Executive Summary Report
MISTER

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Issue history

Issue	Date	Changes summary
0	2021/10/18	Initiation of the Document

CONTENT

0 SCOPE OF THE DOCUMENT

The present document describes the findings of the MISTER activity, providing a brief overview of the whole project, main findings, conclusions and follow-on guidance.

0.1 APPLICABLE AND REFERENCE DOCUMENTS

0.1.1 Applicable documents

ID	Reference	Name
AD01		

0.1.2 Reference documents

ID	Reference	Name
RD01		

1 INTRODUCTION

The targeted product of this development activity is SATLANTIS' iSIM-170 very high-resolution optical imager for microsatellites in Earth Observation (EO) LEO mission. This product is a versatile instrument that can cover multiple EO applications such as coastal ecosystem monitorisation and border surveillance.

iSIM-170 is based on SATLANTIS' proprietary iSIM technology, this is, a technology that combines a compact and efficient diffraction-limited optomechanical design, with the latest advances in electronics (both in detectors and processors), image processing algorithms, the use of commercial-off-the-shelf (COTS) components, and the incorporation of advanced manufacturing procedures. Through the use of these cutting-edge technologies, iSIM significantly reduces delivery times, and aims to provide a new level of affordability to the EO sector, without compromising performance.

The imager works as a staring imager, this is, it detects a two-dimensional field of view at once thanks to the use of matrix CMOS sensors with high frame rate and short exposure times. Therefore, during an image acquisition session, the imager captures a sequence of images with a common area of overlap that are combined to create a super-resolved image. Furthermore, the design of the target payload is optimised to allow for super-resolution techniques that can improve the native spatial resolution of the imager by a factor between 2 and 3 and allow a significant reduction on the amount of data. This has a key implication for the EO sector: iSIM can reach a high spatial resolution with a reduced aperture size and thus overall reduced mass and volume.

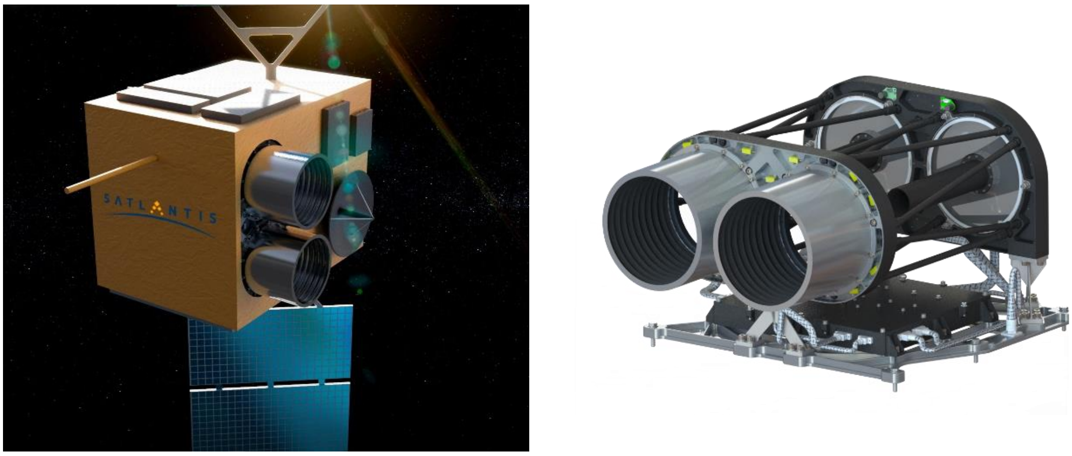

Figure 1-1: Illustration of iSIM-170 onboard a microsatellite (left) and render of the iSIM IOD technology demonstrator, iSIM IOD (right).

iSIM IOD FM was launched to the ISS on the HTV-9 mission on the 20th of May 2020 at 17:30 UTC (21 May at 02:30 JST) from Tanegashima Space Center (Japan) via the H-IIB launch vehicle. Once in the ISS, it was installed on the 10th of June 2020 on the i-SEEP external facility platform of the Japanese "Kibo" module and carried out nominal operations until the end of the primary mission on the 10th of September 2020.

2 DESCRIPTION OF THE ACTIVITY

For EO applications, spatial resolution is a key specification and a major deciding factor when selecting an appropriate instrument. However, optomechanical payloads are sensitive to temperature effects and guaranteeing high-spatial resolution requires very high structural and thermal stability. This aspect is yet more critical in small satellites since they face capability limitations related to reduced volume, mass and power.

In particular, the mass-to-spatial resolution of iSIM-170 is a differentiating advantage and a major “selling point”, with a target value below 1m resolution. Current development status of the baseline technology has derived in the need of a deep understanding of the thermal behaviour under a wide range of environmental and operational configurations, that would result in an exhaustive control of the optical performance of the payload to obtain a reliable product into the market that will lead to more trust from customers.

Furthermore, the development plan beyond iSIM-170 baseline technology relies on the applicability of multi-temperature scenarios. Therefore, the thermal solution of the payload must be easily adaptable and not rigid, in order to operate in a wide range of platforms and orbits.

In this context, MISTER De-Risk activity is focused on the detailed analysis and deep understanding of the thermal behaviour of the iSIM-170 camera.

Taking this into account, a specific De-Risking activity focused on the detailed analysis and validation of thermal behaviour-related activities is proposed as the first phase of the fully-fledged activity.

In order to reach the main technical objective, a deep understanding of the whole influencing parameters from design to integration phase will be characterised and analysed.

3 FINDINGS

3.1 Thermal Subsystem Design

Within the scope of MISTER De-Risk activity, several subsystems have been developed and integrated in the iSIM-170 baseline design. These are the shutter mechanism, the active and passive TCS and the detector subassembly. Each of these subsystems are described below:

3.1.1 Shutter Mechanism

To protect the photosensitive surface of the detector from any potential incident solar light during tumbling phase of the satellite, the camera baseline design has been equipped with a detector protection mechanism (shutter mechanism). This mechanism consists on (1) a mechanical subsystem based on a stainless steel thin plate attached to a constant force spring that enables the system activation and an end-stop made of Teflon to damp the subsequent shock load, and (2) an electronic subsystem formed by a PCB that contains two resistors (main and redundant) and a micro switch that interrupts the current flow as soon as the mechanism is activated. These elements are depicted in the figures below:

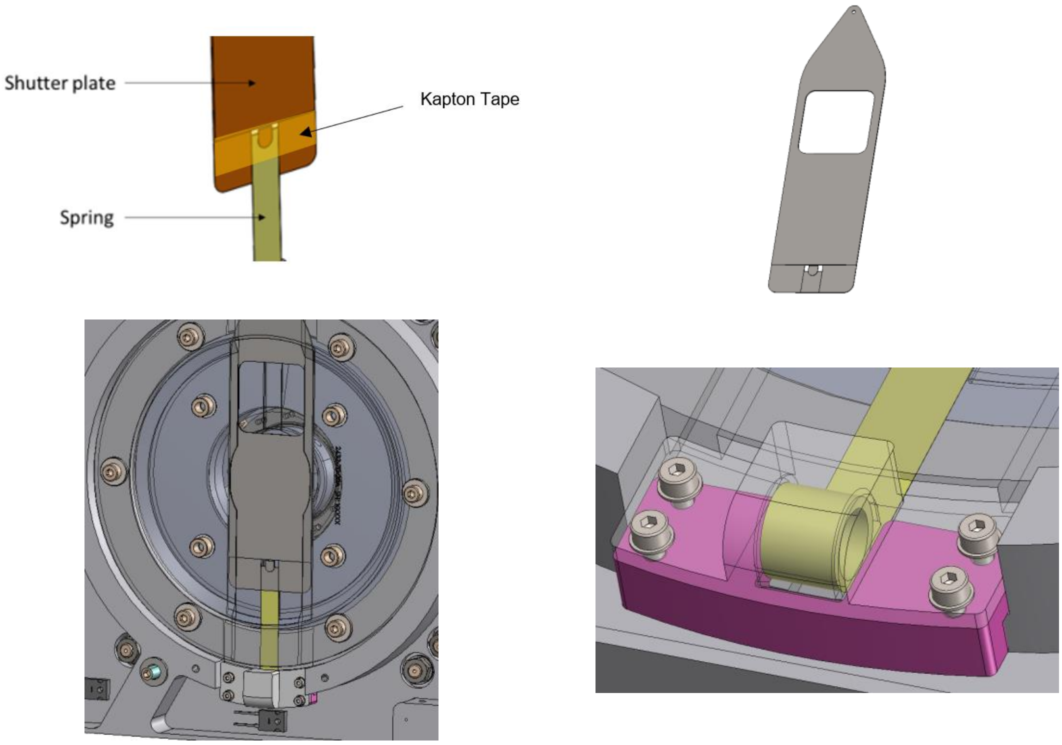

Figure 3-1 Shutter Mechanism mechanical elements

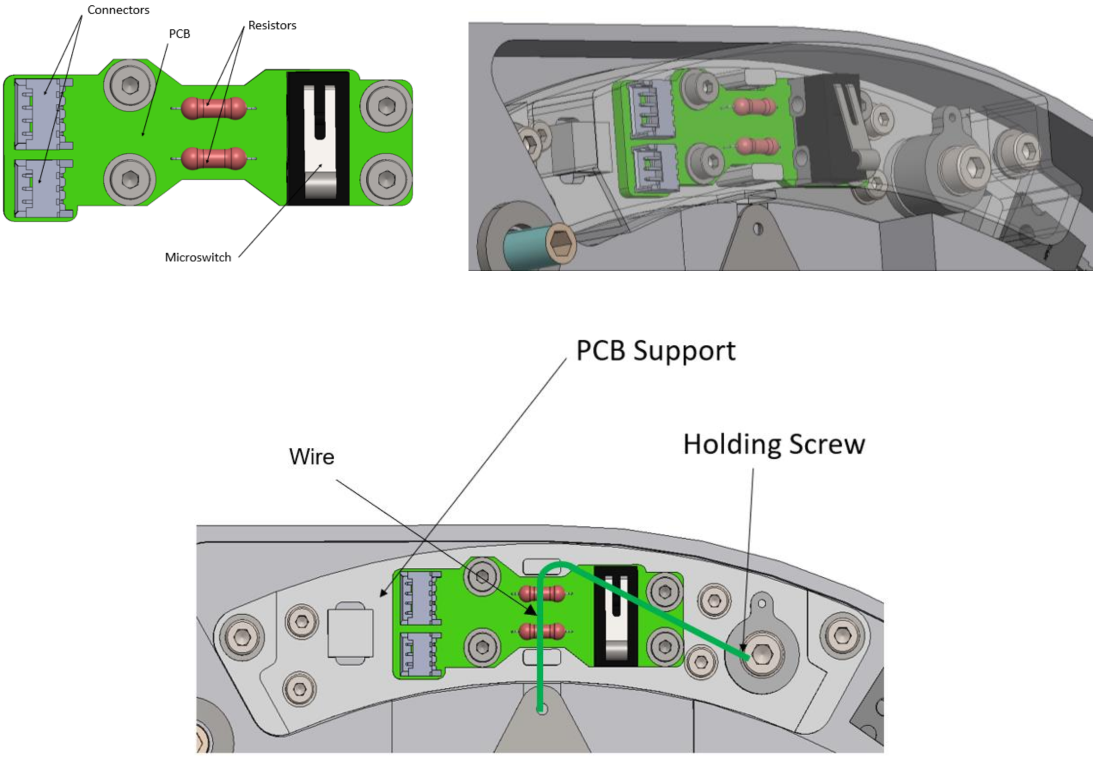

Figure 3-2 Shutter Mechanism electronic elements

3.1.2 TCS

Since the optimal focus of iSIM-170 is reached when the structure's temperature is homogeneous and stable at 23±3.5ºC, a TCS has been designed to stabilize the structure's temperature if it is contained into the range from +5ºC up to +26.5ºC.

The TCS is divided in active TCS (heaters and thermocouples distributed along the whole payload structure) and passive TCS (MLI and SLI blankets installed around the structure and thermal straps attached to each detector aluminium covers).

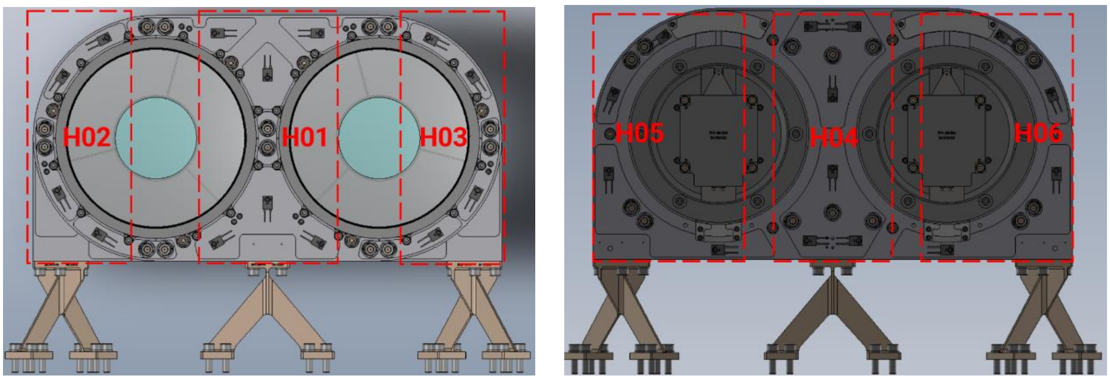

Figure 3-3 Front and Rear Plate heater distribution and channels

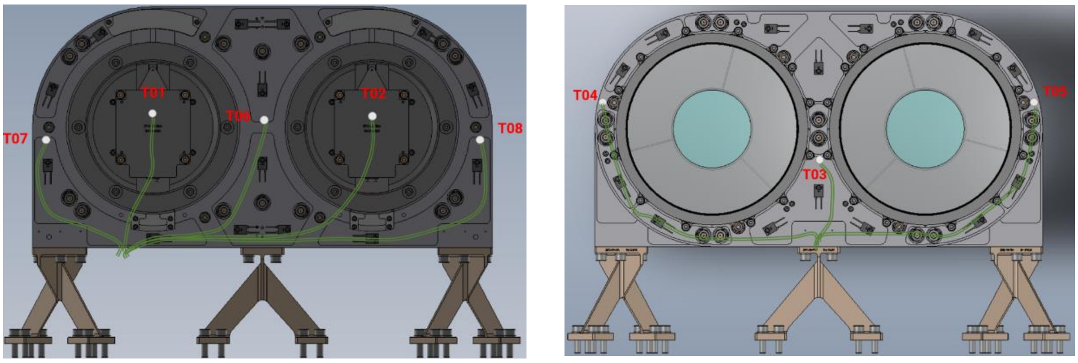

Figure 3-4 Front and Rear Plate thermocouples distribution

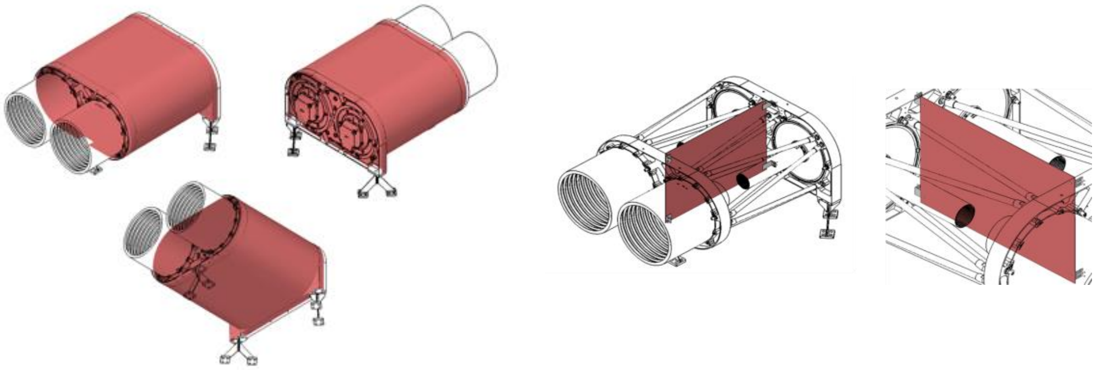

Figure 3-5 MLI and SLI general overview

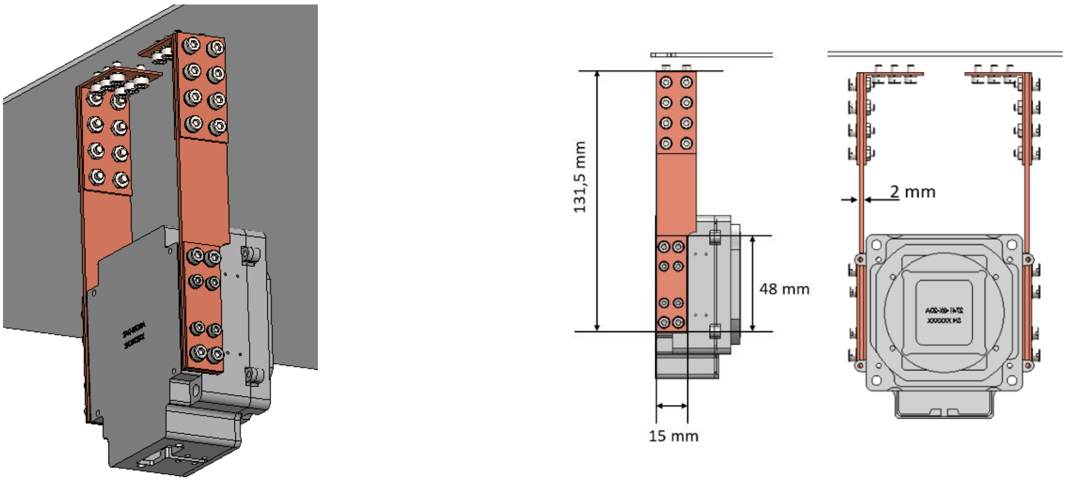

Figure 3-6 Detector thermal straps design overview

3.1.3 Detector Subassembly

The detector assembly is formed by the CMOS detector mounted on its PCB, the power supply PCB and the detector housing, which is composed by the detector support and the case.

In order to avoid the system overheating and efficiently guide the heat through the different elements of the assembly, some improvements have been added to the original architecture, such as dissipators and thermal interface material (TIM) contact pads.

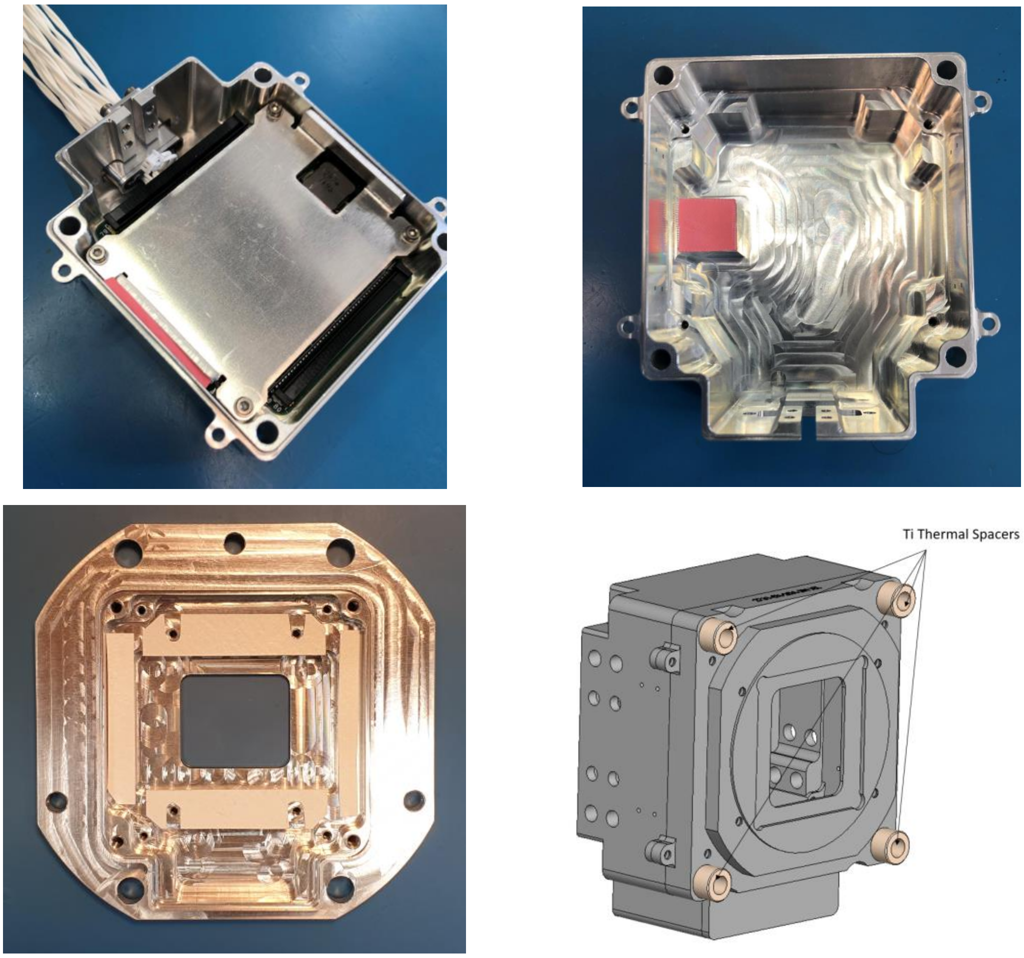

Figure 3-7 Detector thermal management improvements

3.2 Thermal Analysis

As part of the activity, a STOP analysis has been performed to verify the suitability of the previously described improvements.

First, the whole satellite platform with the camera payload inside and the auxiliary subsystems has been modelled to obtain the thermal conditions to which the camera would be subjected during the mission using ESATAN software. The thermal model and temperature map results are shown in the following figures:

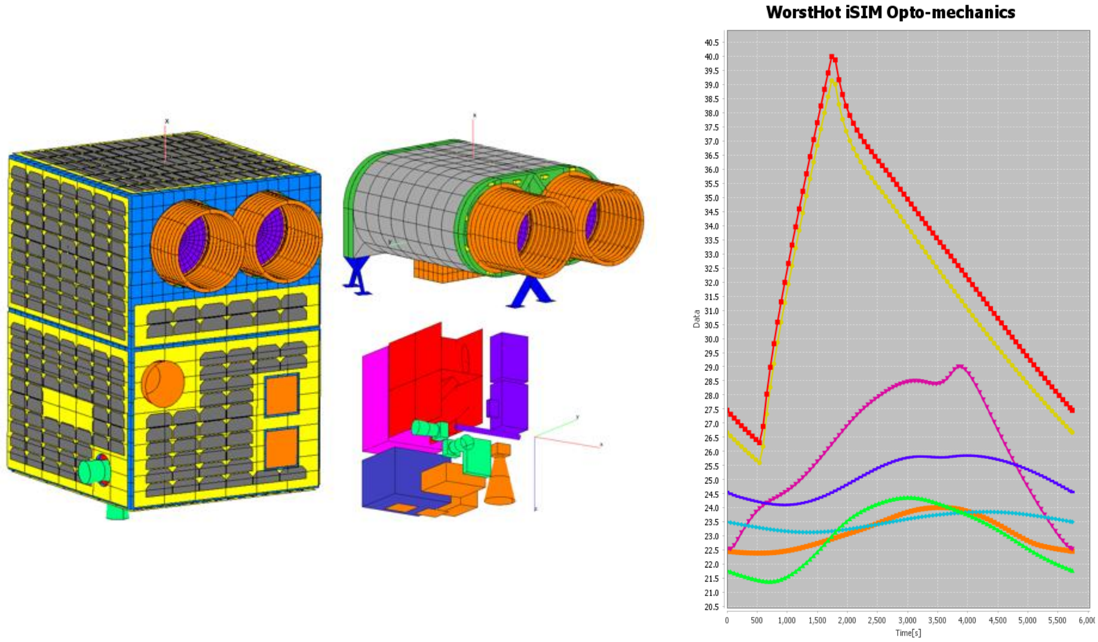

Figure 3-8 Satellite and payload thermal model and worst hot case temperature map

With the result obtained from the thermal analysis, a thermo elastic structural analysis has been performed using FEMAP simulation software. Stresses and deformation levels in the lenses have been obtained and inputted to SigFit optical software together with the temperature profiles. SigFit allowed the translation of mechanical inputs into optical parameters to evaluate the impact of external mission conditions on overall optical performance given by the camera by means of ZEMAX tool. The final results are shown below:

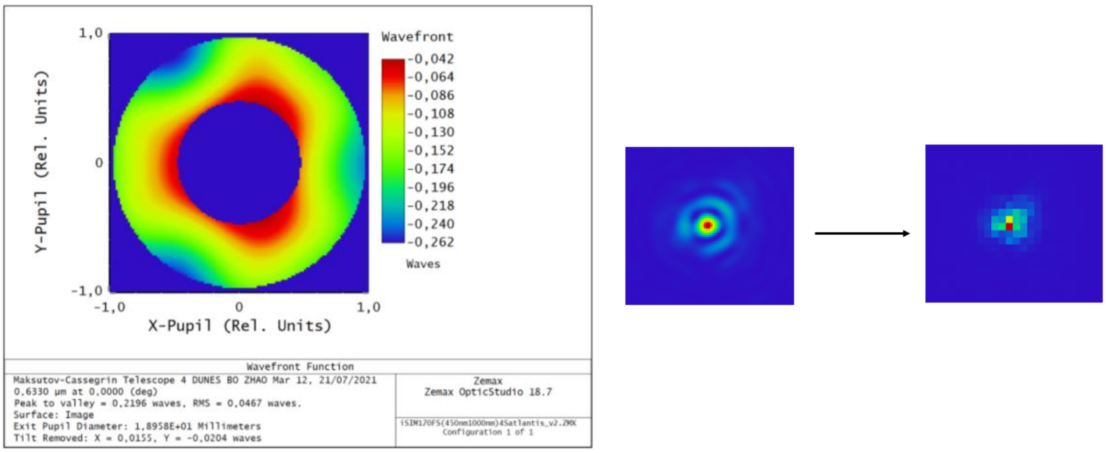

Figure 3-9 WFE and PSF results after ZEMAX analysis

3.3 BB Design and MAIT

In order to validate the initial design and calculations of all the camera subsystems within the scope of the activity, a BB specimen has been designed and built. The BB model was tested up to functionality levels to verify the conceptual design of each of the subsystems of the payload.

First, the MLI and SLI blankets were installed onto the structure and the active TCS (heaters + thermocouples) were positioned to test the TCS in vacuum environment.

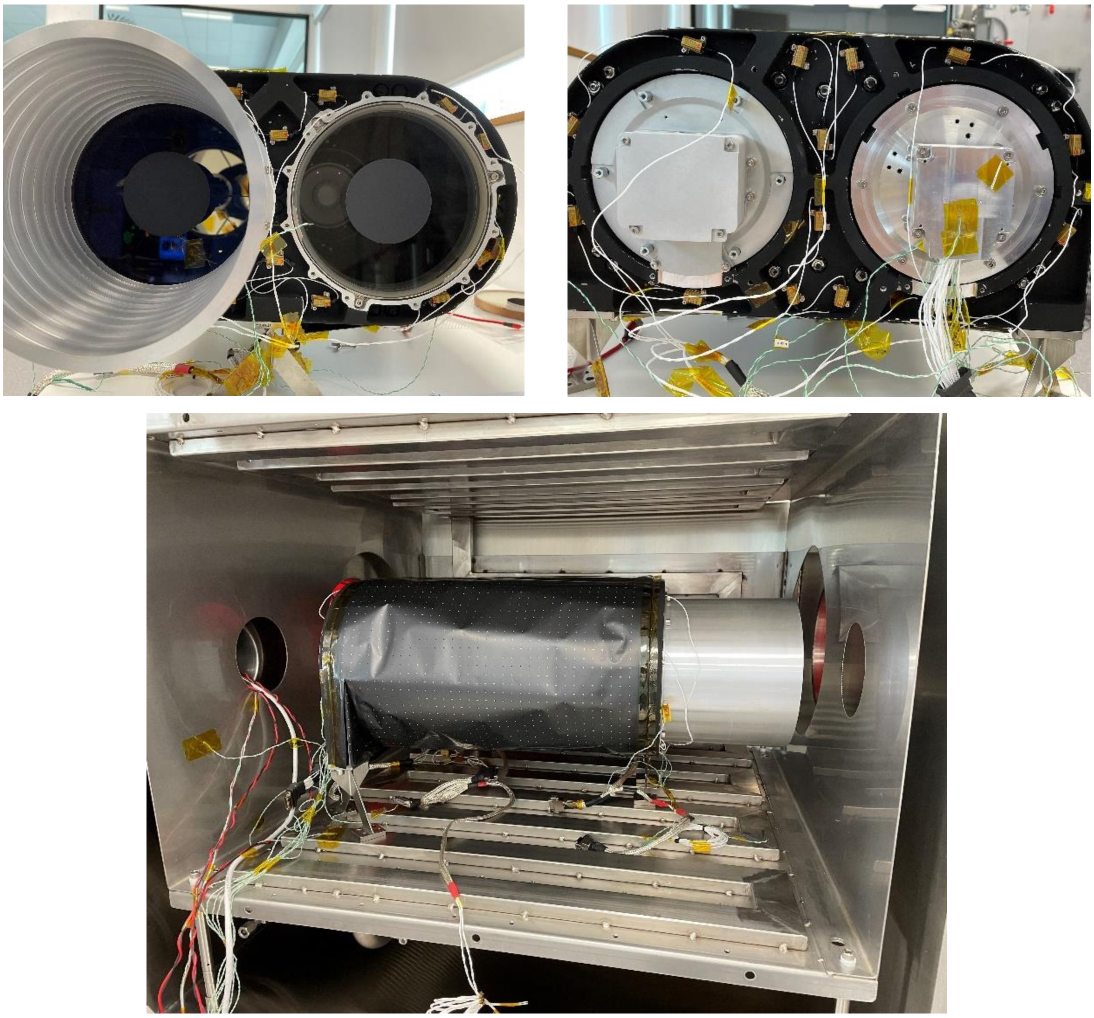

Figure 3-10 iSIM170 BB equipment

Also, the first concept of the shutter mechanism was proven with successful results.

Figure 3-11 Shutter mechanism activation sequence

During the final stage of the BB test campaign, both the detector subassembly and the thermal straps were tested.

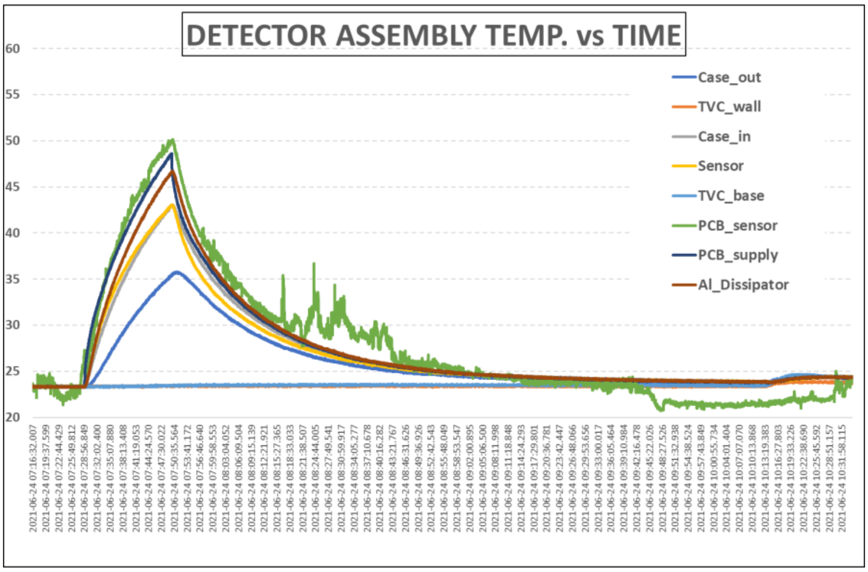

Figure 3-12 Detector assembly temperature evolution with time (20 minutes operation)

Figure 3-13 Copper and aluminium thermal straps mounted onto heat sinks

All the tests were successful and very relevant insights were obtained to the final design of the STM, described in the next section.

3.4 STM Design and MAIT

As the final stage of the activity, the STM model of iSIM-170 camera was designed from the conclusions and improvement points detected during BB test campaign and all the subsystems were assembled onto the main optomechanical structure. The STM test campaign covered physical, functional, optical, mechanical and thermal test to fully validate the evolved design of thermal subsystem.

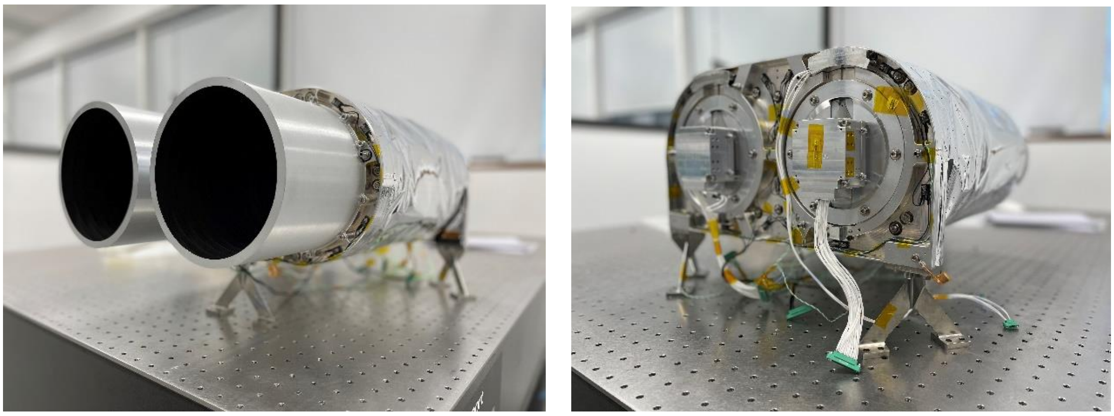

Figure 3-14 iSIM-170 STM fully assembled

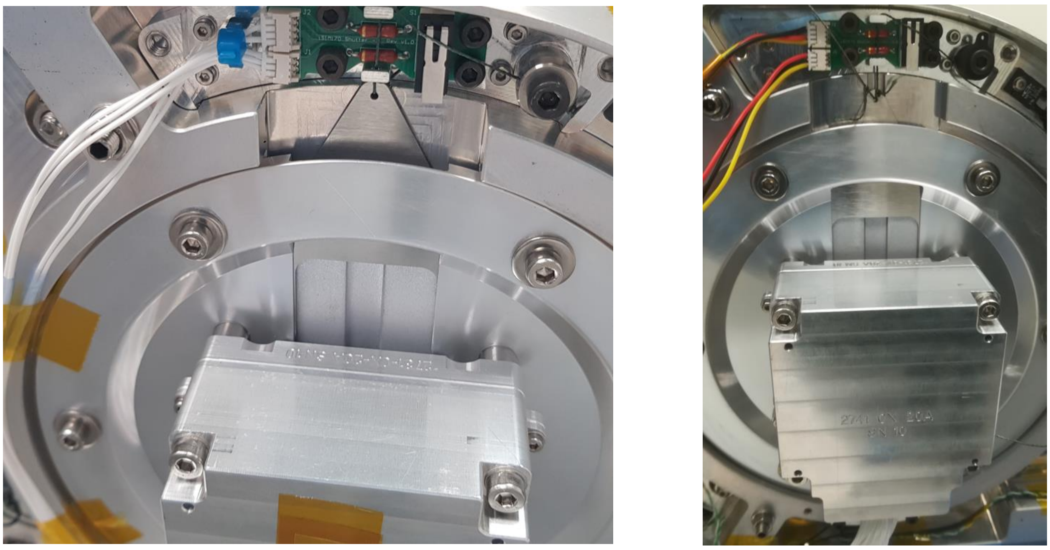

Figure 3-15 Assembled shutter mechanism

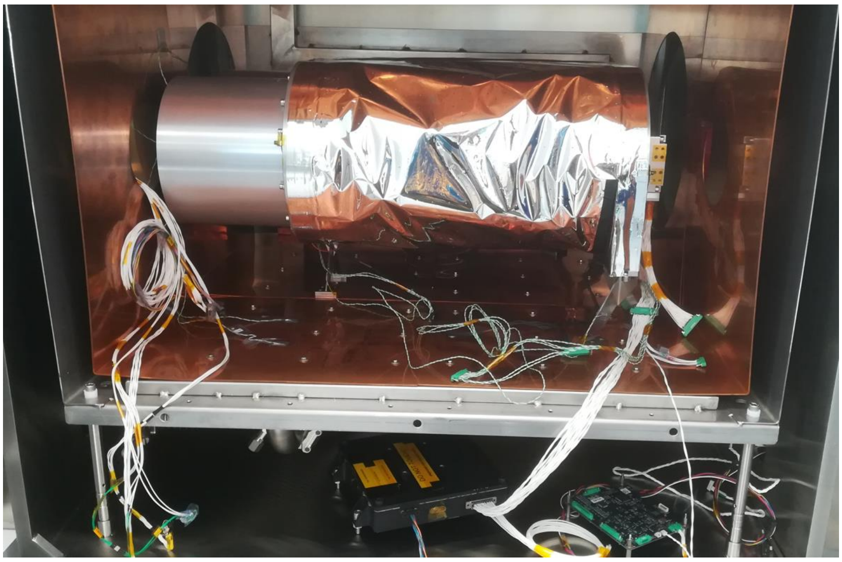

Figure 3-16 MISTER STM equipment inside TVC

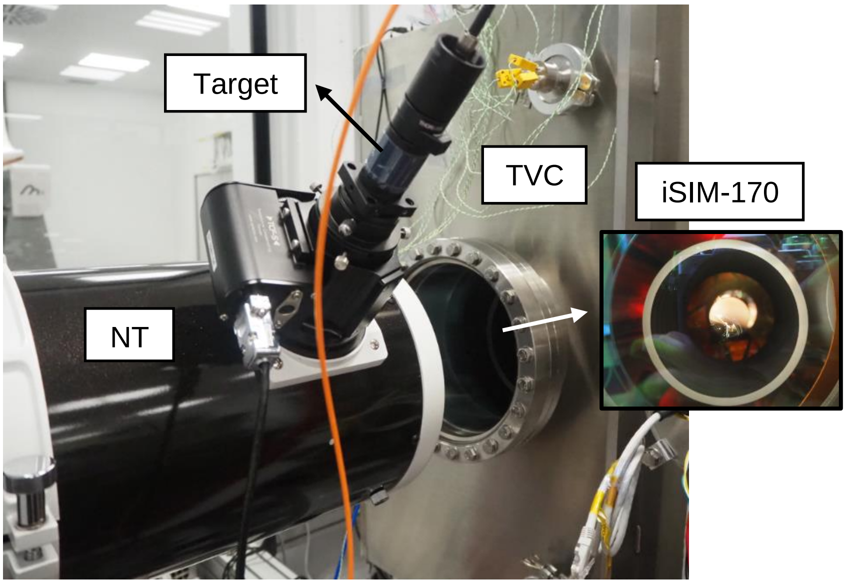

Figure 3-17 Setup for the optical test in the Thermal Vacuum Chamber (TVC). Detail of iSIM-170 seen through the optical window of the TVC.

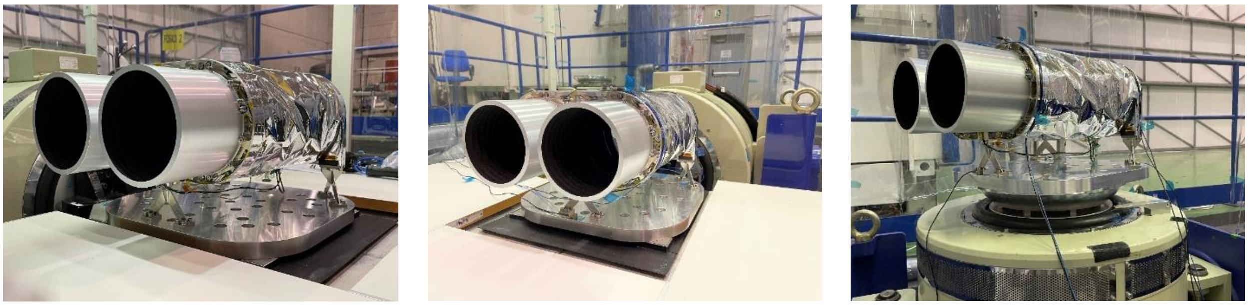

Figure 3-18 iSIM-170 STM during resonance search test in CTA facilities

4 CONCLUSIONS AND FOLLOW-ON

Three main thermal subsystems have been consolidated under MISTER De-Risk activity: (1) a shutter mechanism to protect the detector from solar light incidence during first stage manoeuvres of the mission, (2) an upgraded thermal control system with both active and passive elements to control and stabilize the structure temperature and (3) an improved detector assembly that enables a better thermal management of the hotspots within the baseline design.

During the whole design process several analysis iterations have been performed, forming a complete STOP analysis workflow that has started from the mission thermal boundary conditions and external loads and has given as a result the variations that thermally induced aberrations have in the overall optical performance.

To validate these subsystems design and concepts, first a BB design and testing phase has been executed obtaining very valuable improvements towards the final STM model.

In the future Follow-On activity these thermal subsystems will be upgraded taking as a starting point the lessons learnt from the recently concluded De-Risk stage.