reach the correct balancing. Weights cannot slide out un-expectedly, thanks to a safety bolt. This feature is especially critical during the release phase, when the opto-mech is detached from the handling system, to maintain balance and prevent swinging.
- The CP will be mounted with the optical axis perpendicular to the gravity vector, so for its installation we do not devise the need of having a movable part on the handling, allowing to fine tune the tip-tilt position of the plate during the installation. The handling is thus constituted only by a fixed part, interfacing the CP through three pads spaced by 120 degrees. One M8 screw passing through each pad is screwed to a threaded hole on a pad located on the CP opto-mech.
- The handling can be interfaced to the CP with the mirror protecting cover in place.

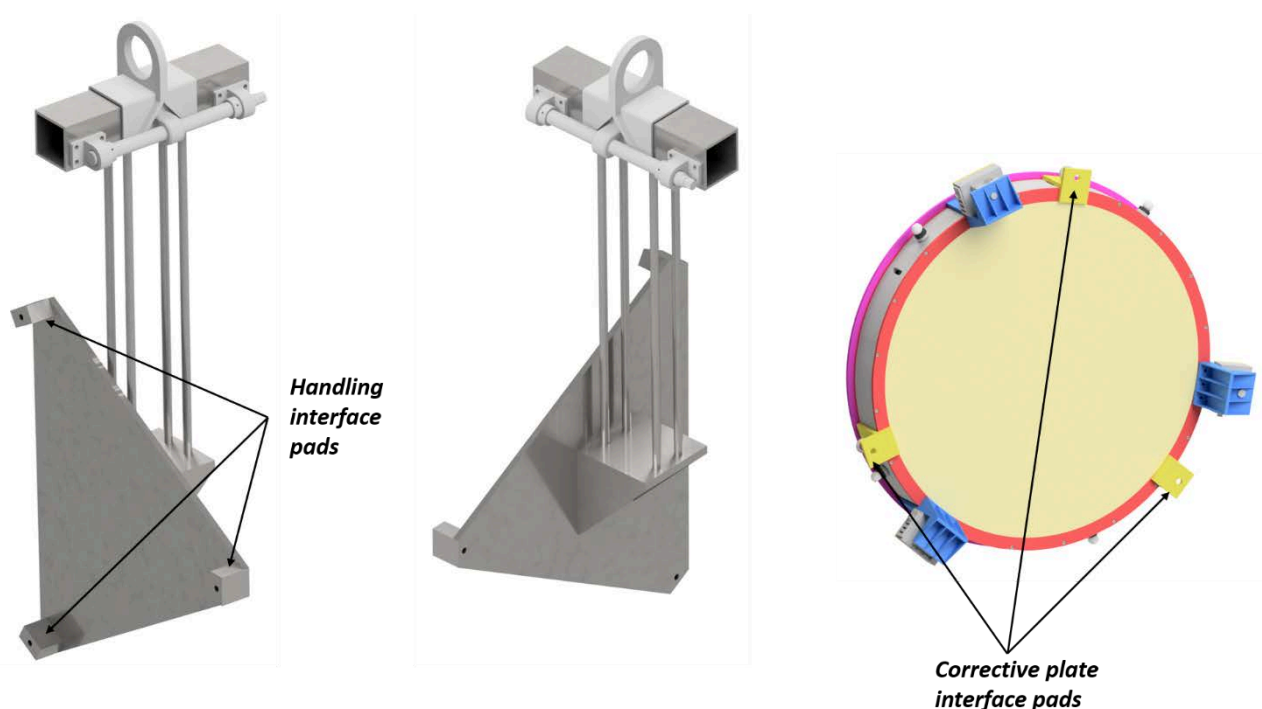


Figure 33: C-shaped handling for corrective plate installation. The interface between the corrective plate and the handling is between the 3 pads on the handling. The handling is equipped with a hook hoisting connection point having the possibility to slide, in order to have it aligned with the barycentre of the system both when M6 is connected and disconnected.



#### **5.4.3.2 Way to be operated/procedure**

The SM0-HT-PFK must be operated in the following way:

- The cover of the corrective plate must be installed
- A minimum of 2 persons plus the crane operator are necessary for the SM0-HT-PFK handling/movement
- The internal ladders, platform and security harnesses to access the corrective plate on the MSS must be in place
- The hoist point on SM0-HT-PFK has to be connected to the crane hook, then the HT approaches the corrective plate and connects to the fixation points on the mirror opto-mech.

#### **5.4.3.3 Special tools needed**

Normal mechanical workshop tools.

#### **5.4.3.4 AIT phase when needed**

The SM0-HT-PFK is needed for the assembly operations in the BIH in Bologna, in the IAA in Chile and in the Nasmyth platform for maintenance in Chile.

#### **5.4.3.5 Deliverable and lifetime**

The SM0-HT-PFK is a deliverable to Chile, where it has to be stored to be used for maintenance and its lifetime shall be equivalent, or larger, than the MORFEO lifetime.

#### **5.4.3.6 Hazard and Safety issues**

The SM0-HT-PFK must be operated in the following way:

- The cover of the corrective plate must be installed
- A minimum of 2 persons plus the crane operator are necessary for the SM0-HT-PFK handling/movement
- The platform allowing to reach the corrective plate area on the MSS must be in place
- Operators shall wear the helmet, safety gloves and safety shoes
- Every operator shall wear safety shoes, safety gloves and helmet
- When operating on the platform, the harness safely secured is mandatory for each operator

No Major Hazards have been identified, but mirror destruction in case of mis-handling



#### **5.4.3.7 BIH CP installation procedure**

The installation procedure in the BIH for the CP using the HT PDR proposed design is described in RD5.

#### **5.4.3.8 IAA CP Installation Procedure**

The installation procedure in the IAA for the CP using the HT PDR proposed design is described in RD6.

#### **5.4.3.9 Nasmyth CP Installation Procedure**

The installation procedure in Nasmyth for the CP will be, most probably, identical to the BIH.

## **5.5 LGSO 3<sup>rd</sup> Folding Mirror (FM) HT (SM0-HT-PFL)**

### **5.5.1 Purpose and functionality: 3<sup>rd</sup> FM HT technical specifications**

The SM0-HT-PFL has the purpose to perform the assembly of the third folding mirror LGSO. It has a fixed hoist point and a system of sliding counterweights to fine tune the barycentre position both when the mirror is connected and disconnected

The SM0-HT-PFL must allow to safely install/un-install the 3<sup>rd</sup> FM on the MSS for assembly and maintenance purposes. The HT shall possibly be the same in all the locations where it will be used (BIH, Entrance Hall, IAA, Nasmyth platform). Should this not be possible, an additional HT shall be designed for that purpose.

The 3<sup>rd</sup> FM will be represented through a 3D volume characterized by a weight, a centre of mass and defined interfaces toward the HT and the MSS. After the installation of the 3<sup>rd</sup> FM, the HT has to be removed and safely stored.

If needed, counterweights shall be added, to have the HT properly balanced in the LOAD configuration, as specified in 9)a.

Since it will be used in a seismic area, the design must consider a load increased according to what specified in AD1. Since the HTs that will be used for all the foreseen locations/operating scenarios, the most stringent driving load shall be applied. Should this not be possible, the HTs shall be designed according to the driving load specific indications for the location where it will be used.

All the general requirements described in Sec. 4 "HANDLING TOOLS" are applicable.

Applicable and reference documents are the following:

- AD doc concerning the available volumes inside the MSS: AD24
- AD doc concerning the volume and interfaces of the opto-mech: AD16 and AD24
- RD docs (MAIT/AIV plans) concerning the procedures for the installation in the various locations: RD5 and RD6



### **5.5.2 Deliverables**

Phase 1: executive drawings, step files and detailed and comprehensive procedure for the 3<sup>rd</sup> FM installation/dis-installation in the various locations

Phase 2: HT manufactured, test report, user and maintenance manual, storage box

### **5.5.3 Additional information: 3<sup>rd</sup> FM HT suggested design**

The proposed design described here assumes the MSS and 3<sup>rd</sup> FM HT PDR design.

#### **5.5.3.1 Description**

The installation of FM3 LGSO happens from the side of the MSS, and since the mirror is located in the bottom part of the structure a C-shaped handling is not advisable. Due to the light weight of FM3 LGSO, the handling is basically a squared tubular beam, with interface plate to the mirror on one side and a sliding mass at the opposite side. The handling dimensions shall be kept as short as possible, to avoid mechanical interference with MICADO, which is on the same side where the installation take place. At the same time, the handling hoist point shall remain always outside the MSS. This means that the counterweights will be positioned very close to the hoist point. In order to maintain the counterweights at a reasonable mass, the interface plate with FM3 is light-weighted, but it maintains the same principle of three connection pads at 120° seen for all the other handlings. For dimensional constraints tip-tilt fine tuning mechanism has not been included to this handling, so correct inclination of the mirror shall be obtained using shims at the interface between the handling and the mirror.

The handling is secured to the mirror through one M8 screw per each pad.

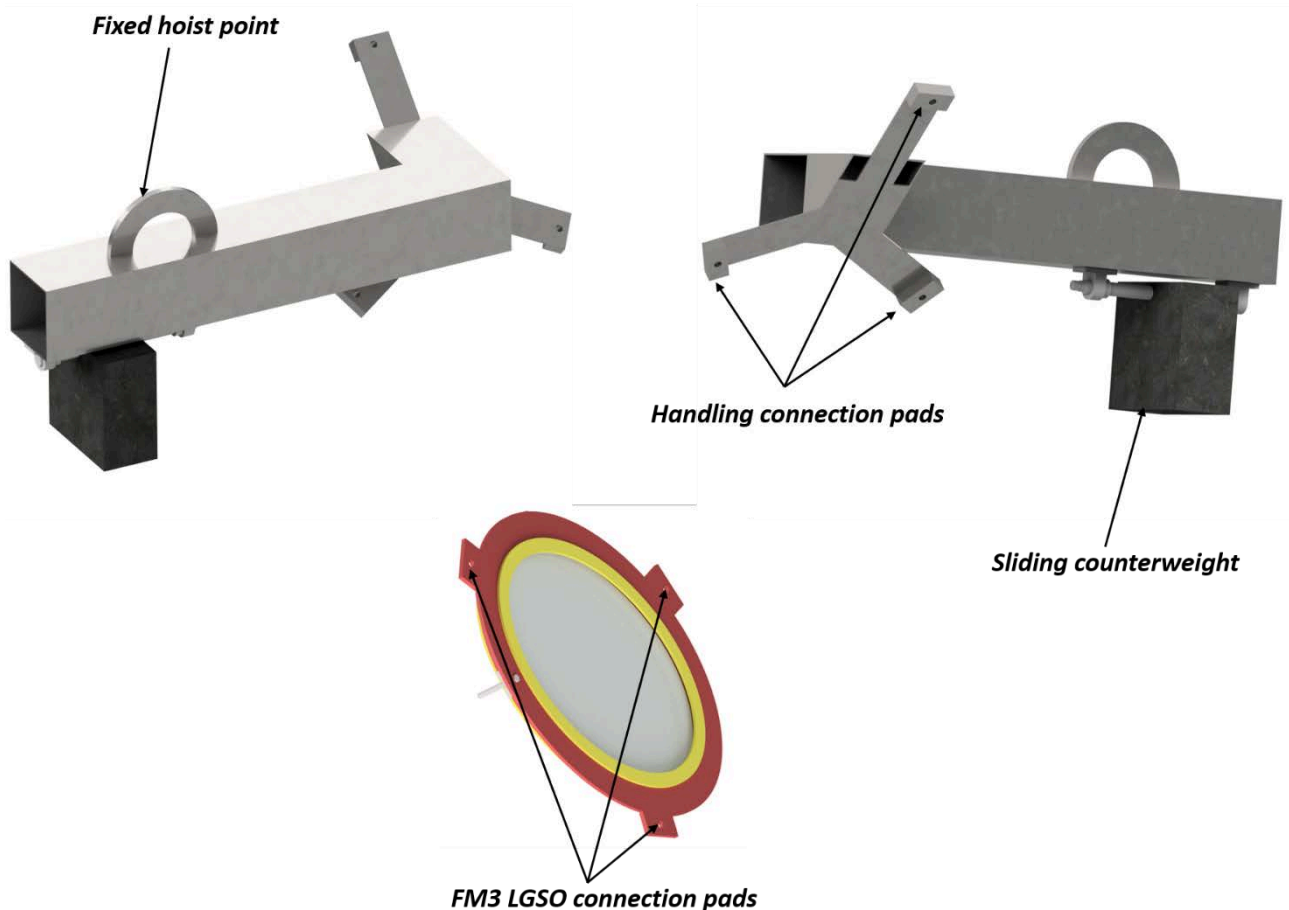


Figure 34: handling for FM3 LGSO installation. The interface between the corrective plate and the handling is between the 3 pads on the handling and the 3 pads on the opto-mech of the mirror. The handling is equipped with a fixed hook hoist point having a sliding counterweights in order to have it aligned with the barycentre of the system both when FM3 LGSO is connected and disconnected.

### 5.5.3.2 Way to be operated/procedure

The SM0-HT-PFL must be operated in the following way:

- A minimum of 1 person plus the crane operator are necessary for the SM0-HT-PFL handling/movement
- The internal ladders, platform and security harnesses to access the corrective plate on the MSS must be in place
- The hoist point on SM0-HT-PFL has to be connected to the crane hook, then the HT approaches FM3 LGSO and connects to the fixation points on the mirror opto-mech.



### 5.5.3.3 Special tools needed

Normal mechanical workshop tools.

### 5.5.3.4 AIT phase when needed

The SM0-HT-PFL is needed for the assembly operations in the BIH in Bologna, in the IAA in Chile and in the Nasmyth platform for maintenance in Chile.

### 5.5.3.5 Deliverable and lifetime

The SM0-HT-PFL is a deliverable to Chile, where it has to be stored to be used for maintenance and its lifetime shall be equivalent, or larger, than the MORFEO lifetime.

### 5.5.3.6 Hazard and Safety issues

The SM0-HT-PFL must be operated in the following way:

- A minimum of 1 person plus the crane operator are necessary for the SM0-HT-PFL handling/movement
- The internal ladders allowing to reach the corrective plate area on the MSS must be in place
- Operators shall wear the helmet, safety gloves and safety shoes
- Every operator shall wear safety shoes, safety gloves and helmet
- When operating on the platform, the harness safely secured is mandatory for each operator

No Major Hazards have been identified, but mirror destruction in case of mis-handling

### 5.5.3.7 BIH 3rd FM installation procedure

The installation procedure in the BIH for the 3<sup>rd</sup> FM using the HT PDR proposed design is described in RD5.

### 5.5.3.8 IAA 3rd FM Installation Procedure

The installation procedure in the IAA for the 3<sup>rd</sup> FM using the HT PDR proposed design is described in RD6.

### 5.5.3.9 Nasmyth 3rd FM Installation Procedure

The installation procedure in Nasmyth for the 3<sup>rd</sup> FM will be, most probably, identical to the BIH.



## **5.6 1<sup>st</sup> folding mirror LGSO Assembly and maintenance Handling Tool (SM0-HT-PFG\_BENCH)**

### **5.6.1 Purpose and functionality: 1st folding mirror LGSO HT Technical Specifications**

The SM0-HT-PFG\_BENCH must allow to safely install/un-install the 1<sup>st</sup> folding mirror LGSO on the MSS for assembly and maintenance purposes. The HT shall possibly be the same in all the locations where it will be used (BIH, Entrance Hall, IAA, Nasmyth platform). Should this not be possible, an additional HT shall be designed for that purpose.

The 1<sup>st</sup> folding mirror LGSO will be represented through a 3D volume characterized by a weight, a centre of mass and defined interfaces toward the HT and the MSS. After the installation of the 1<sup>st</sup> folding mirror LGSO, the HT has to be removed and safely stored.

Since it will be used in a seismic area, the design must consider a load increased according to what specified in AD1. Since the HTs that will be used for all the foreseen locations/operating scenarios, the most stringent driving load shall be applied. Should this not be possible, the HTs shall be designed according to the driving load specific indications for the location where it will be used.

All the general requirements described in Sec. 4 “HANDLING TOOLS” are applicable.

Applicable and reference documents are the following:

- AD doc concerning the available volumes inside the MSS: AD24
- AD doc concerning the volume and interfaces of the opto-mech: AD15 and AD24
- RD docs (MAIT/AIV plans) concerning the procedures for the installation in the various locations: RD5 and RD6

### **5.6.2 Deliverables**

Phase 1: executive drawings, step files and detailed and comprehensive procedure for the 1st FM LGSO installation/dis-installation in the various locations

Phase 2: HT manufactured, test report, user and maintenance manual, storage box.

### **5.6.3 Additional information: 1<sup>st</sup> FM LGSO HT suggested design**

The proposed design described here assumes the MSS and 1st FM LGSO HT PDR design.

#### **5.6.3.1 Description**

The installation of the 1<sup>st</sup> folding mirror LGSO (FM1 LGSO) happens from the side of the MSS. We studied a system with a rail protruding outside the MSS and entering into it. The rail is oriented in a way that the 1<sup>st</sup> FM LGSO will reach its interface points inside the MSS with the correct orientation. The rail is permanently equipped with some sliding carts, and on top of these there is the part of the handling interfacing with the dichroic. It is divided in



two parts: a fixed part and a movable one. The 1<sup>st</sup> FM LGSO is mounted on the movable part, which has three pads at 120° interfacing to three pads on the 1<sup>st</sup> FM LGSO opto-mech. The pads on the opto-mech are located on the opposite side to the one used to interface the 1<sup>st</sup> FM LGSO to SM0-HT-PFG\_CRANE. The movable part of the handling is secured to the fixed part using safety screws, which prevent the payload from overturning.

The rail, in fact, carry the 1<sup>st</sup> FM LGSO in front of its interface points in the MSS, but at a distance of about 15 mm, to avoid the optical surface of the 1<sup>st</sup> FM LGSO being too close to mechanical parts when the handling slides on the rail. Thus, when in position, acting on some screws on the fixed part of the handling and pushing against the movable part, it is possible to push the FM1 LGSO against its interface points.

The part of the rail protruding outside the MSS lean on a support beam connected to the ground. When the 1<sup>st</sup> FM LGSO is secured to the handling on the rail and the handling on the crane is disengaged, the 1<sup>st</sup> FM LGSO can slide inside the MSS. Some security blocks at both ends of the rail prevent the carts to slide off the rail.

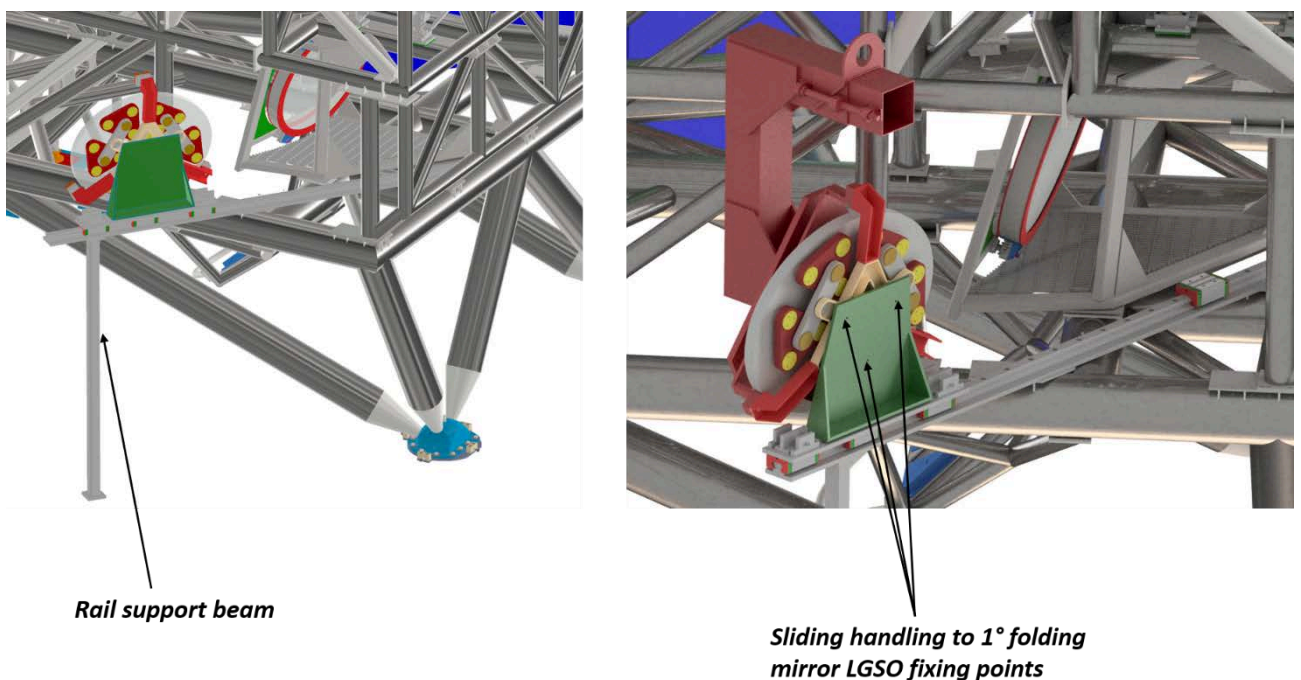


Figure 35: handling for FM1 LGSO installation.

### 5.6.3.2 Way to be operated/procedure

The SM0-HT-PFG\_BENCH must be operated in the following way:

- The cover of the 1<sup>st</sup> FM LGSO must be installed



- A minimum of 2 person for the SM0-HT-PFG\_BENCH handling/movement
- A small internal ladder to access the 1<sup>st</sup> FM LGSO on the MSS must be in place
- Hard stop at both end of the rail must be in place
- Safety screws between handling movable part and fixed part inserted but not fully tightened

#### **5.6.3.3 Special tools needed**

Normal mechanical workshop tools.

#### **5.6.3.4 AIT phase when needed**

The SM0-HT-PFG\_BENCH is needed for the assembly operations in Bologna and in Chile and for maintenance in Chile.

#### **5.6.3.5 Deliverable and lifetime**

The SM0-HT-PFG\_BENCH is a deliverable to Chile, where it has to be stored to be used for maintenance and its lifetime shall be equivalent, or larger, than the MORFEO lifetime.

#### **5.6.3.6 Hazard and Safety issues**

The SM0-HT-PFG\_BENCH must be operated in the following way:

- A minimum of 2 person are necessary for the SM0-HT-PFG\_BENCH handling/movement
- The internal ladders allowing to reach the corrective plate area on the MSS must be in place
- Operators shall wear the helmet, safety gloves and safety shoes
- Every operator shall wear safety shoes, safety gloves and helmet
- When operating on the platform, the harness safely secured is mandatory for each operator

No Major Hazards have been identified, but dichroic destruction in case of mis-handling

#### **5.6.3.7 BIH 1st FM LGSO installation procedure**

The installation procedure in the BIH for the 1st FM LGSO using the HT PDR proposed design is described in RD5.



### **5.6.3.8 IAA 1st FM LGSO Installation Procedure**

The installation procedure in the IAA for the 1st FM LGSO using the HT PDR proposed design is described in RD6.

### **5.6.3.9 Nasmyth 1st FM LGSO Installation Procedure**

The installation procedure in Nasmyth for the 1st FM LGSO will be, most probably, identical to the BIH.

## **5.7 LGSO Assembly and maintenance LGSO HT (SM0-HT-PFH\_CRANE)**

### **5.7.1 Purpose and functionality: LGSO HT Technical Specifications**

The SM0-HT-PFH\_CRANE has the purpose to lower the LGSO on the SM0-HT-PFH\_BENCH. The HT shall possibly be the same in all the locations where it will be used (BIH, Entrance Hall, IAA, Nasmyth platform). Should this not be possible, an additional HT shall be designed for that purpose.

The LGSO will be represented through a 3D volume characterized by a weight, a centre of mass and defined interfaces toward the HT and the MSS. After the installation of the LGSO, the HT has to be removed and safely stored.

Since it will be used in a seismic area, the design must consider a load increased according to what specified in AD1. Since the HTs that will be used for all the foreseen locations/operating scenarios, the most stringent driving load shall be applied. Should this not be possible, the HTs shall be designed according to the driving load specific indications for the location where it will be used.

All the general requirements described in Sec. 4 "HANDLING TOOLS" are applicable.

Applicable and reference documents are the following:

- AD doc concerning the available volumes inside the MSS: AD24
- AD doc concerning the volume and interfaces of the opto-mech: AD18 and AD24
- RD docs (MAIT/AIV plans) concerning the procedures for the installation in the various locations: RD5 and RD6

### **5.7.2 Deliverables**

Phase 1: executive drawings, step files and detailed and comprehensive procedure for the LGSO installation/dis-installation in the various locations

Phase 2: HT manufactured, test report, user and maintenance manual, storage box.

### **5.7.3 Additional information: LGSO HT suggested design**



### 5.7.3.1 Description

Due to the shape of the LGSO, whose mechanical structure is equipped with 4 eye-bolts, this handling is basically 4 chains connected to the hook of the crane. The length of the chains must be tuned in order to keep the system balanced.

This handling is only needed to lower the LGSO on the rails of SM0-HT-PFH\_BENCH, or to lift it up from the rails, in case of extraordinary maintenance.

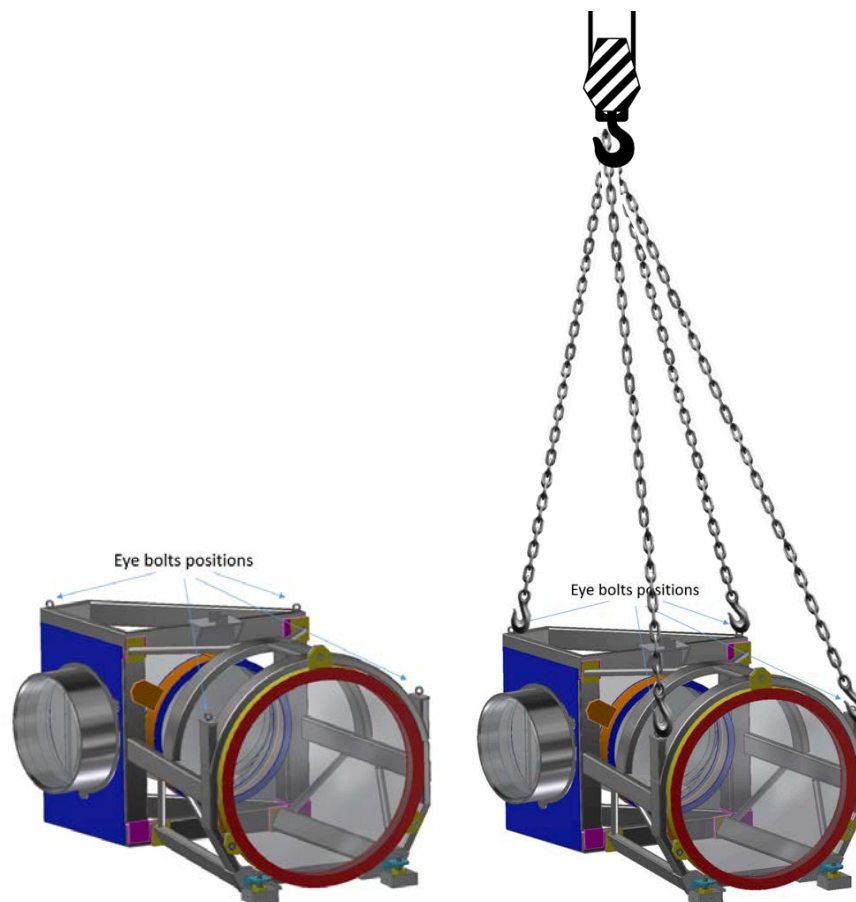


Figure 36: handling for lowering the LGSO

### 5.7.3.2 Way to be operated/procedure

The SM0-HT-PFH\_CRANE must be operated in the following way:

- The cover of the LGSO must be installed
- The length of the chains shall be tuned to keep the system balanced



- A minimum of 1 person + the crane operator are necessary for the SM0-HT-PFH\_CRANE handling/movement

### 5.7.3.3 Special tools needed

Normal mechanical workshop tools.

### 5.7.3.4 AIT phase when needed

The SM0-HT-PFH\_CRANE is needed for the assembly operations in Bologna and in Chile and for maintenance in Chile.

### 5.7.3.5 Deliverable and lifetime

The SM0-HT-PFH\_CRANE is a deliverable to Chile, where it has to be stored to be used for extraordinary maintenance and its lifetime shall be equivalent, or larger, than the MORFEO lifetime.

### 5.7.3.6 Hazard and Safety issues

The SM0-HT-PFH\_CRANE must be operated in the following way:

- A minimum of 1 person + the crane operator are necessary for the SM0-HT-PFG\_BENCH handling/movement
- Operators shall wear the helmet, safety gloves and safety shoes

No Major Hazards have been identified, but LGSO damages in case of mis-handling

## 5.8 M12M Assembly and maintenance HT (SM0-PFF\_HT)

### 5.8.1 Purpose and functionality: M12M HT Technical Specifications

The SM0-PFF\_HT has the purpose to install M12M on its interfaces. The HT shall possibly be the same in all the locations where it will be used (BIH, Entrance Hall, IAA, Nasmyth platform). Should this not be possible, an additional HT shall be designed for that purpose.

The M12M will be represented through a 3D volume characterized by a weight, a centre of mass and defined interfaces toward the HT and the MSS. After the installation of the M12M, the HT has to be removed and safely stored.

Since it will be used in a seismic area, the design must consider a load increased according to what specified in AD1. Since the HTs that will be used for all the foreseen locations/operating scenarios, the most stringent driving load shall be applied. Should this



not be possible, the HTs shall be designed according to the driving load specific indications for the location where it will be used.

All the general requirements described in Sec. 4 “HANDLING TOOLS” are applicable.

Applicable and reference documents are the following:

- AD doc concerning the available volumes inside the MSS: AD24
- AD doc concerning the volume and interfaces of the opto-mech: AD13 and AD24
- RD docs (MAIT/AIV plans) concerning the procedures for the installation in the various locations: RD5 and RD6

### **5.8.2 Deliverables**

Phase 1: executive drawings, step files and detailed and comprehensive procedure for the M12M installation/dis-installation in the various locations

Phase 2: HT manufactured, test report, user and maintenance manual, storage box.

### **5.8.3 Additional information: M12M HT suggested design**

#### **5.8.3.1 Description**

Due to the shape of the M12M, whose mechanical structure is equipped with 3 eye-bolts, this handling is basically 3 chains connected to the hook of the crane. The length of the chains must be tuned in order to keep the system balanced.

This handling is only needed to lower the M12M on its interfaces on the supporting structure installed above MICADO, or to lift it up from the same location in case of maintenance.

Figure 37: handling for lowering M12M

#### **5.8.3.2 Way to be operated/procedure**

The SM0-HT-PFF must be operated in the following way:

- The cover of the M12M must be installed
- The length of the chains shall be tuned to keep the system balanced



- A minimum of 1 person + the crane operator are necessary for the SM0-HT-PFF handling/movement

### 5.8.3.3 Special tools needed

Normal mechanical workshop tools.

### 5.8.3.4 AIT phase when needed

The SM0-HT-PFF is needed for the assembly operations in Bologna and in Chile and for maintenance in Chile.

### 5.8.3.5 Deliverable and lifetime

The SM0-HT-PFF is a deliverable to Chile, where it has to be stored to be used for extraordinary maintenance and its lifetime shall be equivalent, or larger, than the MORFEO lifetime.

### 5.8.3.6 Hazard and Safety issues

The SM0-HT-PFF must be operated in the following way:

- A minimum of 1 person + the crane operator are necessary for the SM0-HT-PFF handling/movement
- Operators shall wear the helmet, safety gloves and safety shoes

No Major Hazards have been identified, but M12M damages in case of mis-handling

## 5.9 CUFM Assembly and maintenance HT (SM0-HT-XXX)

### 5.9.1 Purpose and functionality: CUFM HT Technical Specifications

The SM0-HT-XXX has the purpose to install CUFM on its interfaces. The HT shall possibly be the same in all the locations where it will be used (BIH, Entrance Hall, IAA, Nasmyth platform). Should this not be possible, an additional HT shall be designed for that purpose.

The CUFM will be represented through a 3D volume characterized by a weight, a centre of mass and defined interfaces toward the HT and the MSS. After the installation of the CUFM, the HT has to be removed and safely stored.

Since it will be used in a seismic area, the design must consider a load increased according to what specified in AD1. Since the HTs that will be used for all the foreseen locations/operating scenarios, the most stringent driving load shall be applied. Should this not be possible, the HTs shall be designed according to the driving load specific indications for the location where it will be used.



All the general requirements described in Sec. 4 “HANDLING TOOLS” are applicable.

Applicable and reference documents are the following:

- AD doc concerning the available volumes inside the MSS: AD24
- AD doc concerning the volume and interfaces of the opto-mech: AD17 and AD24
- RD docs (MAIT/AIV plans) concerning the procedures for the installation in the various locations: RD5 and RD6

### **5.9.2 Deliverables**

Phase 1: executive drawings, step files and detailed and comprehensive procedure for the CUFM installation/dis-installation in the various locations

Phase 2: HT manufactured, test report, user and maintenance manual, storage box.

### **5.9.3 Additional information: CUFM HT suggested design**

#### **5.9.3.1 Description**

Due to the shape of the CUFM, whose mechanical structure is equipped with 3 eye-bolts, this handling is basically 3 chains connected to the hook of the crane. The length of the chains must be tuned in order to keep the system balanced.

This handling is only needed to lower the CUFM on its interfaces on the supporting structure installed on the CU selector, or to lift it up from the same location in case of maintenance.

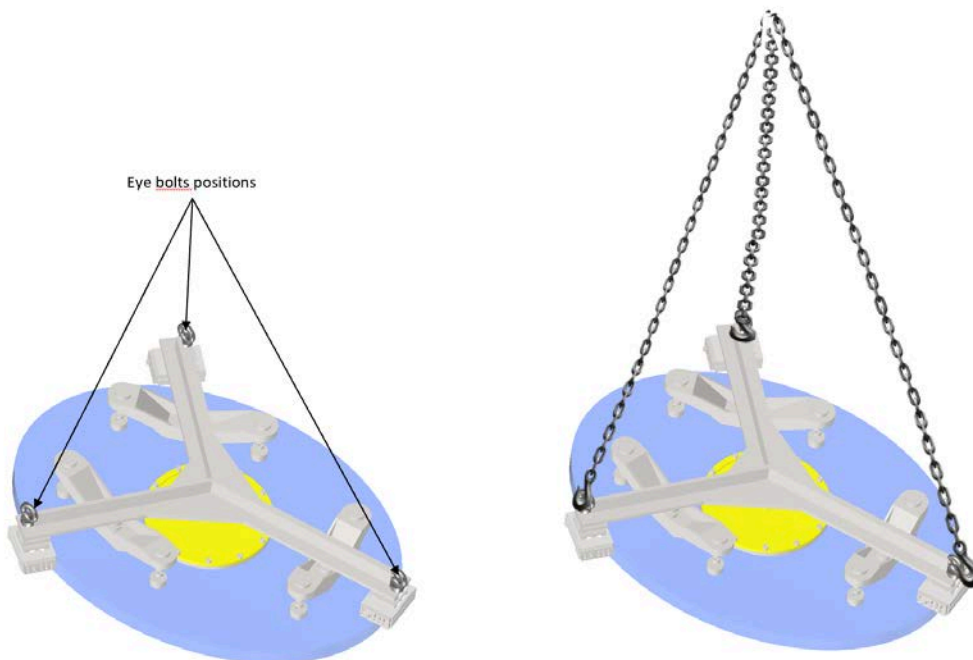


Figure 38: handling for lowering the CUFM

### 5.9.3.2 Way to be operated/procedure

The **SM0-HT-XXX** must be operated in the following way:

- The cover of the CUFM must be installed
- The length of the chains shall be tuned to keep the system balanced
- A minimum of 1 person + the crane operator are necessary for the **SM0-HT-XXX** handling/movement

### 5.9.3.3 Special tools needed

Normal mechanical workshop tools.

### 5.9.3.4 AIT phase when needed

The **SM0-HT-XXX** is needed for the assembly operations in Bologna and in Chile and for maintenance in Chile.



### 5.9.3.5 Deliverable and lifetime

The **SM0-HT-XXX** is a deliverable to Chile, where it has to be stored to be used for extraordinary maintenance and its lifetime shall be equivalent, or larger, than the MORFEO lifetime.

### 5.9.3.6 Hazard and Safety issues

The **SM0-HT-XXX** must be operated in the following way:

- A minimum of 1 person + the crane operator are necessary for the **SM0-HT-XXX** handling/movement
- Operators shall wear the helmet, safety gloves and safety shoes

No Major Hazards have been identified, but CUFM damages in case of mis-handling



## 6. Support Equipment

In this section, we describe all the Support Equipment (SEq) needed for the AIT operations. For every SEq listed, all the relevant information should be reported, such as:

- purpose and functionality
- manufacturing
- description
- way to be operated
- special tools needed
- AIT phase when needed (handling during assembly or necessary for integration or testing or packaging or storage)
- Drawings and/or photos
- Deliverable to Bologna and/or to Chile
- Hazard and Safety issues worth to be underlined

We recall that every support equipment must be listed in the BoM and in the RAMS documents, which have to be referenced for all the issues concerning the Safety and Hazard. A reference directly here for all the support equipment is ok, even if we strongly suggest to recall the main safety and hazard issues related to each Seq also in the correspondent sub-sections describing them, as shown in sec. 5.1.3.6.

All the support equipment which has to be used with a crane and for moving equipment around shall have the CE certification.

Table gives a complete overview of all Handling Tools in the univocal device code that are needed during the system AIT



Table 2: list of SEq for MORFEO AIT/V operations

Support Equipment Device code	Description	Notes
SM0-HT-PFG_BE NCH	LGS Fold Mirror 1 Assembly and Maintenance Handling Tool to make the mirror sliding into the MSS and to finely position it against its interface points on MSS.	Helmet and safety shoes required
SM0-HT-PFH_BE NCH	LGS-Objective Assembly and Maintenance Handling Tool to make it sliding into the MSS and to finely position it against its interface points on MSS.	Helmet and safety shoes required
SM0-PU0_HT-2	CU Assembly and Maintenance Handling Tool to make the CU sliding into the MSS and to finely position it against its interface points on MSS.	Helmet and safety shoes required
Access ladder to MCA platform	Ladder to access the working platform in front of the MCA	Anti-fall protection
Access ladder to selector platform	Ladder to access the working platform in front of the Corrective Plate front side	Anti-fall protection
Ladder+rail system to Calibration Unit left side	Ladders and platforms for operators installing the Calibration Unit. This SEq. provides also support to the CU installation rails protruding out of the MSS.	Anti-fall protection
Ladder to Calibration Unit right side	Ladder to access the working platform on the right side of the Calibration Unit, once installed.	Anti-fall protection
Ladder to Tower Duct front side	Ladder to access the fixation points of the tower duct	Anti-fall protection



## General requirements

### MAO-SM0-1.2: Support Equipments General Requirements

Deviation to the following requirements shall be discussed and agreed with the MORFEO consortium.

**MAO-SM0-1.2.1.** Will be used in a seismic area, the design must consider a load increased according to what specified in AD1. Since the SEqs will be used for all the foreseen locations/operating scenarios, the most stringent driving load shall be applied. Should this not be possible, the SEqs shall be designed according to the driving load specific indications for the location where it will be used.

**MAO-SM0-1.2.2.** Ladder shall be rated for a single operator + earthquake safety factor for AIT procedures.

**MAO-SM0-1.2.3.** The ladder installation process must be designed to ensure the safety of the installer and minimize any potential risks and installation/disinstallation time. A possible concept of interface connection to the MMS is depicted in Figure 22.

**MAO-SM0-1.2.4.** The rails installation process must be designed to ensure safety of the installer and minimize any potential risk and installation/disinstallation time. The rails shall provide safety mechanism for the hardware installed (e.g., mechanical hard stops) also in case of earthquake.

**MAO-SM0-1.2.5.** The SEqs shall comply with all requirements in AD1 and a compliance and verification matrix shall be produced. Non applicable requirements must be marked as NA.

**MAO-SM0-1.2.6.** The Support Equipments that will interface to the telescope Nasmyth platform shall comply with all requirements in AD2 and a compliance and verification matrix shall be produced. Non applicable requirements must be marked as NA.

**MAO-SM0-1.2.7.** All the SEq. shall comply with italian and chilean regulations

**MAO-SM0-1.2.8.** The SEq. shall be used at all MORFEO nodes, thus their installation procedures shall be compatible with the environmental/volume constraints at all the locations

**MAO-SM0-1.2.9.** SEq. modularity/sectioning is acceptable, if modularity does not compromise the other requirements. Depending on the operating scenario (most probably just in the BIH), sectioning of some SEq might be mandatory, to allow its installation on the bench.

**MAO-SM0-1.2.10.** The lifetime of all the SEq shall be equivalent, or larger, than the MORFEO lifetime

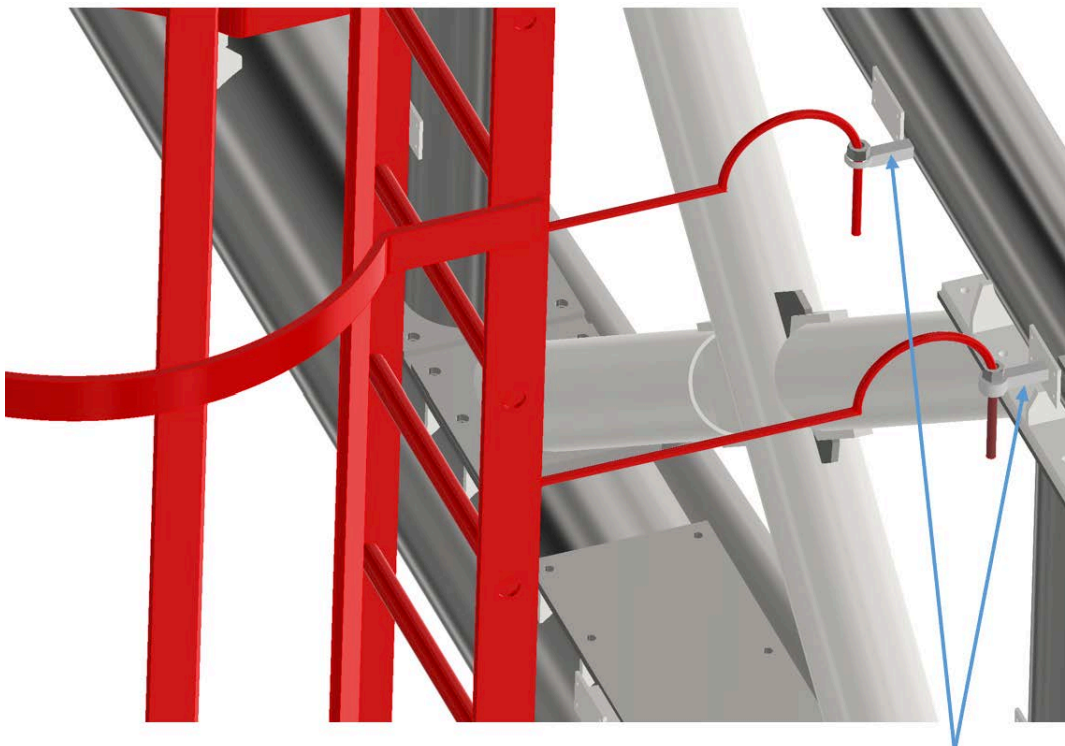


**MAO-SM0-1.2.11.** All the SEq shall be certified as defined in AD25 that is valid for at least 1 year from the time it is delivered to ESO

**MAO-SM0-1.2.12.** All the SEq shall comply with AD26

**MAO-SM0-1.2.13.** All the Support Equipments that will be handled using a crane shall foresee connection eyebolts. Their position shall be identified in a way to have the support equipment balanced. A possible concept for the eyebolts positioning is depicted in Sec. 6.7.

**MAO-SM0-1.2.14.** All the SEq shall be installed/dis-installed within 30 minutes.



Ladder connection points on MSS

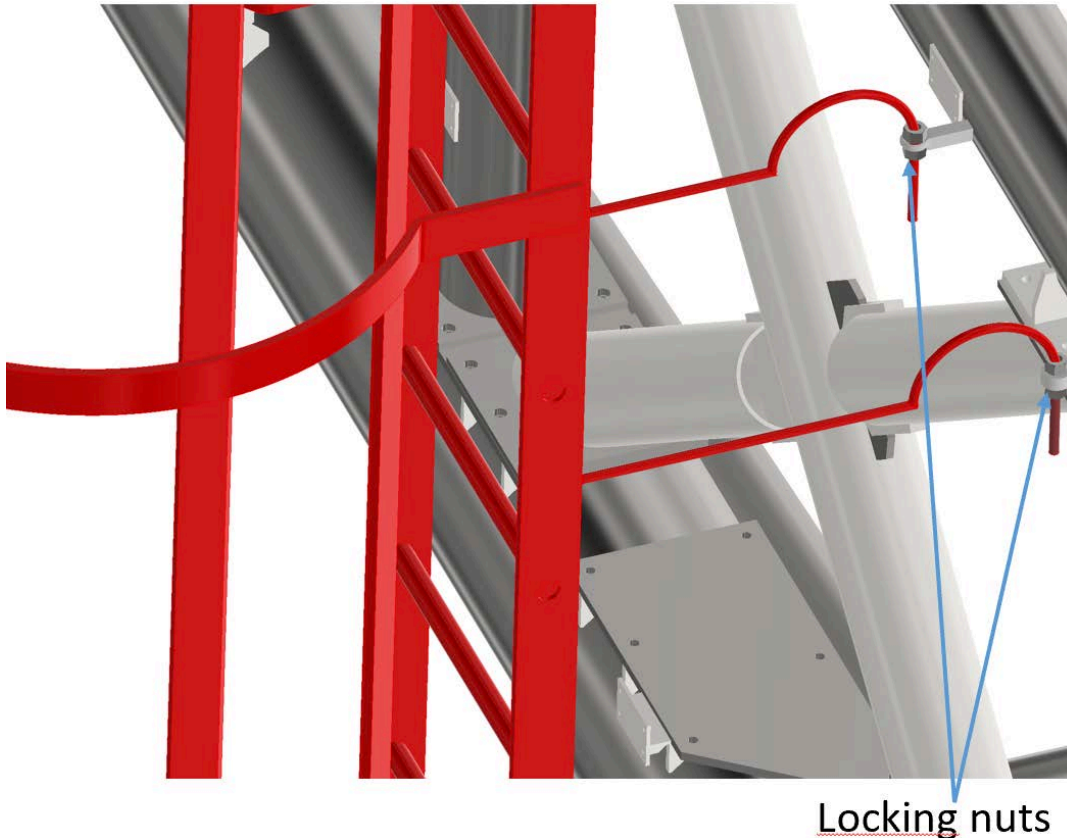


Figure 39: proposed concept to interface ladders to MSS

## 6.1 Access ladder to MCA platform

### 6.1.1 Purpose and functionality: SEq technical specifications

The purpose of this system is to allow an operator on the ground to safely access the working platform located in front of the MCA.

### 6.1.2 Deliverables

Phase 1: executive drawings, step files and detailed and comprehensive procedure for SEq installation/dis-installation in the various locations

Phase 2: SEq manufactured, test report, safety data files, user and maintenance manual, storage/shipment box

### 6.1.3 Additional information: “Access ladder to MCA platform” suggested design

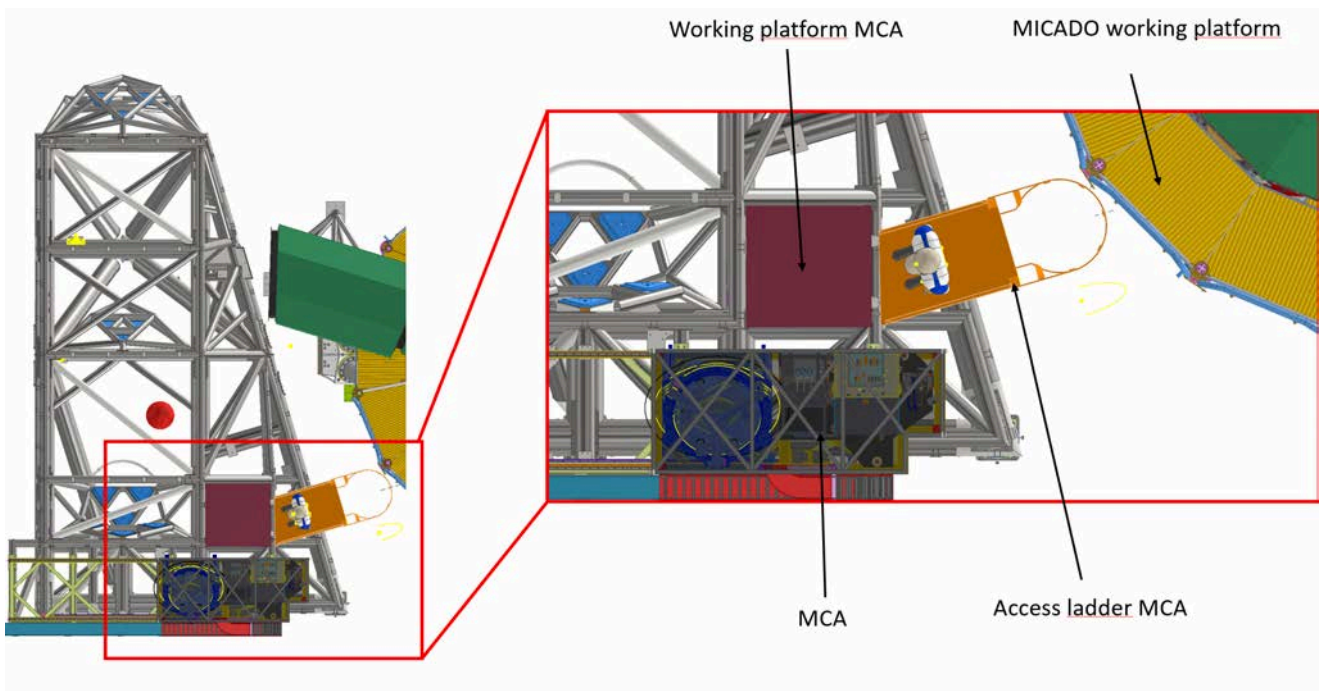
#### 6.1.3.1 Description

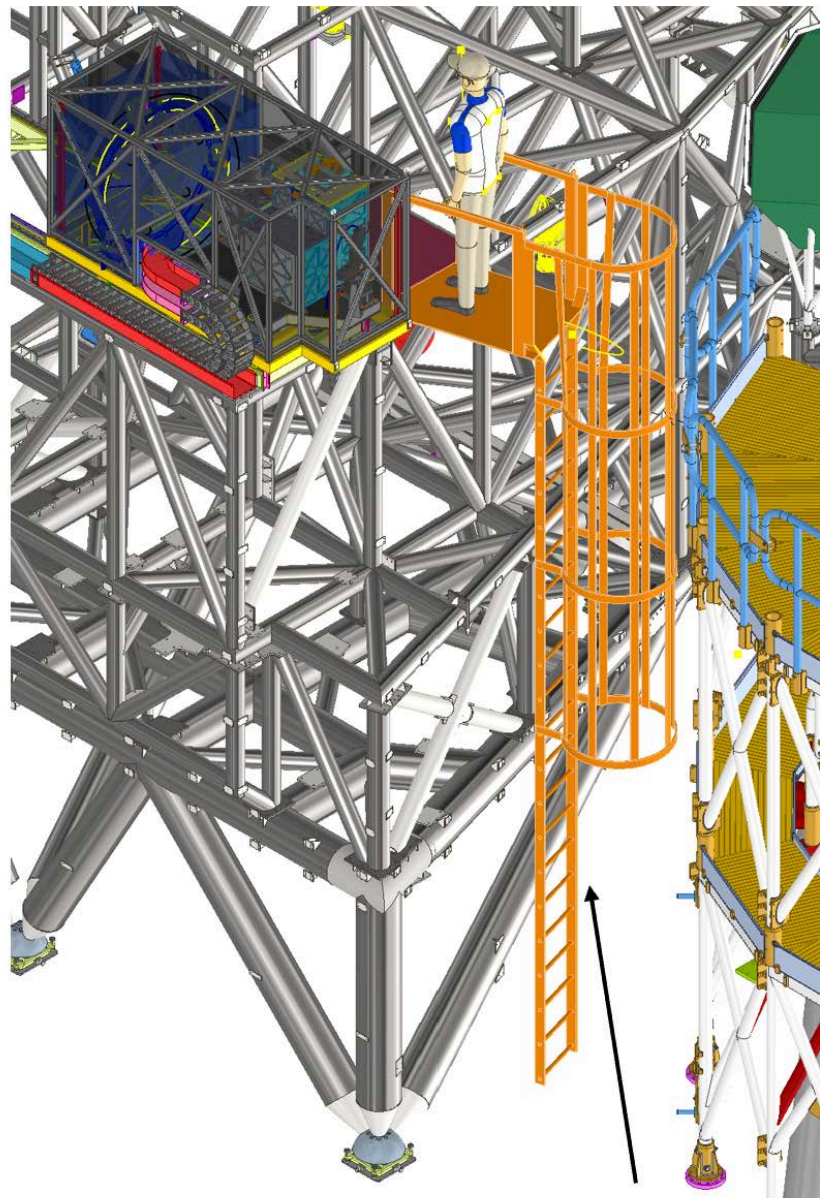
A possible concept of the access ladder to the MCA platform is shown in Figure 41.



It is a standard ladder with safety cage and a platform fitted with handrails, allowing safe transfer to the instrument's working platform. The ladder shall be installed (and removed) whenever it is needed within a reasonable time (e.g., 15min), most probably using a crane. If needed, the ladder can have a modular design. If the operator cannot directly access the MCA platform from the top of the ladder, the ladder system must include an intermediate platform with handrails to allow safe transition to the MCA platform.

Merging of this SEq with the access ladder to the Tower Duct front side (see Section 2.5) with modification that does not change the purpose and functionality of this SEq. can be considered by the Consortium as an option, even using a modular approach for the SEq.





Access ladder MCA

Figure 40: a view of a possible concept for the access ladder to the MCA platform (in orange)



### **6.1.3.2 Manufacturing**

The ladder can be an off-the-shelf ladder, whether a suitable ladder is available on the market, or a modified version of an off-the-shelf ladder, or a custom-made ladder.

### **6.1.3.3 AIT phase when needed**

This ladder is required for MCA dummy installation/removal in BIH, for MCA installation in IAA and for MCA maintenance procedures in Nasmyth. It shall be available the first time in the MSS manufacturer premises for interface and functional test with MSS.

### **6.1.3.4 Deliverable and lifetime**

The ladder is a deliverable to all the nodes and its lifetime shall be equivalent, or larger, than the MORFEO lifetime.

### **6.1.3.5 Hazard and Safety issues**

The ladder must allow the operator to safely access the area in front of the MCA, incorporating appropriate fall protection devices in compliance with ESO/Chile and EU regulations. The ladder shall ensure the operator's safe transfer onto the working platform. The working platform (if part of the SEq.) shall provide a safe working space for the operators, in compliance with ESO/Chile and EU regulations. Exceptions shall be evaluated by the Consortium and agreed with ESO.

### **6.1.3.6 Special tools needed**

For its installation and removal eyebolts or straps can be used. Different tools can be evaluated. The ladder is fixed using captive screws.

### **6.1.3.7 Way to be operated**

It shall be properly and safely secured to its interface points on MORFEO and ground. Its installation to interface points shall be performed in a simple and safe way for the operator. Its installation shall be as much compatible as possible with the thermal cover of MORFEO, i.e., shall minimize the surface of thermal cover to be removed and, ideally, shall not require any dis-installation of the thermal cover. An operator climbs up to the MCA platform, always secured to the fall protection device, when required.

## **6.2 Access ladder to selector platform**

### **6.2.1 Purpose and functionality**

The purpose of this system is to allow an operator on the ground to safely access the working platform (part of the MSS) located in the selector support frame.

### **6.2.2 Deliverables**

Phase 1: executive drawings, step files and detailed and comprehensive procedure for SEq installation/dis-installation in the various locations.

Phase 2: SEq manufactured, test report, safety data files, user and maintenance manual, storage/shipment box.



## 6.2.3 Additional information: “Access ladder to selector platform” suggested design

### 6.2.3.1 Description

A possible concept of the access ladder to the MCA platform is shown in Figure 41.

It is a standard ladder with safety cage and a platform fitted with handrails, allowing safe transfer to the instrument’s working platform. The ladder shall be installed (and removed) whenever it is needed within a reasonable time (e.g., 15min), most probably using a crane. If needed, the ladder can have a modular design. If the operator cannot directly access the working platform from the top of the ladder, the ladder system must include an intermediate platform with handrails to allow safe transition to the working platform.

Merging of this SEq with the access ladder to CU right side (see Section 2.4) with modification that does not change the purpose and functionality of this SEq. can be considered by the Consortium, even using a modular approach for the SEq.

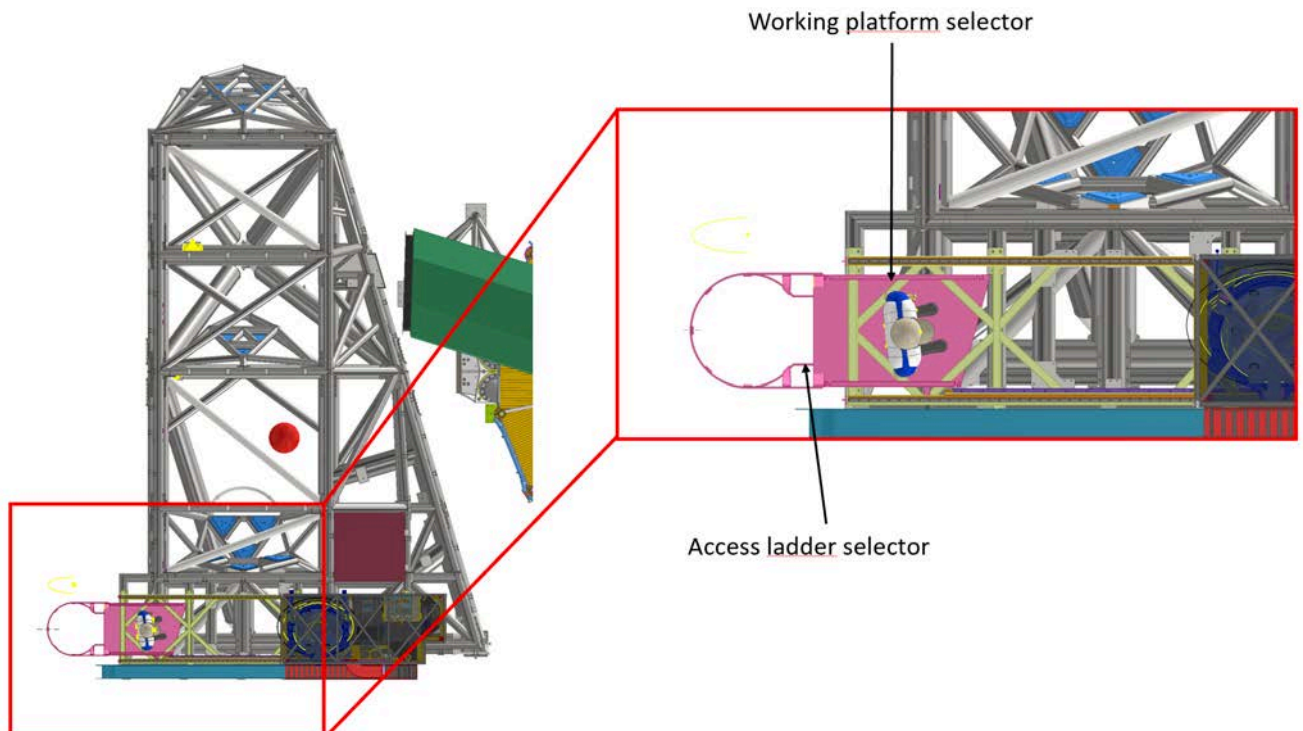


Figure 41: a view of a possible concept for the access ladder (in pink) to the selector platform



### **6.2.3.2 Manufacturing**

The ladder can be an off-the-shelf ladder, whether a suitable ladder is available on the market, or a modified version of an off-the-shelf ladder, or a custom-made ladder.

### **6.2.3.3 AIT phase when needed**

The ladder is required for CUFM installation in BIH, for CUFM re-installation in IAA and for CUFM maintenance procedures in Nasmyth. It shall be available the first time in the MSS manufacturer premises for interface test. It is also needed to reach the Corrective Plate external surface for cleaning

### **6.2.3.4 Deliverable and lifetime**

The ladder is a deliverable to all the nodes and its lifetime shall be equivalent, or larger, than the MORFEO lifetime.

### **6.2.3.5 Hazard and Safety issues**

The ladder must allow the operator to safely access the selector platform, incorporating appropriate fall protection devices in compliance with ESO and EU regulations. The ladder shall ensure the operator's safe transfer onto the working platform. The working platform (if part of the SEq.) shall provide a safe working space for the operators, in compliance with ESO and EU regulations. Exceptions shall be evaluated by the Consortium and agreed with ESO. Earthquake safety factors shall be considered.

### **6.2.3.6 Special tools needed**

For its installation and removal eyebolts or straps can be used. Different tools can be evaluated. The ladder is fixed using captive screws

### **6.2.3.7 Way to be operated**

Its installation shall be as much compatible as possible with the thermal cover of MORFEO, i.e., shall minimize the surface of thermal cover to be removed and, ideally, shall not require any dis-installation of the thermal cover. An operator climbs up to the selector platform, always secured to fall protection device

## **6.3 Ladder+rail system to Calibration Unit left side**

### **6.3.1 Purpose and functionality**

The purpose of this system is to allow two operators on the ground to safely access the platforms located at a proper height to allow them to push the Calibration Unit into the MORFEO Main Structure. Additionally, this system provides support to the Calibration Unit extension rails, which are part of this SEq. Length of the extension rails depends on the length of the permanent rails in the MORFEO Support Structure, and shall allow a full extraction of the CU from the MSS, enabling vertical extraction of the CU with no additional manouvers. When the Calibration Unit is out of reach for the operators on the platforms, an additional ladder module can be added to this SEq, allowing a single



operator to safely reach the CU left (MICADO side) platform inside the MSS. This additional ladder can be a separate SEq., if the modular approach is not viable.

### **6.3.2 Deliverables**

Phase 1: executive drawings, step files and detailed and comprehensive procedure for SEq installation/dis-installation in the various locations.

Phase 2: SEq manufactured, test report, safety data files, user and maintenance manual, storage/shipment box.

### **6.3.3 Additional information: “Access ladder+ rail system to Calibration Unit left side” suggested design**

#### **6.3.3.1 Description**

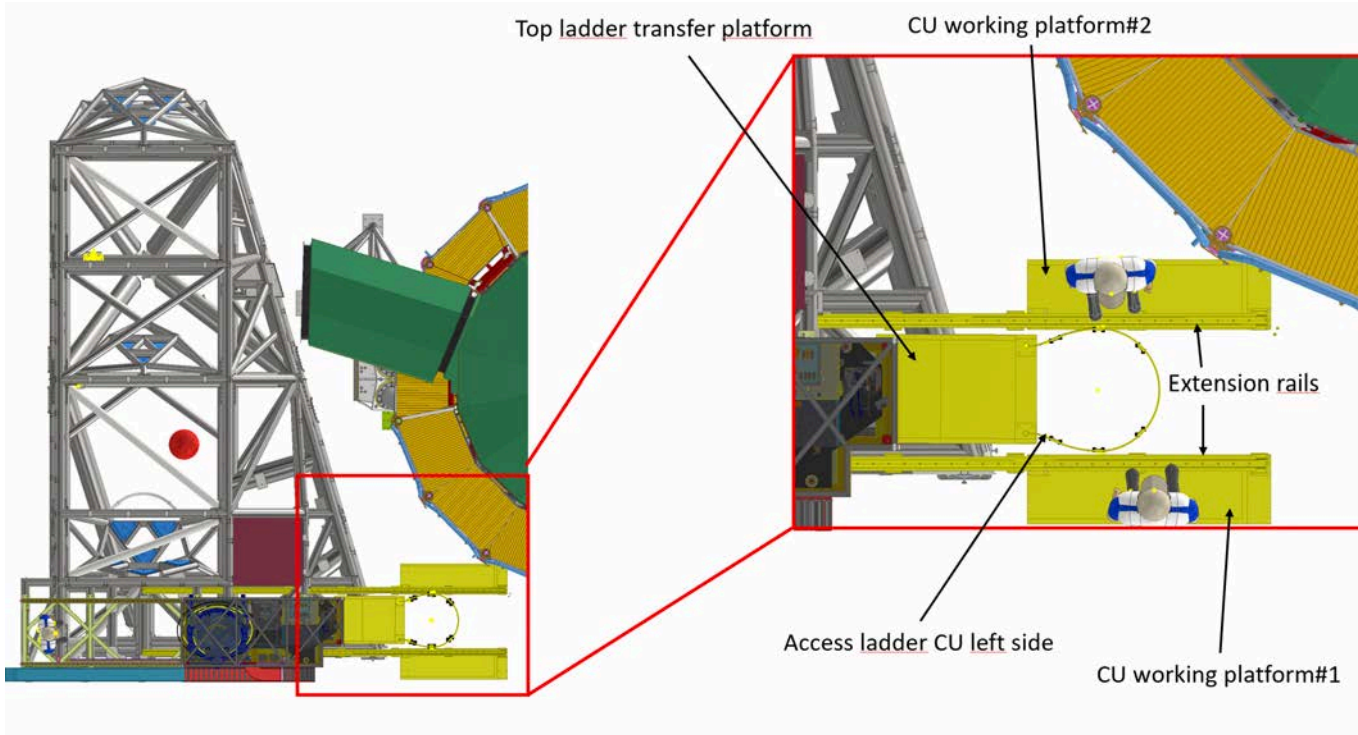
A possible concept of this SEq. is shown in Figure 42, Figure 43 and Figure 44.

The bottom ladder + platforms shall be installed (and removed) whenever it is needed within a reasonable time (e.g., 1hr), using a crane. The additional ladder module can require up to additional 30min. for installation. The installation process must be designed to ensure the safety of the installer and eliminate any potential risks. If needed, the bottom ladder+platforms can have a modular design.

Ladders and single platforms shall be rated for a single operator + earthquake safety factor for AIT procedures. The maximum load exerted on the ground by the ladders and platforms must be assessed and shall comply with the ESO requirements for additional connection point to the Nasmyth platform, if connection to the Nasmyth platform is required. This load shall be provided in the following cases:

- Bottom ladders + two platforms + top ladder + two operators (80Kg) on the platforms
- Bottom ladders + two platforms + extension rails + two operators (80kg) on the platforms + CU lying on the extension rails

Its dimensions shall fit in the applicable volumes (BIH, IAA; Nasmyth), and its installation procedure shall be compatible with the environmental/volume constraints at all the locations.



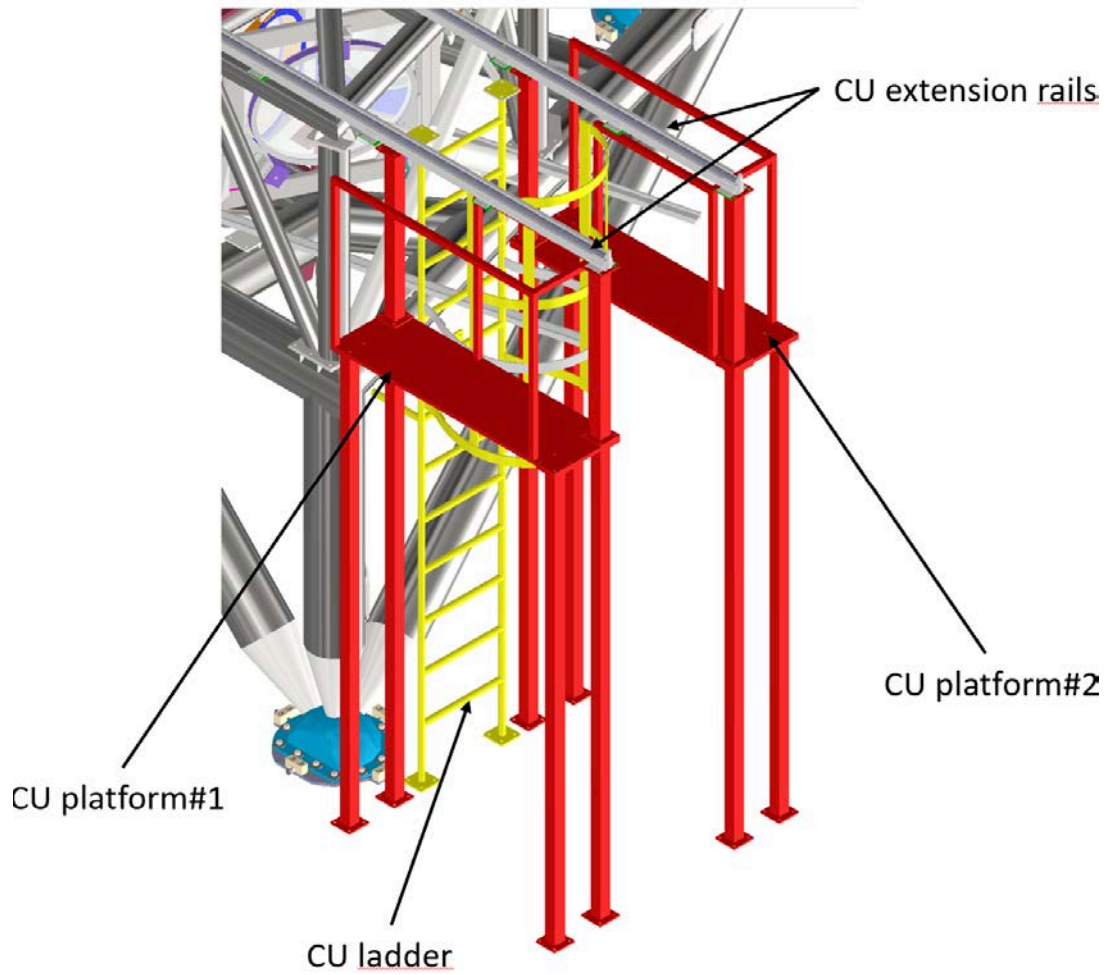




Figure 42: a view of a possible concept for the CU ladder and platforms

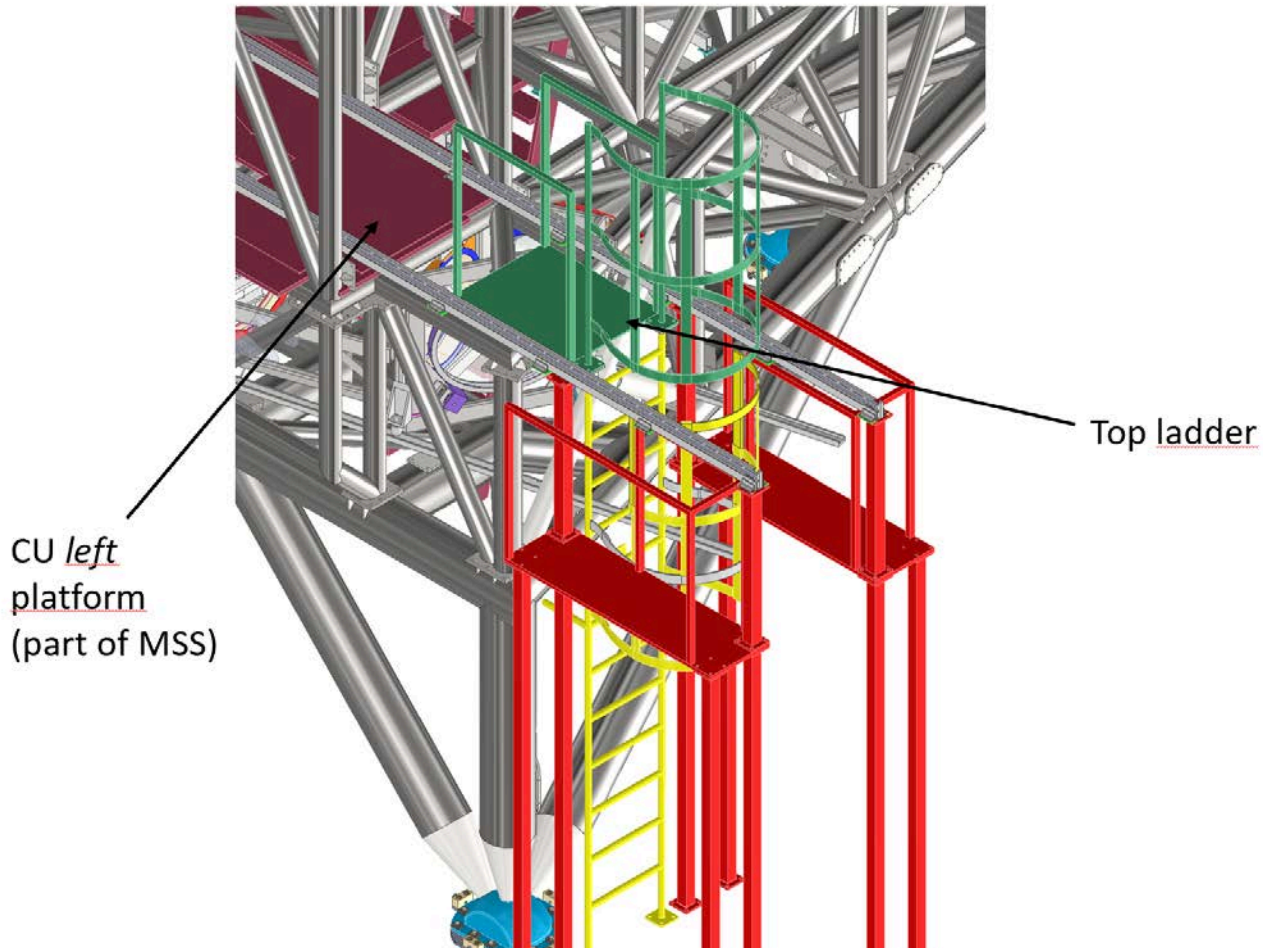


Figure 43: a view of a possible concept for the CU top ladder (in green)

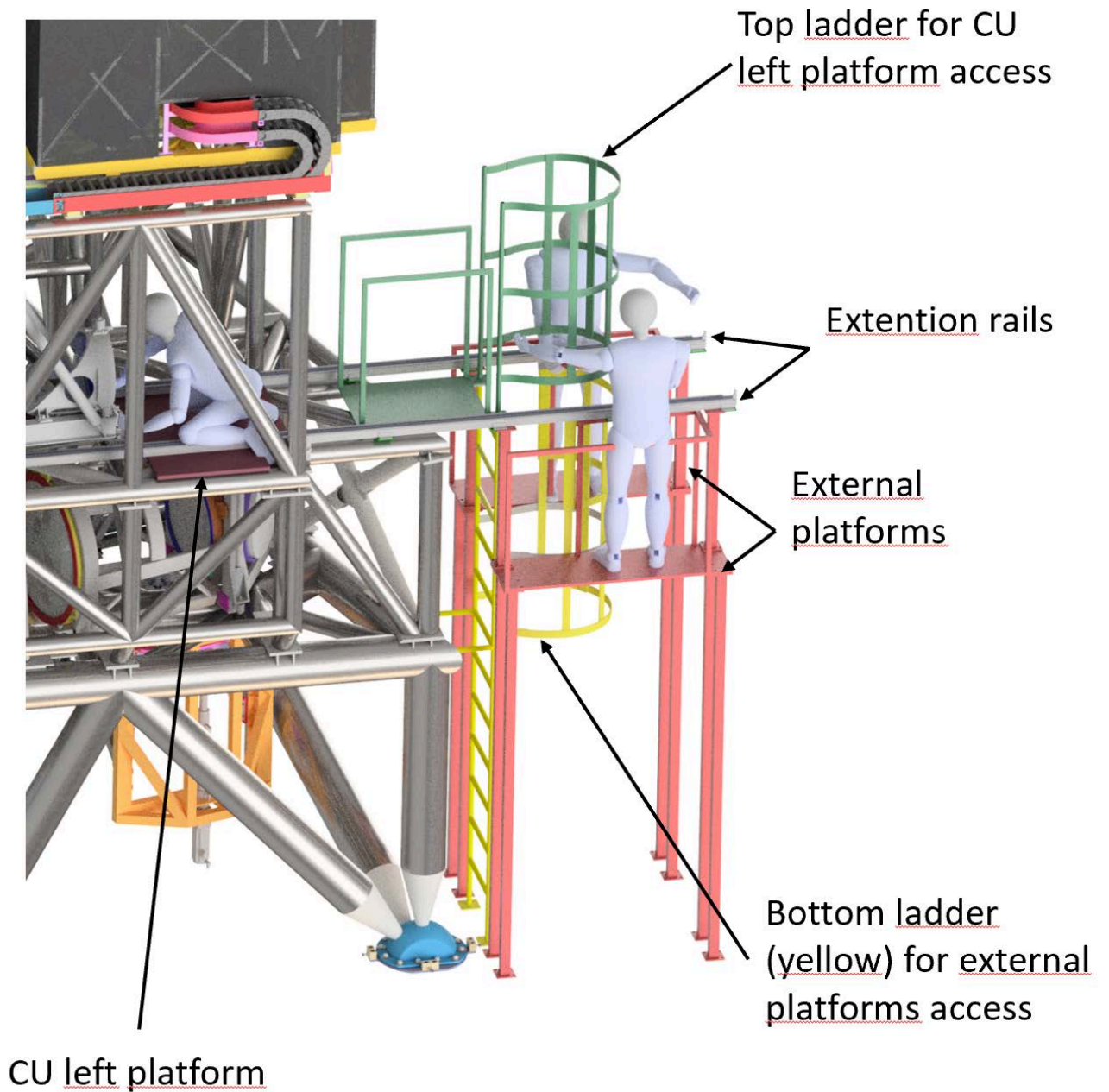


Figure 44: overview of the full SEq.



### **6.3.3.2 Manufacturing**

The ladder can be an off-the-shelf ladder, whether a suitable ladder is available on the market, or a modified version of an off-the-shelf ladder, or a custom-made ladder. Same for the platforms. If possible, ladder+platforms can be installed as a single system, as they will always be used together. The additional ladder module shall be separate, if its presence interferes with the initial sliding of the CU. Same concept applies to the extension rails part of this SEq.

### **6.3.3.3 AIT phase when needed**

The ladders and platforms are required for CU installation in BIH, for CU re-installation in IAA and for CU maintenance procedures in Nasmyth. It shall be available the first time in the MSS manufacturer premises for interface test.

### **6.3.3.4 Deliverable and lifetime**

The ladders and platforms are a deliverable to all the nodes and their lifetime shall be equivalent, or larger, than the MORFEO lifetime.

### **6.3.3.5 Hazard and Safety issues**

The ladders must allow the operator to safely access the working platforms, incorporating appropriate fall protection devices in compliance with ESO and EU regulations. The platforms shall provide a safe working space for the operators, in compliance with ESO and EU regulations. Exceptions shall be evaluated by the Consortium and agreed with ESO. Earthquake safety factors shall be considered. The ladder shall ensure the operator's safe transfer onto the working platform. Earthquake safety factors shall be considered.

### **6.3.3.6 Special tools needed**

For its installation and removal eyebolts or straps can be used. Different tools can be evaluated. The ladders and platforms are fixed using captive screws

### **6.3.3.7 Way to be operated**

First the bottom ladder and platforms are secured to the interface points on MORFEO and ground. An operator climbs up to the CU platform#1, always secured to fall protection device, if needed. A second operator climbs up on CU platform#2. When both the operators are on the platforms they shall install the extension rails on the interface points (if not already installed, to be defined with the SEq. design) and push the CU to make it slide into MSS. Finally the two operators shall remove the extension rails and install the additional ladder module to reach the CU platform inside the MSS.

Its installation shall be as much compatible as possible with the thermal cover of MORFEO, i.e., shall minimize the surface of thermal cover to be removed.



## **6.4 Ladder to Calibration Unit right side**

### **6.4.1 Purpose and functionality**

The purpose of this system is to allow an operator on the ground to safely access the working platform (part of the MSS) located on the right side of the CU. If for mass reasons, or other reasons, the working platform cannot be part of the MSS, the platform shall be part of the ladder system.

### **6.4.2 Deliverables**

Phase 1: executive drawings, step files and detailed and comprehensive procedure for SEq installation/dis-installation in the various locations.

Phase 2: SEq manufactured, test report, safety data files, user and maintenance manual, storage/shipment box.

### **6.4.3 Additional information: “Access ladder to Calibration Unit right side” suggested design**

#### **6.4.3.1 Description**

A possible concept of the access ladder to the CU right side platform is shown in Figure 45.

It is a standard ladder with safety cage and a platform fitted with handrails, allowing safe transfer to the instrument’s working platform. The ladder shall be installed (and removed) whenever it is needed within a reasonable time (e.g., 15min), most probably using a crane. If needed, the ladder can have a modular design. If the operator cannot directly access the working platform from the top of the ladder, the ladder system must include an intermediate platform with handrails to allow safe transition to the working platform.

Merging of this SEq with the access ladder to the selector platform (see Section 2.2) with modification that does not change the purpose and functionality of this SEq. can be considered by the Consortium, even using a modular approach for the SEq.

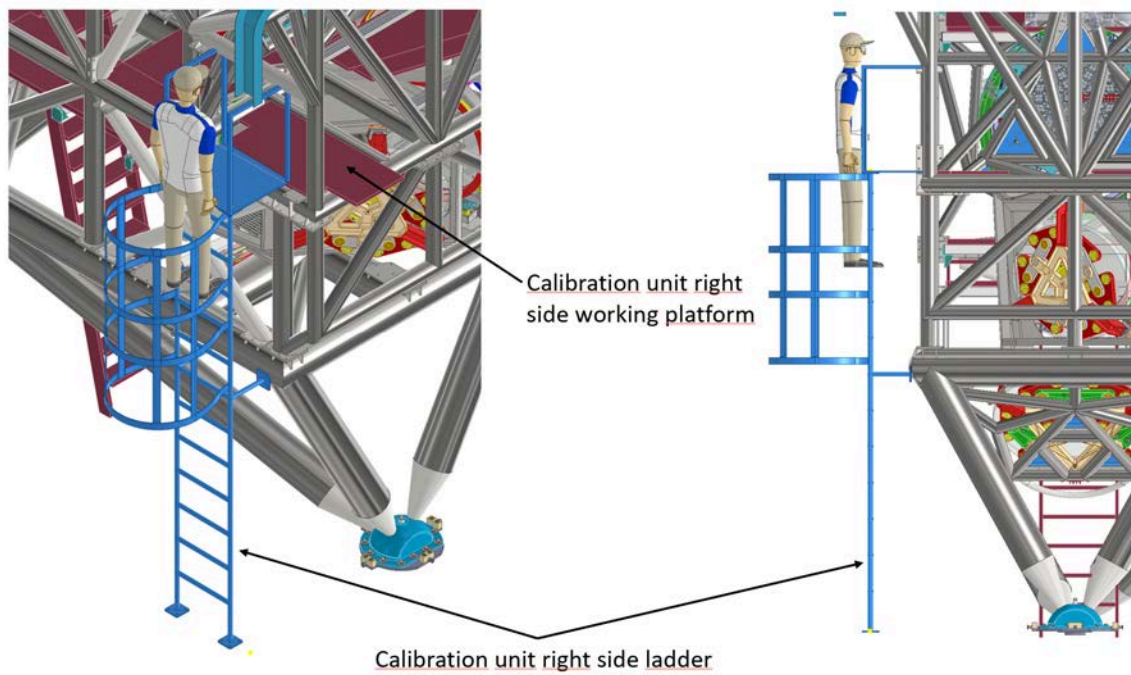
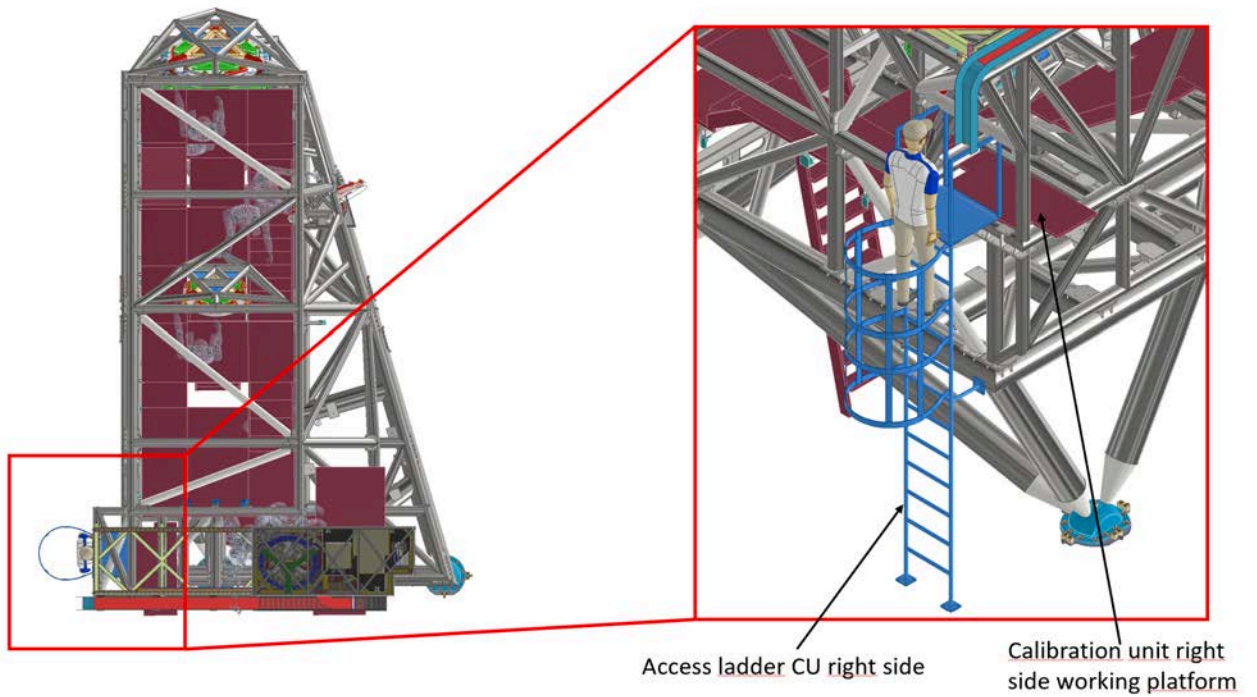


Figure 45: a view of a possible concept for the CU right side access ladder (in blue)



#### **6.4.3.2 Manufacturing**

The ladder can be an off-the-shelf ladder, whether a suitable ladder is available on the market, or a modified version of an off-the-shelf ladder, or a custom-made ladder.

#### **6.4.3.3 AIT phase when needed**

The ladder is required for CU installation in BIH, for CU re-installation in IAA and for CU maintenance procedures in Nasmyth. It shall be available the first time in the MSS manufacturer premises for interface test. It is also needed to reach the DM1 rear side for its installation/removal, after the CU has been shifted to the left side of the permanent rails.

#### **6.4.3.4 Deliverable and lifetime**

The ladder is a deliverable to all the nodes and its lifetime shall be equivalent, or larger, than the MORFEO lifetime.

#### **6.4.3.5 Hazard and Safety issues**

The ladder must allow the operator to safely access the CU right side platform, incorporating appropriate fall protection devices in compliance with ESO and EU regulations. The ladder shall ensure the operator's safe transfer onto the working platform. The working platform (if part of the SEq.) shall provide a safe working space for the operators, in compliance with ESO and EU regulations. Exceptions shall be evaluated by the Consortium and agreed with ESO. Earthquake safety factors shall be considered.

#### **6.4.3.6 Special tools needed**

For its installation and removal eyebolts or straps can be used. Different tools can be evaluated. The ladder is fixed using captive screws

#### **6.4.3.7 Way to be operated**

Its installation shall be as much compatible as possible with the thermal cover of MORFEO, i.e., shall minimize the surface of thermal cover to be removed and, ideally, shall not require any dis-installation of the thermal cover. An operator climbs up to the selector platform, always secured to fall protection device



## **6.5 Ladder to Tower Duct front side**

### **6.5.1 Purpose and functionality**

The purpose of this system is to allow an operator on the ground to safely reach the front side (Pre-Focal Station side) of the Tower Duct. The operator shall be able, from this position, to safely access the interface points between the tower duct and the MSS and MORFEO thermal cover on this side and to detach the tower duct, enabling the tower duct removal when needed (e.g., M11M installation/removal)

### **6.5.2 Deliverables**

Phase 1: executive drawings, step files and detailed and comprehensive procedure for SEq installation/dis-installation in the various locations.

Phase 2: SEq manufactured, test report, safety data files, user and maintenance manual, storage/shipment box.

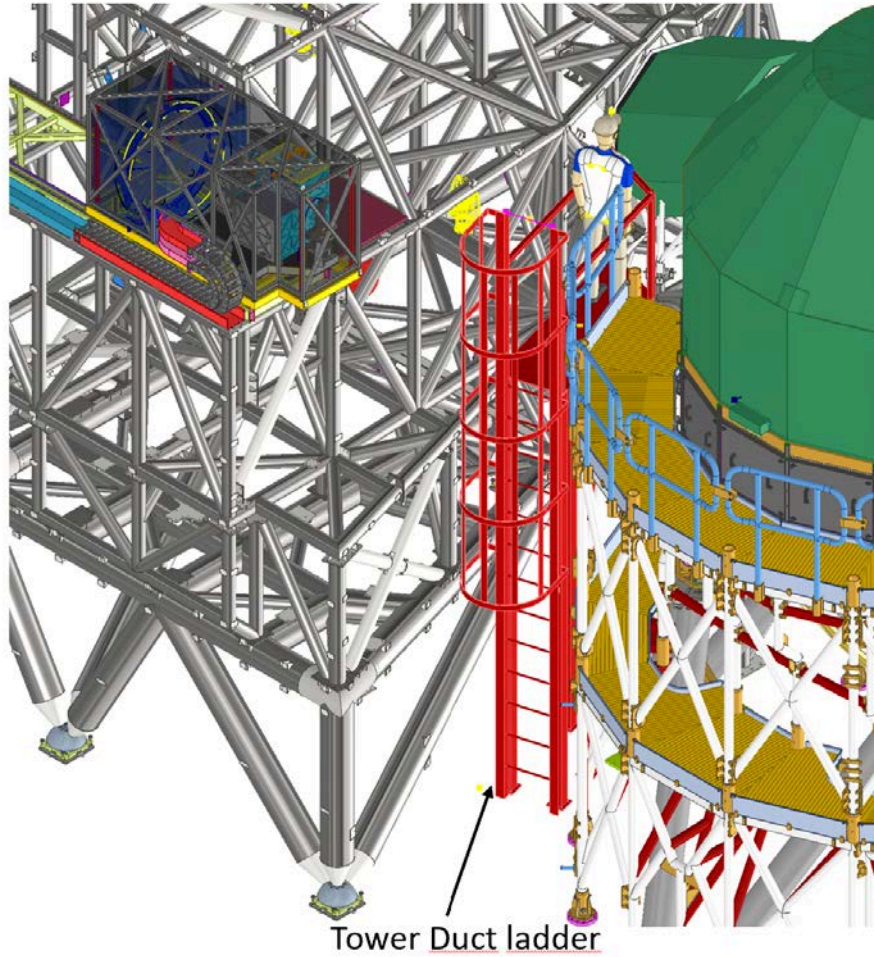
### **6.5.3 Additional information: “Access ladder to Tower Duct front side” suggested design**

#### **6.5.3.1 Description**

A possible concept of the access ladder to the Tower Duct front side is shown in Figure 46.

It is a standard ladder with safety cage and a platform fitted with handrails, allowing safe transfer to the instrument’s working platform. The ladder shall be installed (and removed) whenever it is needed within a reasonable time (e.g., 15min), most probably using a crane. If needed, the ladder can have a modular design.

Merging of this SEq with the access ladder to the MCA platform (see Section 2.1) with modification that does not change the purpose and functionality of this SEq. can be considered by the Consortium, even using a modular approach for the SEq.



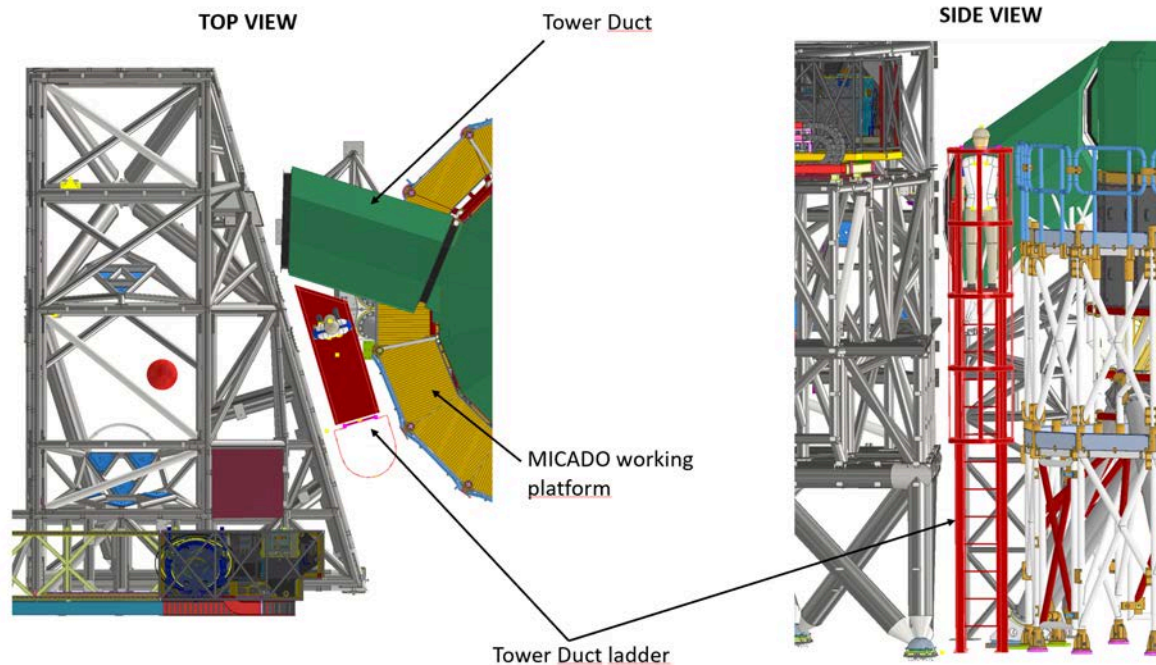


Figure 46: a view of a possible concept for the Tower Duct front side ladder (in red)

### 6.5.3.2 Manufacturing

The ladder can be an off-the-shelf ladder, whether a suitable ladder is available on the market, or a modified version of an off-the-shelf ladder, or a custom-made ladder.

### 6.5.3.3 AIT phase when needed

The ladder is required for tower duct installation/removal in BIH and in Nasmyth. Its use is NOT foreseen in IAA. It shall be available the first time in the MSS manufacturer premises for interface test. It can be also useful for installation/removal procedures of M11M.

### 6.5.3.4 Deliverable and lifetime

The ladder is a deliverable to all the nodes and its lifetime shall be equivalent, or larger, than the MORFEO lifetime.

### 6.5.3.5 Hazard and Safety issues

The ladder must allow the operator to safely access the Tower Duct front side, incorporating appropriate fall protection devices in compliance with ESO and EU regulations. The ladder shall ensure the operator's safe transfer onto the working platform. The working platform (if part of the SEq.) shall provide a safe working space for the operators, in compliance with ESO and EU regulations. Exceptions shall be evaluated by the Consortium and agreed with ESO. Earthquake safety factors shall be considered.

### 6.5.3.6 Special tools needed

For its installation and removal eyebolts or straps can be used. Different tools can be evaluated. The ladder is fixed using captive screws.



### **6.5.3.7 Way to be operated**

Its installation shall be as much compatible as possible with the thermal cover of MORFEO, i.e., shall minimize the surface of thermal cover to be removed and, ideally, shall not require any dis-installation of the thermal cover. An operator climbs up to the selector platform, always secured to fall protection device

## **6.6 LGSO Assembly and maintenance Handling Tool (SM0-HT-PFH\_BENCH)**

### **6.6.1 Purpose and functionality**

The SM0-HT-PFH\_BENCH has the purpose to perform the installation of the LGSO inside the MSS.

### **6.6.2 Deliverables**

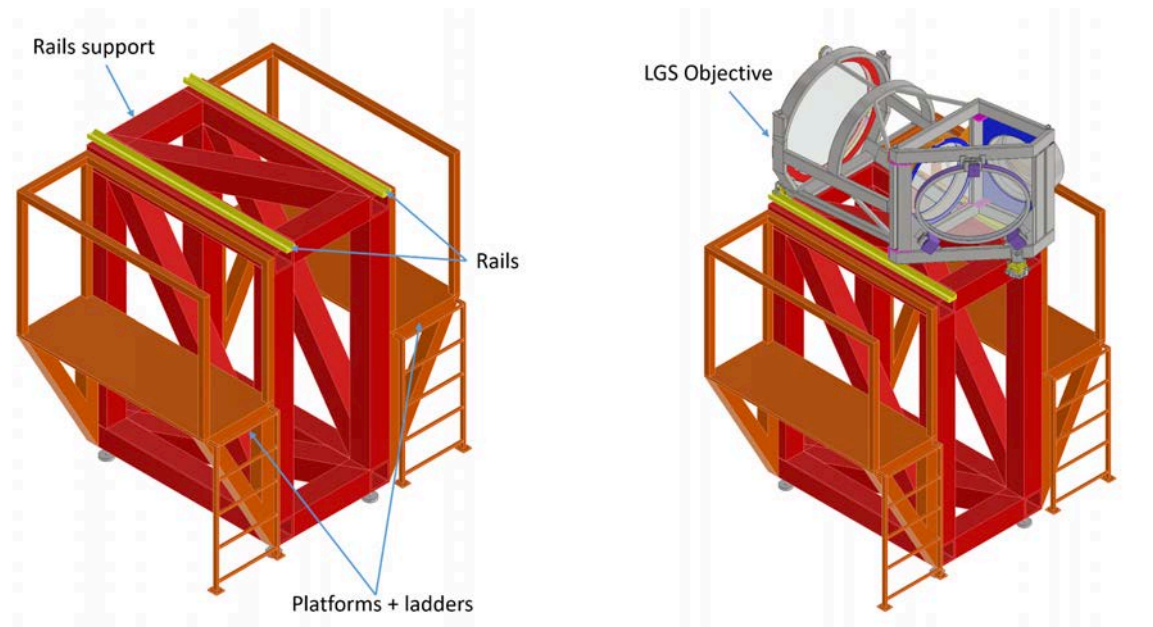
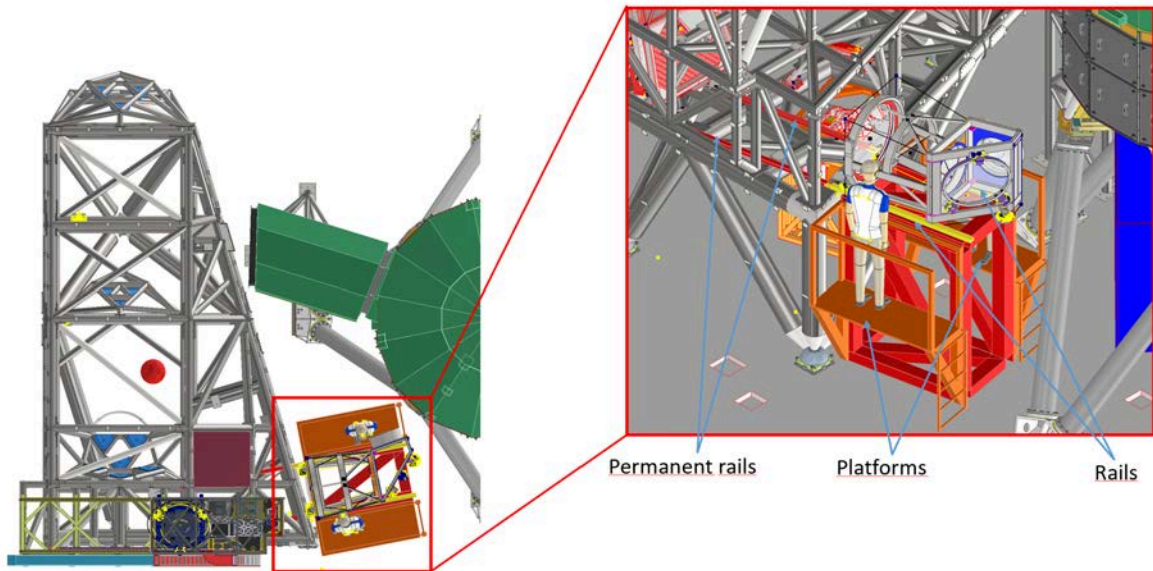
Phase 1: executive drawings, step files and detailed and comprehensive procedure for SEq installation/dis-installation in the various locations.

Phase 2: SEq manufactured, test report, safety data files, user and maintenance manual, storage/shipment box.

### **6.6.3 Additional information: LGSO Assembly and maintenance Handling Tool (SM0-HT-PFH\_Bench)**

#### **6.6.3.1 Description**

The LGSO is installed inside the MSS using a rail system, making it sliding in the MSS from the side. Part of these rails will be most likely permanently installed inside the MSS, while the part protruding outside the MSS shall be installed when needed. The rail protruding outside will lean on this SEq, placed next to the aperture in the MSS where the LGSO will enter. The supporting structure can be lowered with the crane thanks to the four eyebolt on the top part of the structure. Once the structure reaches the floor, its height can be fine tuned acting on retractable feet which can be screwed to the ground. On the top part of this structure the missing part of the rails can be installed and screwed by two persons, due to the small size and weight of a single rail. The permanent and temporary part of the rails shall be jointed together and it shall be possible to finely co-align them. Due to the height of the LGS-Objective within the MMS, two persons can stay on two platforms on the side of this SEq (one per each side) to perform the installation of the rails, the interface of the rails to the permanent rails into the MMS and to push the LGS-Objective inside the MMS. Platforms can be accessed with short ladder integrated into the SEq.



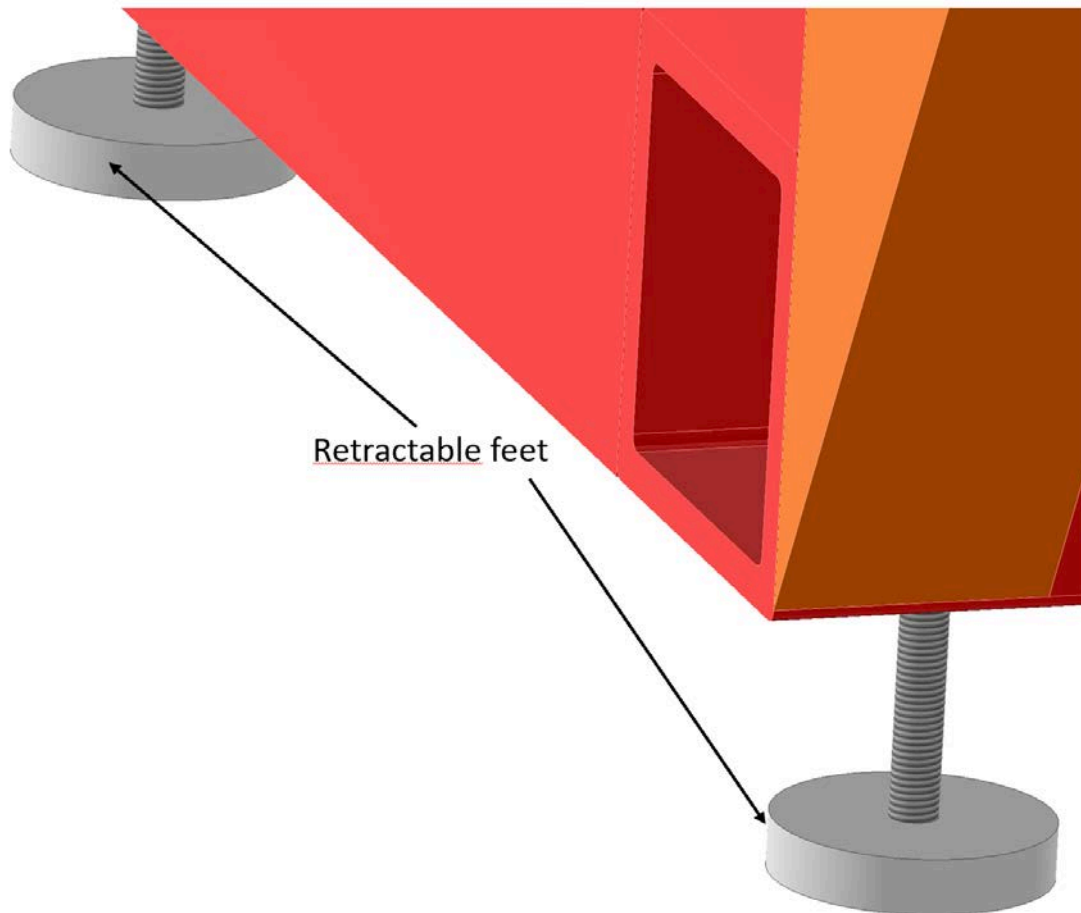


Figure 47: This SEq. provides working platforms for two operators, located on the sides of the SEq. itself. On the top of the SEq. two rails can be mounted (and aligned) by the operators. These rails will serve to slide the LGSO inside the MSS. Sliding can be done by the operators pushing the LGSO or using an appropriate tool (such as endless screw driving the LGSO inside the MSS). The height of the whole SEq can be fine tuned acting on the retracting feet at the bottom. The feet can be screwed to the ground to give stability to the system.

### 6.6.3.2 Manufacturing

The conceptual design is done within the MORFEO consortium, the final design and construction will be out-sourced to an external company.

### 6.6.3.3 AIT phase when needed

The SM0-HT-PFH\_BENCH is needed for the assembly operations in Bologna and in Chile and for maintenance in Chile.



#### **6.6.3.4 Deliverable and lifetime**

The SM0-HT-PFH\_BENCH is a deliverable to Chile, where it has to be stored to be used for extraordinary maintenance.

#### **6.6.3.5 Hazard and safety issues**

The SM0-HT-PFH\_BENCH must be operated in the following way:

- A minimum of 1 person + the crane operator are necessary for the supporting structure handling/movement and two person for rail installation on top of the supporting structure
- Operators shall wear the helmet, safety gloves and safety shoes
- Every operator shall wear safety shoes, safety gloves and helmet
- When operating on the platform, the harness safely secured is mandatory for each operator
- The load on the rails shall be always safely constrained during transportation on the rails and it shall not fall out of the rails, even in case of earthquake.

No Major Hazards have been identified, but mis-handling of the rails and of the supporting structure might damage the items nearby.

#### **6.6.3.6 Special tools needed**

Normal mechanical workshop tools.

#### **6.6.3.7 Way to be operated**

Before its installation the relevant thermal cover panel(s) shall be removed using standard ladder(s).

It shall allow to align the rails to the rails permanently installed inside the MSS.

Two operators shall work on the two sides of this SEq., both do help the crane operator during the lowering/lifting of the LGSO and to push/pull the LGSO on the rails for its installation/deinstallation.

The implementation of a manual mechanism to help the insertion/extraction of the LGSO (positioned on the rails) in the MSS shall be considered.

### **6.7 Handling of the SEq**

The installation concept for all external ladders should be kept as simple as possible. Ideally, four eye-bolts positioned near the top of the ladder and aligned with its center of



gravity when vertical are sufficient. To control any potential unwanted swinging of the ladder while suspended from the crane, a pair of ropes attached to the bottom of the ladder, managed by an operator, may be used. As an example, but the same concept can be applied to all the Seq. described in Sec.6, we depicted the concept for “Access ladder to selector platform” (Sec.6.2) in Figure

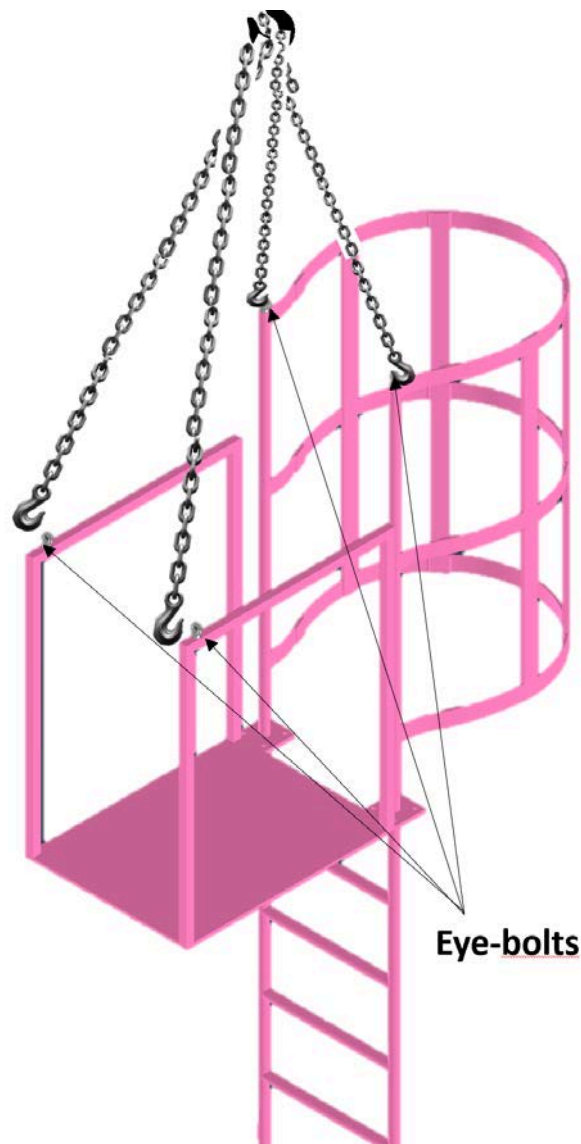


Figure 48: eye-bolts at the top of the ladder serving as interface for the crane, for vertical transportation of the ladder.

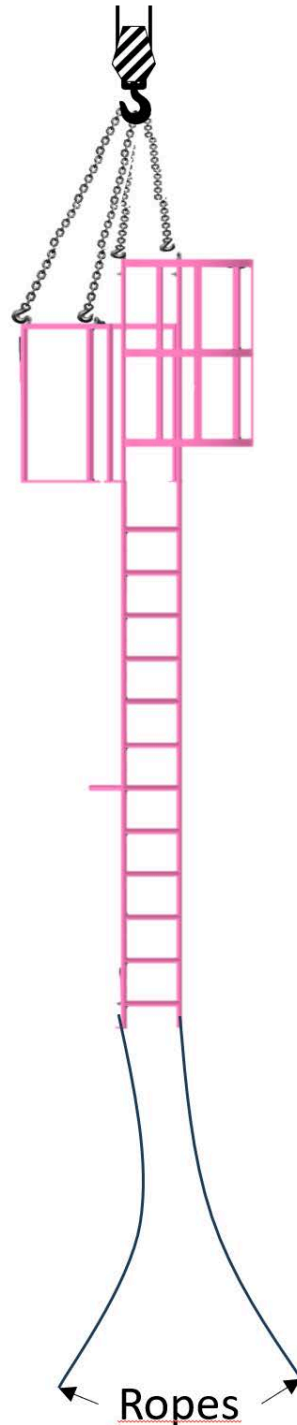


Figure 49: ropes at the bottom of the ladder allows an operator to avoid unwanted swinging of the ladder during transportation with the crane.



In BIH, due to the room geometry and the positioning of MORFEO, the installation of the sequence described in Sections 6.2 and 6.4 will require passing the ladder horizontally over the fully installed MORFEO MSS, followed by rotating it back to the vertical position. A possible concept is illustrated in Figure XXX.

Four eye-bolts at each end of the ladder allow attachment of four chains to maintain the ladder in a horizontal orientation. Once the ladder reaches its intended location, it can be rotated using a spreader bar with two attachment points:

- one equipped with a chain hoist to lower the bottom end of the ladder in a controlled manner, and
- the other as an adjustable rigging point with ropes and pulleys, to keep the system balanced throughout the rotation.

As a simpler alternative—which may be acceptable for use exclusively in BIH—the ladder can be placed horizontally on the ground, the chains at the bottom released, and then lifted by the crane only from the top connection points. This allows the ladder to be raised almost vertically. An operator on the ground assists to prevent any unwanted swinging during the lift.

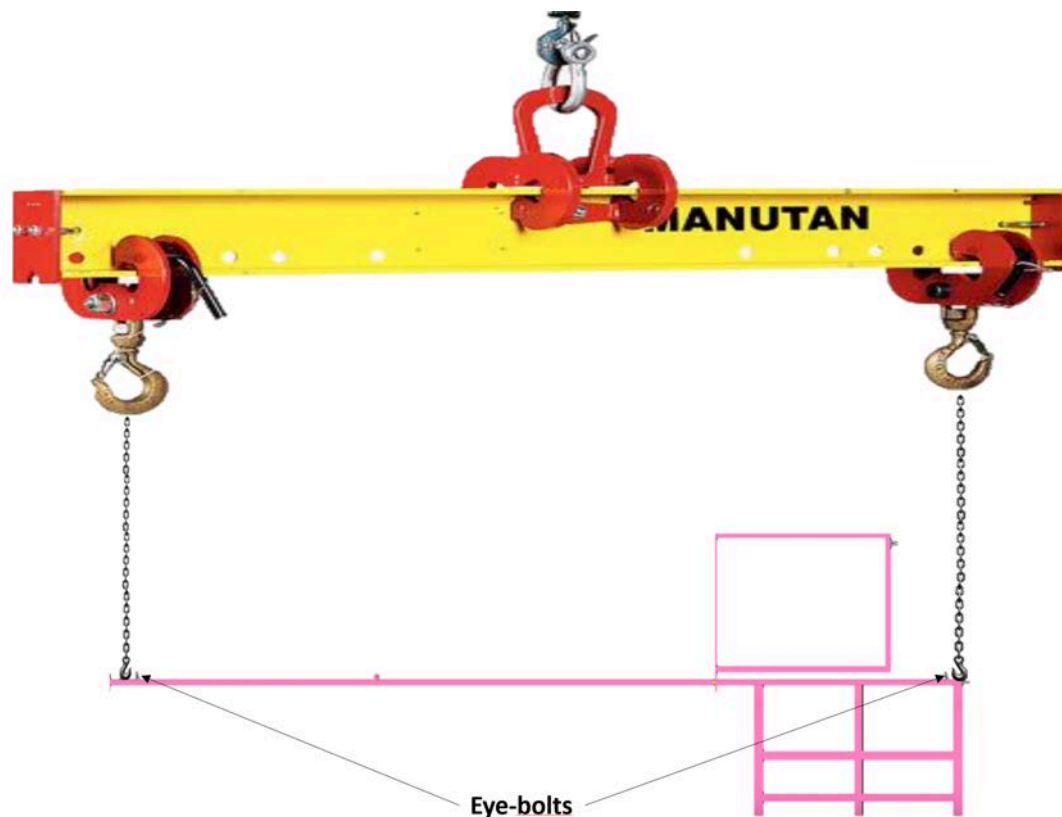


Figure 50: a possible concept to transport ladder horizontally above MSS, when needed. One attachment point on the spreader bar can be movable, to keep the system balanced during ladder rotation, the second attachment point has a chain hoist, to lower remotely



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the bottom of the ladder. If the simpler solution is adopted, spreader bar is not necessary and only 4 eye-bolts and chains are needed.



## 7. Requirement Verification

Requirement ID	FDR verification	ARR verification
MAO-SM0-1.1.1	Design	Test
MAO-SM0-1.1.2	Info	info
MAO-SM0-1.1.3	Design	Test
MAO-SM0-1.1.4	Design	Test
MAO-SM0-1.1.5	Design/Analysis	Test
MAO-SM0-1.1.6	Design	Test
MAO-SM0-1.1.7	Design	Test
MAO-SM0-1.1.8	Design	Test
MAO-SM0-1.1.9	Design	Test
MAO-SM0-1.1.10	Design/ Analysis	Test
MAO-SM0-1.1.11	Design	Inspection
MAO-SM0-1.1.12	Design	Test
MAO-SM0-1.1.13	Design	Test
MAO-SM0-1.1.14	Design	Inspection
MAO-SM0-1.1.15	Design/ Analysis	Test/Analysis
MAO-SM0-1.1.16	Design/ Analysis	Test/Analysis
MAO-SM0-1.1.17	Design	Inspection
MAO-SM0-1.1.18	Design/ Analysis	Test/Analysis
MAO-SM0-1.1.19	Design/ Analysis	Test/Analysis
MAO-SM0-1.2.1	Design/ Analysis	Test/Analysis
MAO-SM0-1.2.2	Design/ Analysis	Test/Analysis
MAO-SM0-1.2.3	Design	Inspection/Test
MAO-SM0-1.2.4	Design	Inspection/Test
MAO-SM0-1.2.5	Design/ Analysis	Test/Analysis
MAO-SM0-1.2.6	Design/ Analysis	Test/Analysis
MAO-SM0-1.2.7	Design/ Analysis	Test/Analysis
MAO-SM0-1.2.8	Design/ Analysis	Test/Analysis
MAO-SM0-1.2.9	Design	Inspection
MAO-SM0-1.2.10	Design/ Analysis	Test/Analysis
MAO-SM0-1.2.11	Design/ Analysis	Test/Analysis
MAO-SM0-1.2.12	Design/ Analysis	Test/Analysis



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