Main Structure general overview: mechanical design update from PDR towards the final design phase

Vincenzo De Caprio*[a], Vincenzo Cianniello[a], Christian Eredia[a], Domenico D'Auria[a,b], Enrico Cascone[a], Edoardo Redaelli[c], Matteo Aliverti[c], Giorgio Pariani[c], Marco Riva[c], Jacopo Farinato[d], Demetrio Magrin[d], Luca Marafatto[d], Simonetta Chinellato[d], Gabriele Rodeghiero[e,f] Gianluca Di Rico[e], Ludovico Teodori[f], Andrea Di Rocco[f] and Paolo Ciliegi[f]

[a]INAF - Osservatorio Astronomico di Capodimonte, Salita Moiariello 16, 80131 Napoli, Italy; [b]Università degli Studi di Napoli Federico II - Dipartimento di Ingegneria Industriale (DII), Via Claudio 21, 80125 Napoli, Italy; [c]INAF - Osservatorio Astronomico di Brera, Via E. Bianchi 46, 23807 Lecco, Italy; [d]INAF - Osservatorio Astronomico di Padova, Vicolo dell'Osservatorio 5, 35122 Padova, Italy; [e]INAF - Osservatorio Astronomico d'Abruzzo, Via Mentore Maggini s.n.c., 64100 Teramo, Italy; [f]INAF - Osservatorio di Astrofisica e Scienza dello Spazio di Bologna, Via P. Gobetti 93/3, 40129 Bologna, Italy.

ABSTRACT

MORFEO (Multi-conjugate adaptive Optics Relay For ELT Observations, known as MAORY), is the Multi-conjugate Adaptive Optics (MCAO) relay for the Extremely Large Telescope (ELT) that will provide diffraction-limited optical quality to two instruments at the ELT Nasmyth Platform. One first light instrument fed by MORFEO is the Multi-AO Imaging Camera for Deep Observations (MICADO) that will provide imaging, astrometric, spectroscopic and coronographic observing modes; a second-generation instrument, still to be defined, will occupy the second instrument port powered by MORFEO. The two instruments will be assisted alternately by MORFEO thanks to a flat steering mirror that can redirect the beam towards one or the other instrument. The particular shape of the MORFEO module is closely related to the position of the optical elements and the relative optical path that is mainly developed in a vertical plane. For this reason, the Main Support Structure is "almost empty" in the central plane, in order to accommodate both the opto-mechanical elements and sub-systems and allow the light to pass into. MORFEO has officially passed the Preliminary Design Review in February 2023. The general overview of the mechanical design for the MAIN STRUCTURE described in this paper is an updated version of the configuration presented for the Preliminary Design Review in the first half of 2021.

Keywords: Instrumentation for Extremely Large Telescopes, Multi-conjugate Adaptive Optics, Astronomy with AO, MORFEO, MICADO, ESO

*contact author: vincenzo.decaprio@inaf.it

1. INTRODUCTION

MORFEO (Multiconjugate adaptive Optics Relay For ELT Observations) that is not a scientific instrument in itself (as it does not produce scientific data on its own), is designed to support two different client instruments both with the same optical quality: MICADO (a near-infrared camera and spectrograph) and a second port for a future instrument. It will be located on the ELT Nasmyth platform B - Cerro Armazones (Chile). In February 2020 the MORFEO Consortium carried out a trade-off study comparing two optical different configurations MMC (MORFEO Mirror Configuration) and MOC (Modified Offner Configuration). The first optical configuration was selected as a new baseline, and starting from this optical design developed in three dimensions. The mechanical design, completely revised, was presented at ESO in July 2021 for the PDR. In February 2023 MORFEO has officially passed the Preliminary Design Review and it is entering the final design phase This paper describes the design update, from PDR towards the final design phase, of mechanical design for the Main Structure of MORFEO for the MMC optical configuration.

Ground-based and Airborne Instrumentation for Astronomy X, edited by Julia J. Bryant, Kentaro Motohara, Joël R. D. Vernet, Proc. of SPIE Vol. 13096, 130965L
 · 0277-786X · doi: 10.1117/12.3019972

2. MORFEO MAIN STRUCTURE - DESIGN OVERVIEW

The Main Structure of MORFEO is a sub-system (see next Figure 1) of the whole MORFEO module that includes, in the current baseline configuration, the following listed items:

- MORFEO Main Support Structure (MORFEO_MSS), is the mechanical structure hosting all the Optomechanical elements.
- Thermal Enclosure – MORFEO side, is the cover structure of the MORFEO_MSS.
- MORFEO – MICADO Thermal Duct, is a structure between MORFEO and MICADO, that includes the mechanical frame (bottom part – TOWER) and the actual Thermal Duct with its proper structure.
- Thermal Enclosure – MICADO side, is the cover structure around M12 installed on the top side of MICADO, that includes its mechanical structure.
- CU Selector for MORFEO Folding Mirror (FM CU) and MICADO Calibration Assembly (MCA), is the linear guide carriage that allows the system to switch between different positions.

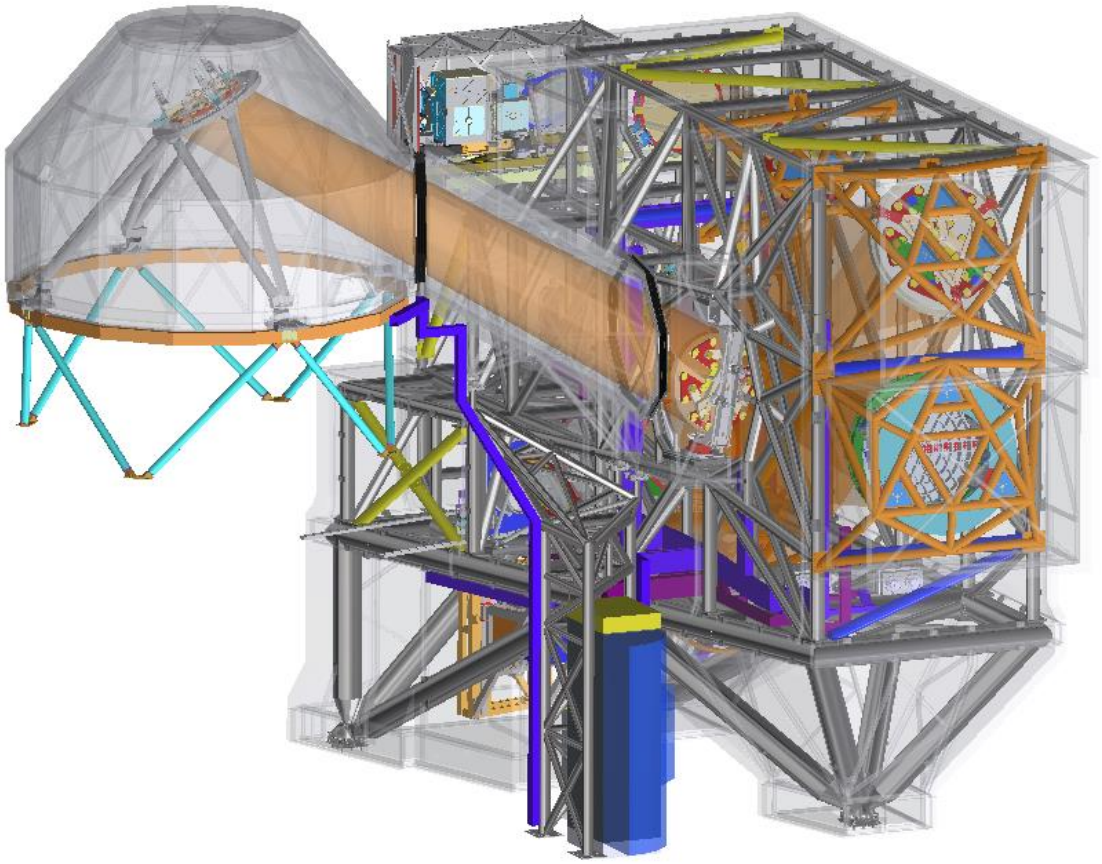

Figure 1. 3D CAD model assembly of MORFEO Main Structure.

The MORFEO Main Support Structure (MORFEO_MSS) will require to be fixed through three main support points on the grid of ESO Nasmyth Platform. In addition to these points, other three points will be necessary to fix the Support Structure for the Thermal Duct, between MORFEO & MICADO, that connects MORFEO Thermal Enclosure to MICADO Thermal Enclosure.

The MICADO Thermal Enclosure (this mechanical structure is visible in the Figure 1) will be mounted directly on MICADO Main Support Structure (MICADO Top Bench) via four dedicated flanges.

3. MORFEO MAIN SUPPORT STRUCTURE - DESIGN OVERVIEW

The mechanical design for MORFEO – MSS (Main Support Structure), presented at ESO for PDR (3D CAD shown in the next Figure 2 with its overall dimensions), is made of standard structural steel truss-beam shaped, with tubes both welded or bolted. These tubes have been sized (different section properties) in order to reach an optimal ratio between the global stiffness and the global mass of the whole MORFEO MSS.

This structure hosts up all optomechanical elements, via their Optomechanical Support Structures themselves (OSS – elements painted in orange in the next Figure), and provide a very stable opto-mechanical reference and a support both for the opto-mechanics and for all the other subassemblies and components mounted on it.

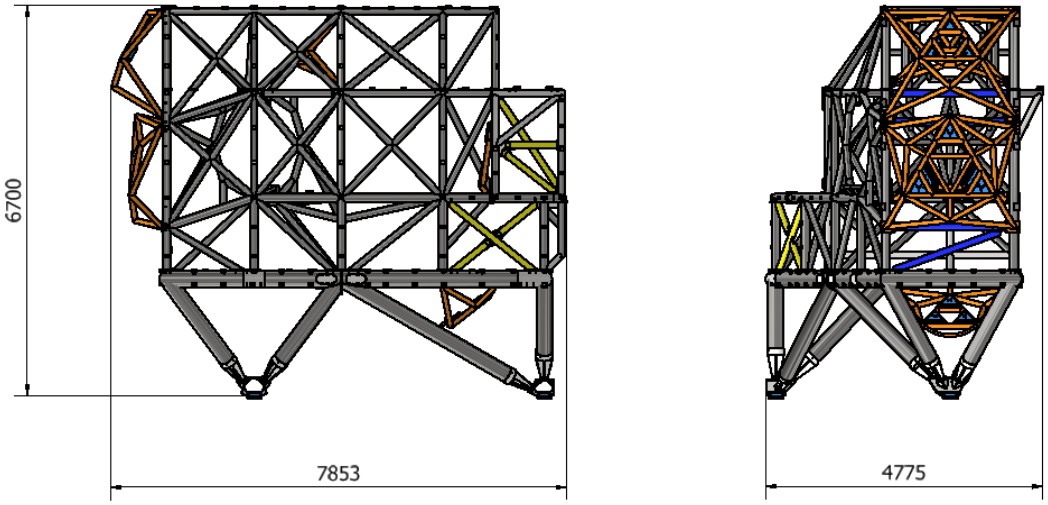

Figure 2. MSS overall dimensions without Enclosure.

The MSS lattice structure is equipped, in its bottom part, with 10 legs that converge on 3 "Instrument Main Interface flanges" (on the grid) of ESO-ELT Nasmyth Platform through 3 dedicated MSS interface joints.

The design has been constrained to fit with the three supports points concept in order to have an ideal interface plane; this strategy mitigates the distortions induced by the Nasmyth Platform displacements out of a rigid body motion. After PDR, the mechanical design of the joint structure was update: the "spherical joint" inserted between the ESO Nasmyth attachment flanges and the MORFEO MSS Main Interface flange (to mitigate local moments), at the end of the MSS legs, has been replaced with a different concept ("flexure joint").

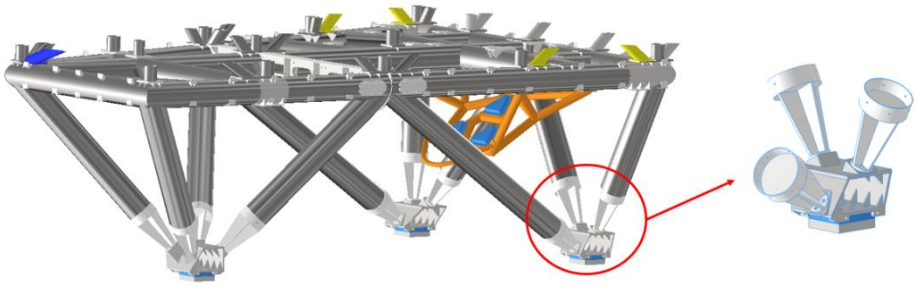

Figure 3. 3D Sketch of the new concept of the Nasmith flexure joints for MSS.

This new design (which also includes a new shape of the final part of the 10 legs) it is both easier to build and allow a much wider margin for the mechanical alignment operations of the MSS as well as to provide some additional margin to the alignment operations for the AIV of the whole instrument.

Due to reasons of building, transport, mounting and maintenance operations, MORFEO MSS will be split in in several parts connected to each other with bolts and using, also, reference pins in order to have an accurate mounting/dismounting

for the various provisional phases. The number of final parts, and their final dimensions, are actually under evaluation with a view to the final design.

The lattice structure (selected material for all the standard tubes is the S355JR steel) described (and including also the OSS that will be described in the following subparagraph 3.1), once mounted together, compose the MORFEO Main Support Structure. Adding together all the weight contributes, the whole dimension in terms of mass can be obtained that is about 8400Kg (updated respect to PDR design and without contingency). In order to have a more conservative estimation regarding the mass budget, a 3% of contingency for welding was considered; furthermore, also the small pieces, like bolts and accessories, are taken in account.

The protective treatment provided for all the steel parts is sandblasting and painting (TBC).

3.1 Optomechanical Support Structure

The Optomechanical Support Structures (OSS) (orange structures highlighted in the next Figure 4), will be used in order to accommodate accurately the optical with its optomechanical elements to install on the MORFEO module. The optical elements hosted are: SP (this OSS is an "octagonal aperture" - part of one of the Main Part of MSS), M6, M7, M8, M9/DM1, M10/DM2. The structure of these sub-assemblies is made of structural steel pipes and interface steel plates with the cinematic supports for the Optomechanics.

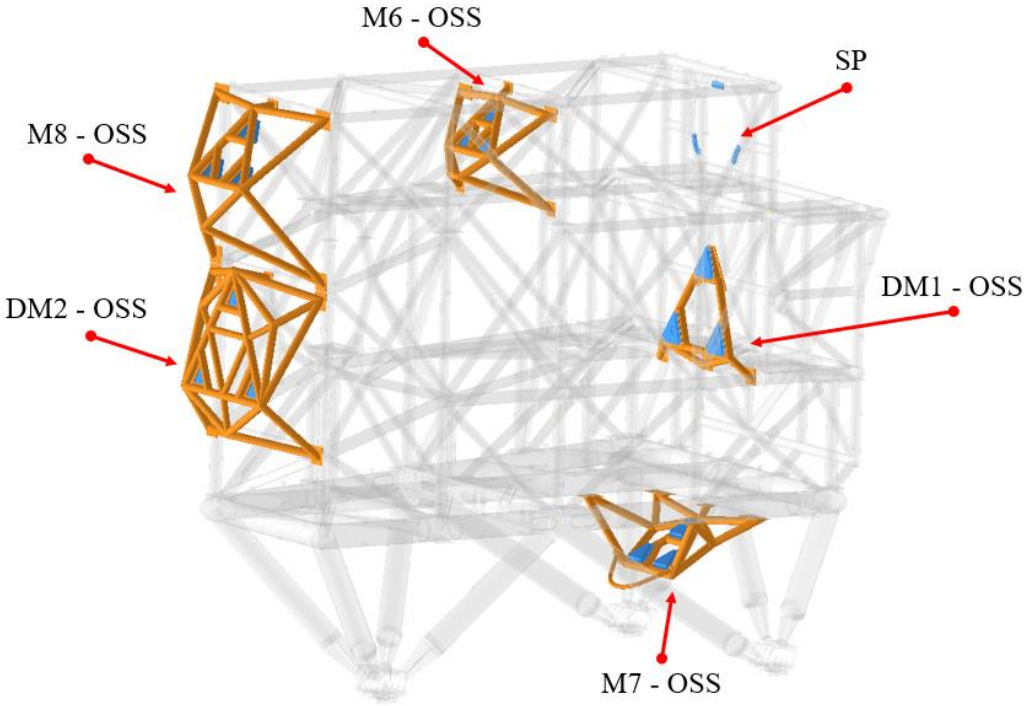

Figure 4. OSS - Optomechanical Support Structures (depicted in orange) mounted on MSS.

The interface with Optomechanical element, i.e. the Optomechanical reference plane, is made up of 3 screwed reference steel plates (depicted in light blue in the previous Figure 4), that offer the mounting reference plane, and a good precision in connection, for the optomechanical sub-systems. These plates can be re-machined or substituted in case of relatively "large movement" of the optomechanical supports respect its present nominal position.
The selected material for all the standard tubes which compose all the OSS is the S355JR steel (TBC).

3.2 CU Selector for MORFEO FM_CU and MCA

The Calibration Unit Selector (CU Selector - as defined in the previous chapter 2.) is it one of the items of the Main Structure hosted on the MSS made, essentially, of two main components:

1. a fixed frame (made in structural steel tubular square and rectangular profiles), mounted ton the MORFEO MSS through 8 interface plates;

2. a mobile frame (equipped with its own cover), also made in structural steel tubular square profiles, to which is allowed a translation movement; this mobile structure is connected to the fixed frame of the CU Selector through the bearing blocks and the guide rails; is this sub-assy that effectively hosts the instrument needed for the calibration operations: the MORFEO Folding mirror CU and the three Calibration Modules of MICADO (MCA).

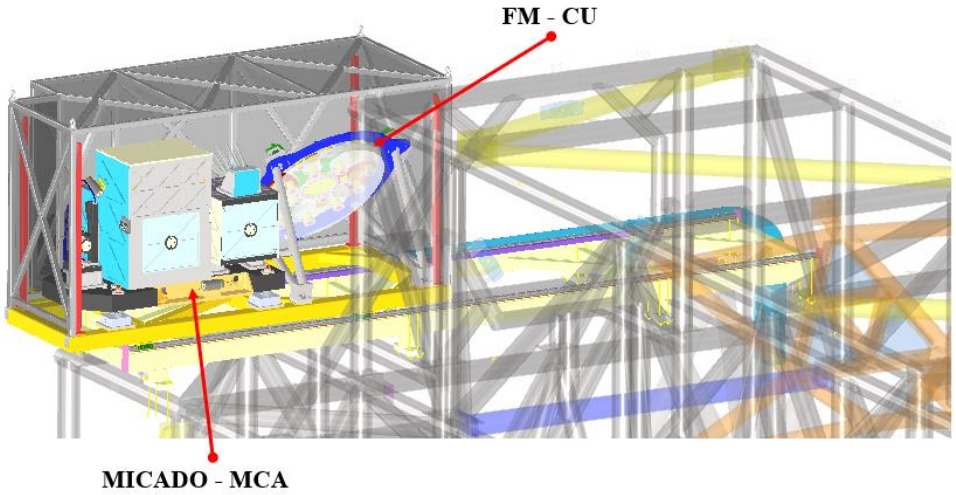

Figure 5. View of the location of the CU Selector and its onboard modules (MCA and FM - CU.

4. THERMAL ENCLOSURE GENERAL OVERVIEW – MORFEO SIDE

A passive thermal cover was design in order to protect the optics from light and dust, and thermally insulate the internal side of MSS from outside (see Figure 6).

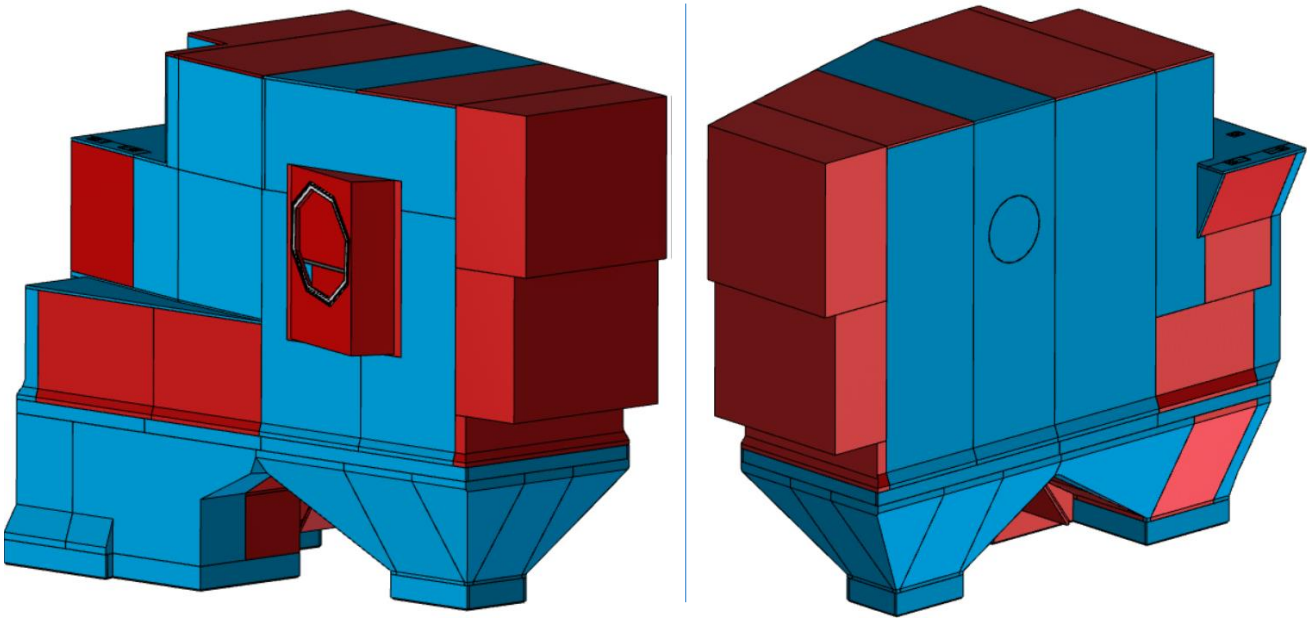

Figure 6. MORFEO: Thermal Enclosure overall view.

This Enclosure will consist of several panels, mounted on the MSS or, where it is not possible, to intermediate aluminum structures (built with tubular 40 x 40 x 2 mm) attached on the tubes of the MSS itself. By way of example in the next Figure 7 (next page) is shown in the left side the mounting of the panels - DM2 side - via an intermediate aluminum frame and, in the right side the panels painted in two different ways: the red ones are the removable panels, while the blue one

are the fixed on the MSS. The red panels can be easily dismounted for maintenance access, while the blue ones require more time and the dismounting of other panels before.

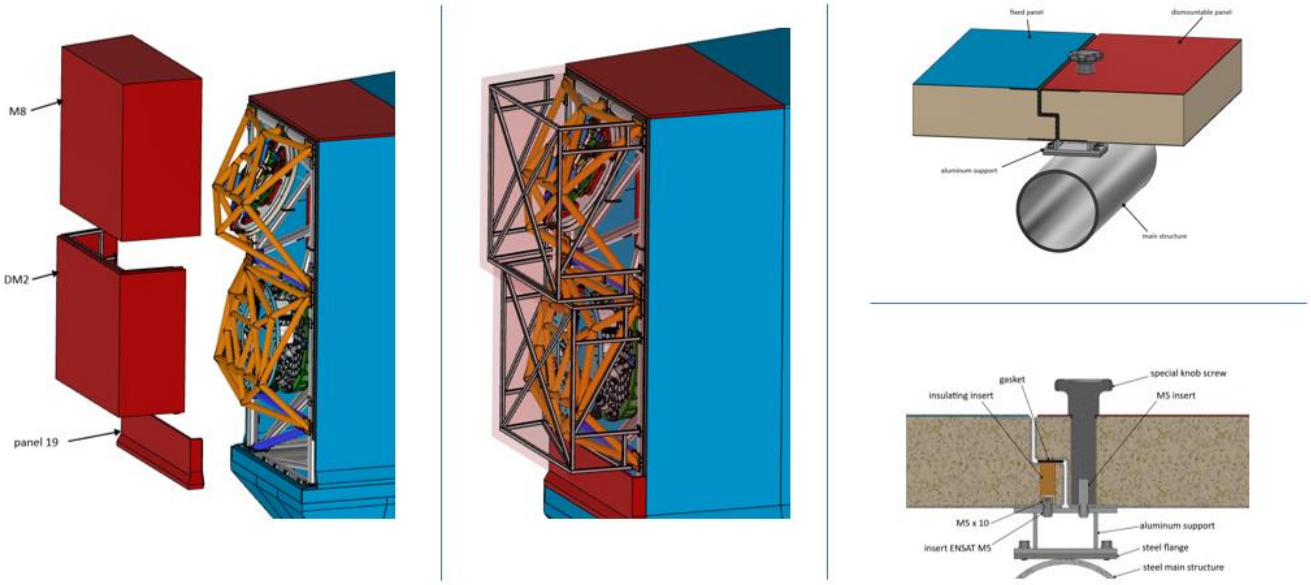

Figure 7. MORFEO: Thermal Enclosure: M8/DM2 3D view - left side; 3D layout of junction between two panels, panels fixing section - right side (up, bottom).

The mechanical layout of a thermal panel (for passive insulation) is composed by more layers: an internal aluminum sheet, with a thickness of 1 mm, a thermal insulating layer in PIR (polyisocyanurate), with 70 mm of thickness, and an external plastic sheet (polycarbonate) with 1 mm of thickness.

The PIR material has a relatively low thermal conductivity (λo = 0.022 W/mK) and a low density (35 kg/m3 ± 10%), for this reason it is suitable for a lightweight insulating cover. The edges of the panel are made of a carbon fibre composite profile, with a thickness of 1.5 mm, with different shapes, depending on the position and the function of the panel, and also in order to compose the Thermal Enclosure.

The several components of the panel are bonded together (glue to use TBD). The shape of the edge is designed to have a light trap and a surface for a soft gasket seal, that is attached using adhesive, with a dimension of 20 x 2 mm and made of EPDM foam (TBC).

The typical junction between two panels is shown in the Figure 7 - right side. The blue painted panel is fixed to the MSS structure (on small specific plates) and screwed with an M5x10, hexagon socket head, and anti-loosening washer; an insert in insulating material covers the hole (on the external side of the panel). The adhesive gasket in EPDM foam is bonded on the fixed panel, and the red (removable panel) is fixed with a special plastic knob, with a steel insert threaded M5, as schematically shown in the previous Figure 7 right side – in the bottom.

The access inside MORFEO will be guarantee in two different areas, near M7 and LGS subassemblies.

5. MORFEO - MICADO THERMAL DUCT OVERVIEW

The MORFEO-MICADO Thermal Duct is a structure between MORFEO and MICADO that “protects” the optical path between M11 and M12 optical elements; It is made of a tubular lattice structure (made from ISO tubes - steel S275JR), closed on the sides by aluminum sheets, an insulating layer and an external plastic layer, and its irregular shape follows the optical path and the angle of the MORFEO and MICADO surfaces.

The structure includes the mechanical frame (bottom part, formally named “tower”, that will be fixed directly on the ESO Nasmyth Platform via three additional support points (following the dedicated tec. specs - different from those of the main points), and the Thermal Duct structure (with its shaped like hollow cylinder) mounted on the previous one and made from

aluminum (AL6082) standard tubes ISO 6362-6, with the different diameters and thickness. The protective treatment provided is painting (TBD).

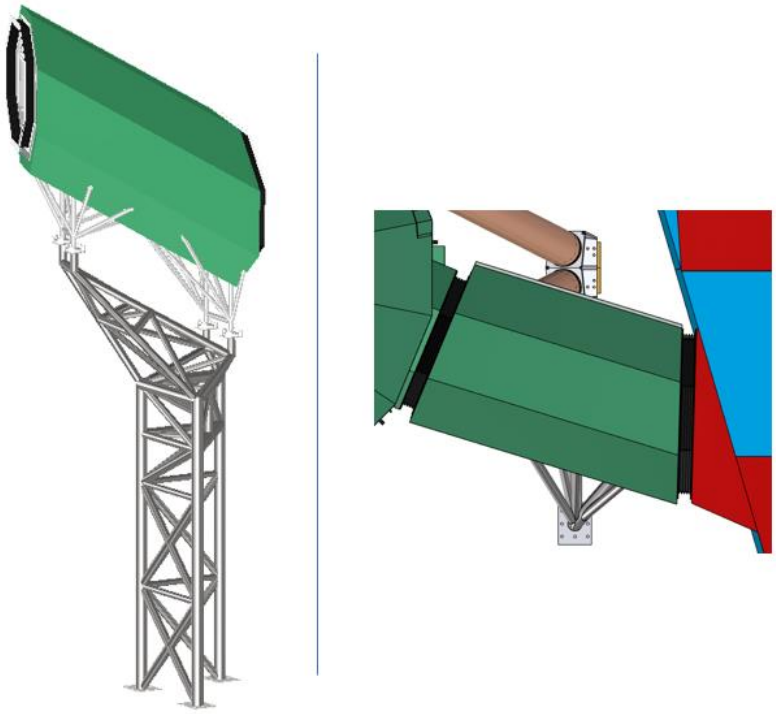

Figure 8. MORFEO: Thermal Enclosure overall view - left side; top view - right side.

The Thermal Duct is connected, at both ends, to MORFEO and MICADO Enclosures, with two bellows, to allow relative motions between the two instruments (see next Figure 9 - right side), for example for earthquake and/or thermal expansion, leaving these free to move in relation to each other.

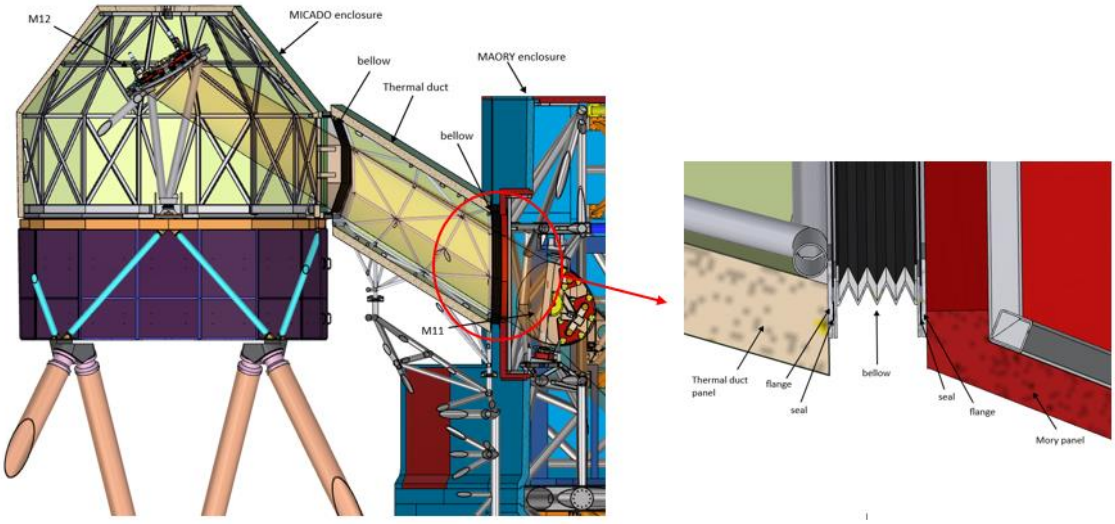

Figure 9. Section view of the area between MORFEO and MICADO - left side; section view of the bellow - right side.

The thermal insulating layer, covering the Thermal Duct structure, is made of different layers. It is composed by panels of PIR (polyisocyanurate) with 100 mm of thickness glued on the aluminum sheets, as described in the previous chapter, and covered by a protective polycarbonate sheet.

6. MICADO THERMAL ENCLOSURE OVERVIEW

The MICADO thermal Enclosure will be mounted on the top bench of MICADO instrument and insulates (passive insulation) the upper part of MICADO itself together with M12 subsystem, and protects them from light and dust. The present overall dimensions are shown in the next Figure 10.

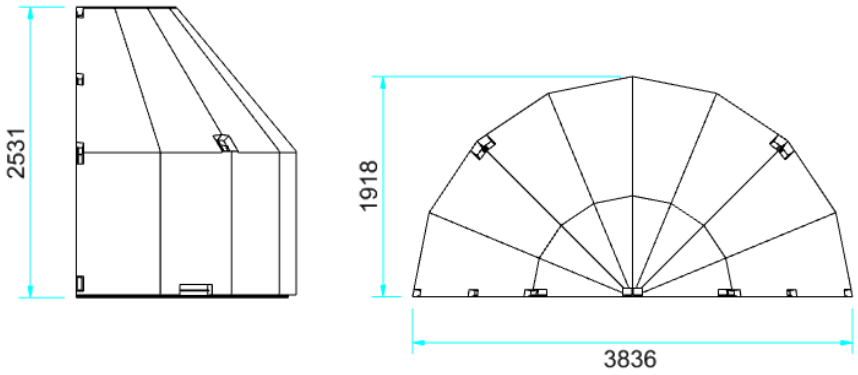

Figure 10. MICADO Thermal Enclosure overall dimensions.

The mechanical structure of MICADO Enclosure (made of standard aluminum rectangular and square shaped tubulars, with round edges) is composed by two parts almost symmetrical (for transport reasons), connected together by 74 bolts M10x35. The shape, in plant view, is a polygon with 16 edges; this choice has been made in order to fit the shape of MICADO. The protective treatment provided is painting (TBD).

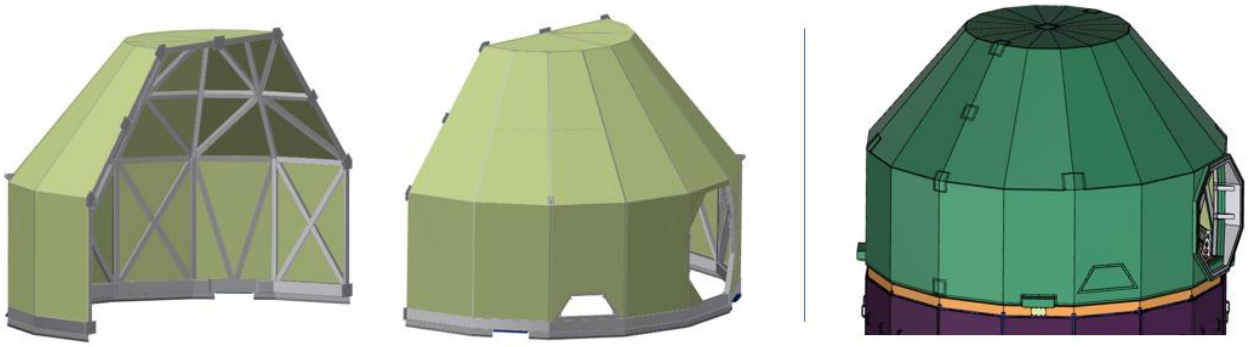

Figure 11. 3D views of MICADO Thermal Enclosure.

The structure must be light and easily removable for maintenance access, for this reason the 12 connection bolts are on the external side, reachable from the walkway around MICADO. The MICADO Enclosure structure can be lifted in one piece with 4 attachment points positioned at first level of the structure. It is necessary unscrew the bellow between this Enclosure and the MORFEO-MICADO Thermal Duct, besides disconnecting the electrical cables of M12 subassembly to lift the structure.

In the side toward the MORFEO-MICADO Thermal Duct there are the openings for the optical path and for the cables, as shown in Figure 11.

The MICADO thermal Enclosure is built with the same philosophy of the panels for MORFEO Enclosure and MORFEO-MICADO Thermal Duct: aluminum sheet inside, a layer of PIR in the middle and a plastic sheet outside.

7. CONCLUSIONS

A general overview of the last baseline mechanical design of the MORFEO Main Structure has been presented in this paper. Significant changes of requirements and instrument design have been made since the MORFEO project phase A. The detailed set of preliminary FEM Analyses performed, prove that the mechanical model presented in this paper is compliant with the requirements imposed by ESO for ELT Instrumentation.

8. ACKNOWLEDGEMENTS

The MORFEO instrument is developed in the framework of the Agreement No. 65221/ESO/15/67001/JSC between the European Organisation for Astronomical Research in the Southern Hemisphere (ESO) and the Istituto Nazionale di Astrofisica (INAF) on behalf of the Consortium consisting of INAF, Institut National des Sciences de I'Univers du Centre National de la Recherche Scientifique (INSU/CNRS) acting on behalf of the Institut de Planetologie et d'Astrophysique de Grenoble (IPAG), School of Physics at the National University of Ireland Galway (NUIG), National Research Council Canada (NRC) and of National Astronomical Observatory of Japan (NAOJ).

REFERENCES

[1] E. Diolaiti et al., "Preparing for the phase B of the E-ELT MCAO module project", Proc. SPIE 9148, Adaptive Optics Systems IV, 91480Y (7 August 2014); https://doi.org/10.1117/12.2056550
[2] E. Diolaiti et al., "MAORY: adaptive optics module for the E-ELT", Proc. SPIE 9909, Adaptive Optics Systems V, 99092D (27 July 2016); https://doi.org/10.1117/12.2234585
[3] M. Lombini et al., "Optical design of the Post Focal Relay of MAORY", Proc. SPIE 9908, Ground-based and Airborne Instrumentation for Astronomy VI, 9908AB (9 August 2016); https://doi.org/10.1117/12.2234569
[4] V. De Caprio et al., "MAORY for ELT: preliminary mechanical design of the support structure", Proc. SPIE 10703, Adaptive Optics Systems VI, 107034H (12 July 2018); https://doi.org/10.1117/12.2314189
[5] M. Lombini et al., "Optical design of the post focal relay of MAORY", Proc. SPIE 10690, Optical Design and Engineering VII, 1069011 (5 June 2018); https://doi.org/10.1117/12.2312010
[6] V. De Caprio et al., "MAORY Main Structure design: general overview", Proc. SPIE 11448, Adaptive Optics Systems VII, 1144832 (13 December 2020); https://doi.org/10.1117/12.2562124
[7] P. Ciliegi et al., "MAORY: the adaptive optics module for the Extremely Large Telescope (ELT)", Proc. SPIE 11448, Adaptive Optics Systems VII, 114480Y (13 December 2020); https://doi.org/10.1117/12.2561754
[8] V. De Caprio et al., "Mechanical design overview for the Main Structure of MAORY-MORFEO", Proc. SPIE 12184, Ground-based and Airborne Instrumentation for Astronomy IX, 121842X (29 August 2022); https://doi.org/10.1117/12.2628893
[9] V. Cianniello et al., "Structural Analyses of the MAORY/MORFEO Main Support Structure at global level for Preliminary Design Review", Proc. SPIE 12184, Ground-based and Airborne Instrumentation for Astronomy IX, 121843R (29 August 2022); https://doi.org/10.1117/12.2628333
[10] P. Ciliegi et al., "MAORY@ELT: general overview up to the preliminary design and a look towards the final design", Proc. SPIE 12185, Adaptive Optics Systems VIII, 1218514 (29 August 2022); https://doi.org/10.1117/12.2628969
[11] G. Pariani et al, "MAORY optical design and performances: status at preliminary design review", Proc. SPIE 12185, Adaptive Optics Systems VIII, 121855M (29 August 2022); https://doi.org/10.1117/12.2629415
[12] V. Cianniello et al., "Finite Element modelling technique: trade-off between two different FE models of a mechanical selector for Astronomical Instrumentation", Proc. SPIE 12184, Ground-based and Airborne Instrumentation for Astronomy IX, 121842P (29 August 2022); https://doi.org/10.1117/12.2628334
[13] E. Redaelli et al., "MAORY@ELT: Optomechanical preliminary design", Proc. SPIE 12185, Adaptive Optics Systems VIII, 121854Q (29 August 2022); https://doi.org/10.1117/12.2629864
[14] M. Aliverti et al., "MAORY@ELT: Thermal Control System preliminary design", Proc. SPIE 12185, Adaptive Optics Systems VIII, 121854P (29 August 2022); https://doi.org/10.1117/12.2629908
[15] V. Cianniello et al., "Global to Local FEA validation for complex geometries: submodeling technique applied to mechanical structures for ELT class of instrumentation", Proc. SPIE 12184, Ground-based and Airborne Instrumentation for Astronomy IX, 121842O (29 August 2022); https://doi.org/10.1117/12.2628332

[16] C. Eredia et al., “Trade-off between different PLC based architectures of Instrument Control Hardware for ESO ELT class of instrumentation”, Proc. SPIE 12184, Ground-based and Airborne Instrumentation for Astronomy IX, 1218432 (29 August 2022); https://doi.org/10.1117/12.2628954
[17] E. Cascone et al., “General overview of MORFEO (formerly known as MAORY) Instrument Control Hardware design”, Proc. SPIE 12184, Ground-based and Airborne Instrumentation for Astronomy IX, 1218431 (29 August 2022); https://doi.org/10.1117/12.2628936
[18] M. Riva et al., “MAORY@ELT: System Engineering activity up to preliminary design review”, Proc. SPIE 12187, Modeling, Systems Engineering, and Project Management for Astronomy X, 121871O (25 August 2022); https://doi.org/10.1117/12.2630353
[19] V. Cianniello et al., “FE model evolution of the main support structure interfaces to the ELT Nasmyth Platform: from PDR to FDR”, Proc. SPIE 13096-227, in these Proceedings, (2024).
[20] D. D’Auria et al., “A look into alternative mechanical designs for the MORFEO-MICADO thermal duct mechanical: developments and alternatives”, Proc. SPIE 13096-201, in these Proceedings, (2024).
[21] C. Eredia et al., “Implementation of safety functions through dedicated PLC modules for astronomical ground-based instrumentation”, Proc. SPIE 13098-109, in these Proceedings, (2024).
[22] E. Cascone et al., “General overview of MORFEO instrument control hardware during the final design phase”, Proc. SPIE 13096-212 (2024), in these Proceedings, (2024).
[23] E. Redaelli et al., “MORFEO @ ELT: testing of the kinematics connection for the optomechanical elements”, Proc. SPIE, 13096-209 (2024), in these Proceedings, (2024).
[24] M. Riva et al., “MORFEO@ELT System Engineering after PDR, MBSE and beyond”, Proc. SPIE, 13099-70, in these Proceedings, (2024).
[25] P. Ciliegi et al., “MORFEO: the adaptive optics module for ELT”, Proc. SPIE, 13097-75, in these Proceedings, (2024).