E-ELT PROGRAMME

MICADO Phase A
MAIT Plan

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CHANGE RECORD

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ABBREVIATIONS AND ACRONYMS

AO	adaptive optics
CAD	computer aided design
CAE	computer aided engineering
ECSS	European Cooperation for Space Standardization
E-ELT	European Extremely Large Telescope
ESO	European Southern Observatory
FDR	Final Design Review
FTE	Full Time Equivalent (year)
GLAO	ground layer adaptive optics
GMT	Giant Magellan Telescope
JWST	James Web Space Telescope
LESIA	Laboratoire d'Etudes Spatiales et Instrumentations pour l'Astrophysique
LTAO	laser tomography adaptive optics
MAIT	Manufacture, Assembly, Integration, Test
MAORY	Multi-conjugate Adaptive Optics Relay
MCAO	multi-conjugate adaptive optics
MICADO	Multi-adaptive optics Imaging Camera for Deep Observations
MPE	Max-Planck-Institut für extraterrestrische Physik
MPIA	Max-Planck-Institut für Astronomie
NOVA	Nederlandse Onderzoekschool voor Astronomie
OAPD	Osservatorio Astronomico di Padova
PAE	Preliminary Acceptance in Europe
PAO	Preliminary Acceptance at the Observatory
PA/QA	Product Assurance / Quality Assurance
PDR	Preliminary Design Review
PSF	Point Spread Function
RTD	Real Time Display
SCAO	single-conjugate adaptive optics
TMT	Thirty Meter Telescope
USM	Universitäts-Sternwarte München
WP	Workpackage

1 APPLICABLE AND REFERENCE DOCUMENTS

1.1 Applicable Documents

The following applicable documents form a part of the present document to the extent specified herein. In the event of conflict between applicable documents and the content of the present document, the present document shall be taken as superseding.

AD1 Common definitions and acronyms , E-ESO-SPE-313-0066, Issue 1

AD2 E-ELT Interfaces for Scientific Instruments, E-TRE-ESO-586-0252, issue 1

AD3 Call for Proposal For a Phase A Study of a High Angular Resolution Camera for the E-ELT, Specifications of the Instrument to be studied, E-ESO-SPE-561-0097, v2.0

AD4 Statement of Work for the Phase A Design of MICADO, E-SOW-ESO-561-0127, v1.0

1.2 Reference Documents

RD1 Proposal “MICADO: the MCAO Imaging Camera for Deep Observations”, 12 Nov 2007, in response to the call CFP/ESO/07/17768/LCO

RD2 MICADO Instrument Development and Management Plan, E-PLA-MCD-561-0020, v1.0

RD3 MICADO Design Trade-Off and Risk Assessment, E-TRE-MCD-561-0010, v2.0

RD4 MICADO Opto-Mechanics Design and Analysis, E-TRE-MCD-561-0011, v5.0

RD5 MICADO Control Electronics Design, E-TRE-MCD-561-0013, v1.0

RD6 MICADO Top Level Instrument Software User Requirements, E-TRE-MCD-561-001, v1.0

RD7 MICADO Top Level Data Reduction User Requirements, E-TRE-MCD-561-0024, v1.0

RD8 MICADO Single Conjugate Adaptive Optics Module, E-TRE-MCD-561-0022, v1.0

RD9 MICADO-MAORY Phase A Interface Specification, E-SPE-MCD-561-0014, v1.0

RD10 MICADO-EELT Phase A Interface Information and Requests, E-SPE-MCD-561-0015, v1.0

2 SCOPE

This document outlines the manufacturing, assembly, integration, and test plan for MICADO.

3 INSTRUMENT DESCRIPTION

3.1 General Concept

The design of MICADO has been developed by combining the results and conclusions from parallel scientific and technical trade-off studies (see the Design Trade-Off and Risk Assessment, RD3). These have resulted in a concept for the camera that has a primary arm for direct imaging of a large field and an auxiliary arm for imaging a smaller field at a finer pixel scale as well as for spectroscopy.

The camera has been optimised to work with the multi-conjugate adaptive optics system MAORY (Figure 1 right); but during initial operations will operate with its own single-conjugate adaptive optics system (Figure 1 left).

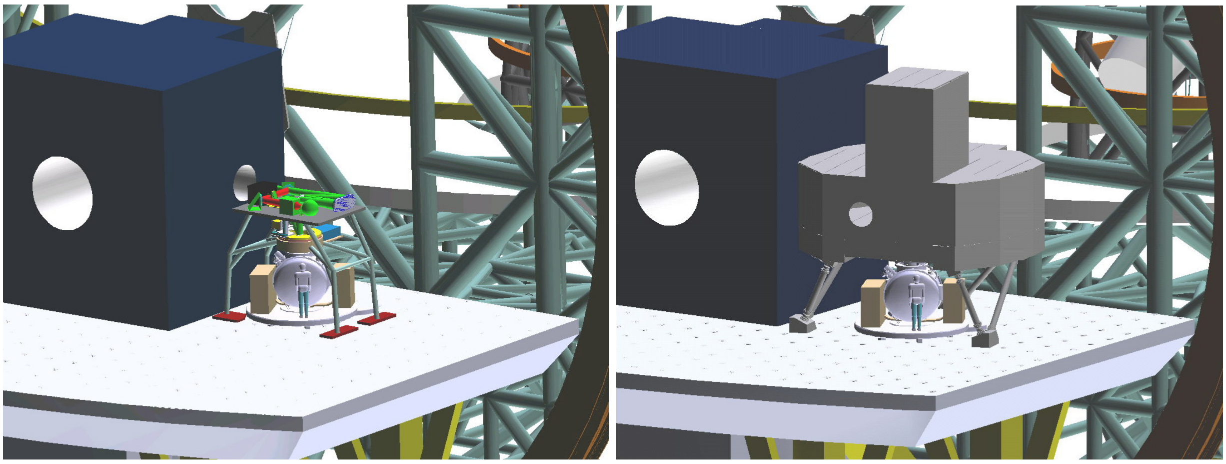


Figure 1: View of MICADO as it will be mounted in a gravity invariant orientation under the SCAO module (left) and under MAORY (right). For the SCAO module, the relay optics is mounted on the upper optical table together with the calibration unit (both will be covered).

4 GENERAL MAIT SCHEDULE

The general schedule for MAIT is shown in Figure 2.

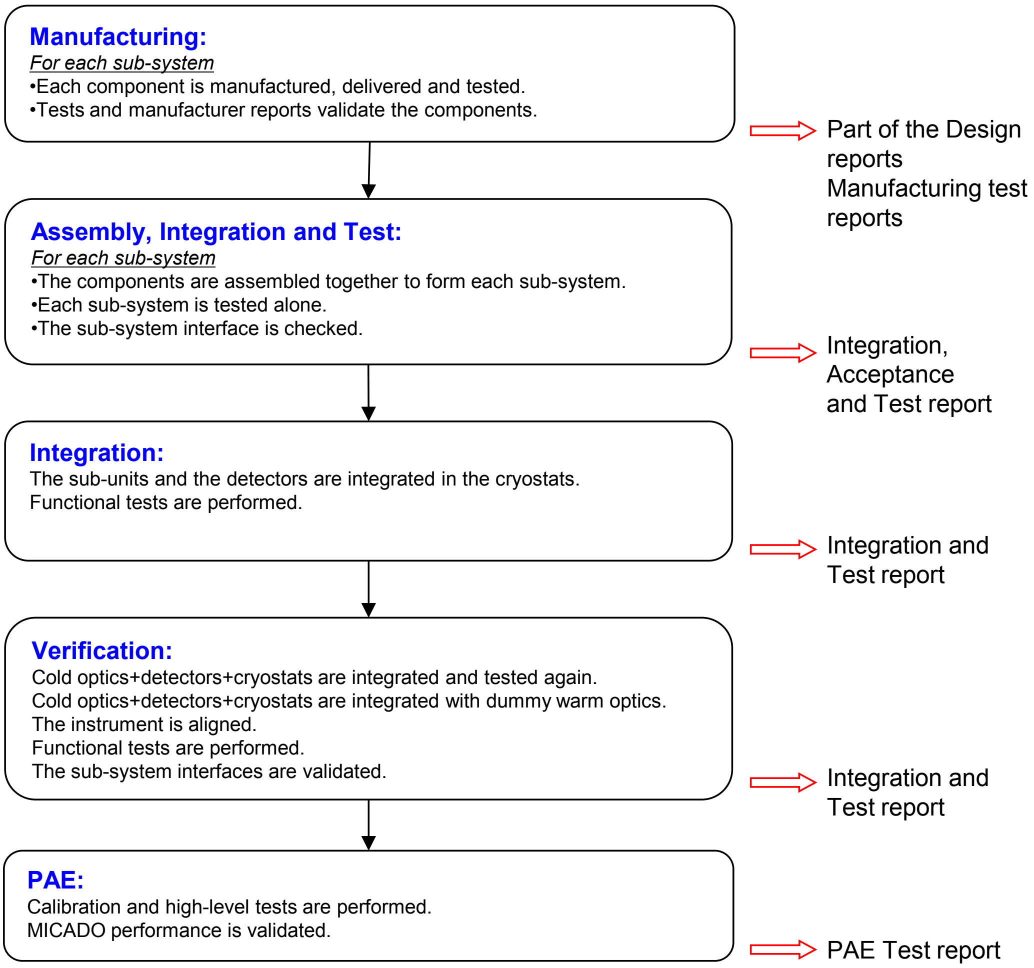


Figure 2: Overview of the manufacturing, assembly, integration and test plan for MICADO.

4.1 MAIT steps

The MAIT consists in the following steps:

- Manufacturing: the components are manufactured by institutes or delivered by manufacturers. Each component is validated after series of tests.

  The data sheets of the standard commercial components are included in the Design Reports of the different sub-systems. Manufacturing Test Reports give tests results of the other components. They also report non-conformances and their impacts on the concerned sub-system performance.

- Assembly, Integration and Test: during the assembly, the components of each sub-system are assembled together in different modules. These modules are integrated to form a sub-system. The modules are tested alone up to a certain level. The interfaces are validated. At the end of the AIT, each sub-system provides an Integration, Acceptance and Test report.

- Integration: the cryostat with cold optics and detectors are progressively assembled together. The sub-systems are tested together up to a certain level. Integration results are reported in Integration and Test reports.
- System Level Tests: the high-level tests of MICADO are performed in a continuous and routine way. This phase validates the end-to-end performance of MICADO and results in the system level Verification Matrix and the Preliminary Acceptance.
- PAE: the calibration and high-level tests of MICADO are performed under supervision of the system engineer. This phase validates the end-to-end performance of MICADO and results in the Preliminary Acceptance Europe

4.2 Location and responsibility

During the Manufacturing, the respective partners take care of the delivery and validation of the components which are parts of their sub-systems.

During the Assembly, Integration and Test of each sub-system, the respective partners ensure the coherence and the validation of the assembly, integration and tests.

During the MAIT steps, the responsible for each sub-system supervises the different tasks from the manufacturing to the validation of test procedures and the sub-system delivery. He delivers the reports to the System Engineer and the Project Manager, and advises them of any problem that could affect cost and planning.

If during the process, an item does not meet the specifications or needs to be repaired for any reason, the following procedure will be adopted:

- If it is possible to make a modification which does not affect the planning and cost, the responsible of the relevant sub-system takes care of it. He makes sure the manufacturing plans take it into account and submits a Non-Conformance report to the PA/QA manager.
- If the modification has an impact on the planning and cost, he informs the Project Office which takes appropriate action.
- If the item must be returned for complete manufacturing, or if another manufacturer must be found and a process is delayed, the responsible again informs the Project Office, which holds an emergency meeting to find the best way to solve the problem.

5 MAIT OUTLINE

MICADO consists of a cryostat holding the cold optics and periphery structures, as shown in Figure 3.

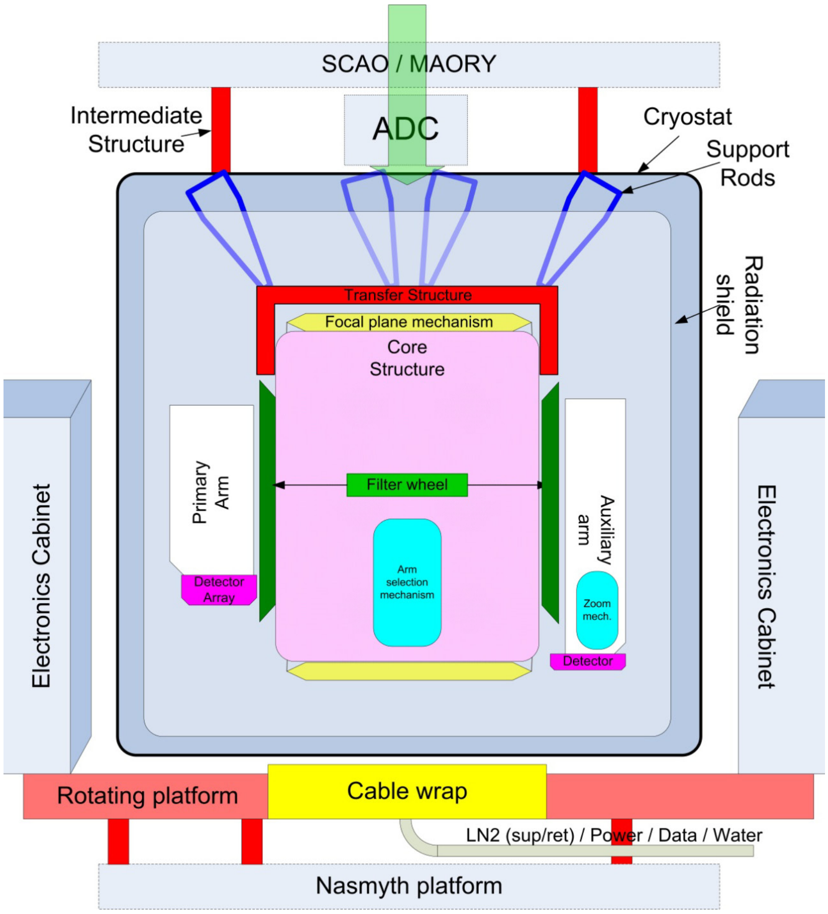


Figure 3: Schematic overview of MICADO

In the cold optics bench the following modules can de distinguished:

Modules	**FUNCTIONS**
Core structure	Holds all subsystems, the interface to the cryostat, cooling interfaces, and the arm selection mechanism
Filter wheels	Holds filters, prisms, grism and polarimetric components
Primary Arm	Holds the high resolution optics and the detector array.
Auxiliary Arm	Holds the zoom-mechanism and a detector
Focal plane selection mechanism	Holds masks and filters

In the periphery structures the following modules can de distinguished:

Modules	FUNCTIONS
Intermediate structure	Interface between the cryostat.and SCAO / MAORY
Cryostat	Is a CFC, holding electrical feedthroughs and window.
Radiation shield	Holds the MLI and cabling thermal sink.
Support rods	Stiff interface between cryostat wall and cold optics.
Transfer structure	Holds the cold optics. Converts a 3-point connection (Support rods) into a 4-point connection (Core structure)
Electronics cabinets	Holds Detector electronics, motor LCUs, cryo- and vacuum control
Rotating platform	Rotation is slaved to the cryostat. Holds the cablewrap and electronics cabinets
Cable wrap	Guide lines of data, electrical power, cooling water and liquid Nitrogen supply and return.

5.1 Cold optics Manufacturing

All parts are produced by design with tolerances that mean they will fit, function or perform according to their specifications. This is the standard way of producing and procuring parts and systems by ASTRON (as described in detail in ASTRON quality assurance plans), and MICADO may make use of the experience and facilities available at ASTRON for manufacturing and/or testing components. All drawings are reviewed by relevant and competent project members and revised accordingly. Parts are procured accompanied by a released drawing. Complex parts are accompanied by a procurement document, describing every aspect of production, materials, tools, handling and shipment. After production, all parts are at least verified with respect to their critical dimensions and tolerances. By critical is meant: fittings, form and position tolerances, other tolerances and interfaces. Verification is performed where possible by ASTRON or subcontractor based on measurement drawings. A general incoming inspection will be performed on all parts. Typically the packaging, indicators (shock, humidity), appearance, damage, and paperwork are assessed. The material used, production steps, processes applied, and measurement reports are collected in production reports. Production aids, optics witness samples and spare parts are stored at least for the period of guarantee.

5.2 Production Order:

Optics: Directly after FDR, procurement of optics and specific long lead items is started. Once reviewed, optics production ordering can start, based on drawings and/or procurement documents.

Transfer Structure: Production of the transfer structure will start first after FDR, since the Core structure needs a parking structure

Core structure: Is a mechanism by itself and needs to be tested in an early stage.

Mechanisms: All mechanisms are subject to functional verifications. Some can be verified as "stand-alone" items, while others need to be verified in their module.

Auxiliary arm: Holds a mechanism and can support functional verification.

Primary arm: Holds critical optics and shall be verified.

Cryostat: Needs to be adjusted in operational condition. A STM is recommended to allow cryostat adjustments.

Periphery: Intermediate structure, Rotating platform and cable wrap are prone to be outsourced. There is not foreseen to be critically dependent on other components or sub-systems.

The order of production will be presented at FDR. Electronics are considered as a module.

5.2.1 Optics

Small flat mirrors may be polished in-house (e.g. at ASTRON) and coated by manufacturers (e.g. Philips Nat-lab). Most other components are outsourced. The optical elements are outsourced based on a procurement document, describing all mechanical, optical and packaging details. Optical verifications are described in Section 4.2.4.1.

5.2.2 Mechanics

Simple parts are made in-house by conventional production techniques such as turning, drilling and milling. More complex parts are CNC-milled or turned. Optical parts or high precision parts made of aluminium are subject to an elaborate thermal process reducing thermal/mechanical stress. All parts are subject to a thermal aging process in order to guaranty mechanical stability over time. Performance and therefore the design of mechanisms is based on experience. This ensures that mechanisms are prone to perform according to specification. New types of mechanism are subjected to qualification tests. Optics is positioned by design and the clamping techniques used are based on experience. New types of clamping are subject to qualification tests. Mechanical verifications are described in Section 4.2.4.2.

5.3 Design qualification tests prior to FDR

A set of tests has been defined to qualify applicability of some principle designs and processes. These tests are generally done before FDR and are performed on a test bench.

5.3.1 Focal plane mechanism

This is a chain of carriages holding filters and masks, and is driven around the Core structure. The design is based on the MIDI-rail system, and this mechanism needs qualification tests. For this test the Core Structure and the Transfer Structure are needed, as well as motor electronics and LCU. These mechanisms will be verified at room temperature on:

- functional performance
- accuracy / reproducibility
- speed
- travel

- handling
- (lifetime)

Cryogenic performance will be recorded after integration.

5.3.2 Arm and zoom selection mechanism

For this test the Core Structure, the Transfer Structure and the Auxiliary Arm are needed, as well as motor electronics and LCU. These mechanisms will be verified at operational temperature on:

- functional performance
- accuracy / reproducibility
- speed
- travel
- pointing
- handling
- (lifetime)

5.3.3 Filter wheels

For this test the Core Structure and the Transfer Structure are needed, as well as motor electronics and LCU. These mechanisms will be verified at room temperature on:

- functional performance
- accuracy / reproducibility
- speed
- travel
- pointing
- handling
- (lifetime)

Cryogenic performance will be recorded after integration.

5.3.4 Core structure

The thermal behaviour of the “cooling highway” of the cold optics will be verified. A copy of the real core structure, armed with dummy masses will represent the cold optics during thermal test on the cryostat.

5.4 Detailed verification of components

All parts, mechanical or optical, procured or made in-house, are subject to measurements of the physical dimensions. These 3D mechanical measurements are performed in-house or by subcontractors.

5.4.1 Optical components

Verifications of optical parts concerns mechanical shapes of optics, translucent behaviour (@633nm), surface quality, focal distance measurements (@633nm), spectral transmission and spectral reflection. The characteristics will fit with the following requirements:

- Optical surface quality in P-V@ 633 nm by interferograms.

- Dimensions/thickness/face parallelism.
- Wedge angles for prismatic optical elements.
- Curvature for conic optics or focal distances
- Spectral transmission and reflection curves of material, coating, AR, glue in the p- and s-direction.
- Spectral curves for spectral filters.

All coated optics are accompanied with a witness sample of the same material and coated in the same coating run. These witness samples may be subject to performance tests on their transmission or reflection. The witness samples will accompany the optics until the moment they are finally integrated. Afterwards, the witness samples are stored under nitrogen protection as reference pieces. When parts are delivered, the measured values are compared with the procurement document or production drawings and accepted, modified or rejected. Production aids, optics witness samples and spare parts are stored for the period of guarantee.

5.4.2 Mechanical components

All mechanical components are subject to dimensional verification. Simple components are measured with standard measuring tools like callipers, calibres, angle gauges and micrometer gauge. The measurement accuracy is generally in the order of 10 μm. These simple parts are verified according to the specifications on the production drawings.

More complex components are CNC-milled or turned. The general production drawing only contains overall dimensions and general specifications of the component. A special measurement drawing will accompany the part for 3D measurements. This drawing outlines the important dimensions and tolerances, as well as shape and position tolerance. The measurement accuracy is generally in the order of 3 μm. A specialist evaluates the 3D measurement results and decides whether the part is within specification (according to the measurement drawing).

As described in RD5, tolerance of optical parts and/or critical interfaces is a result of tolerance distribution, based on the optical tolerance analysis. All parts are produced based on reviewed and released drawings and models. Of the more complex parts, which will be manufactured on CNC machines using computer generated models, only essential dimensions and tolerances are presented on drawings. These dimensions and tolerances shall be verified by metrology. The results are stored in production report, accepted and the parts released for assembly.

When the results do not match the design, a non-conformance report (NCR) is released, describing the deviation and the optional correction. In addition, changes made during assembly and integration are recorded in NCRs. The drawings, production and metrology reports and the NCRs are together defined as the “as-built” documentation. In the project frame, the procedure described in Section 4.1.2 is followed. Parts for which the production is outsourced are subject to a quality assurance policy (e.g. that applied at ASTRON) and will be treated this way. When it is stated that parts are aligned by design, the procedure described above is applicable. This procedure is a standard way of instrument building and therefore an essential part of the quality assurance.

All aluminium parts are coated with alodine coating and parts that are (potentially) facing optical beams are black painted. On "paint-drawings" is indicated what zones shall be free from paint. All aluminium parts are subject to thermal treatments. The goal of this treatment is to prevent deformation of finished parts due to aging of the aluminium. Thermal treatment reports are part of the production reports of parts.

5.4.3 Electrical components

Electrical components are verified by evaluating the accompanied reference or calibration documents. Once wired and assembled, connectivity tests will consequently check all electrical parts and resistor values are recorded. We note that this is not applicable with the detectors. No electrical measurements will be performed on the connectors due to the risk of electrical discharge. Electrical parts or systems will be purchased in accordance with the E-ELT standards.

5.5 General philosophy of the Cold optics AIT

5.5.1 Support equipment

Depending on the design, each module may need a specific baseplate for testing. The goal is, however, to design the sub-units in such manner that they directly interface to test aids and supports. If the instrument is transported in its cryostat, a special (suspended) support structure will be needed. A lit-frame will be designed to lift the instrument with and without the transport support structure onto the transport crate or telescope.

A support structure that can hold the weight of MICADO is needed. Possibly the VISIR telescope simulator can act as an instrument support. A dummy intermediate structure may be needed. An E-ELT optical simulator will feed MICADO with light in the operational bands, with the same f-ratio and if possible with the same pupil size and location. Standard optical lab equipment will be needed. This includes an interferometer, alignment telescope, auto-collimators, infrared camera, infrared sources, spectrometer, alignment laser, targets, reference flats and prisms.

For handling the cryostat, the best option appears to be a trolley that runs on temporary rails, as shown in Figure 4. This can be used both in the lab, and is also foreseen for use on the Nasmyth platform since it has minimal impact on the AO systems.

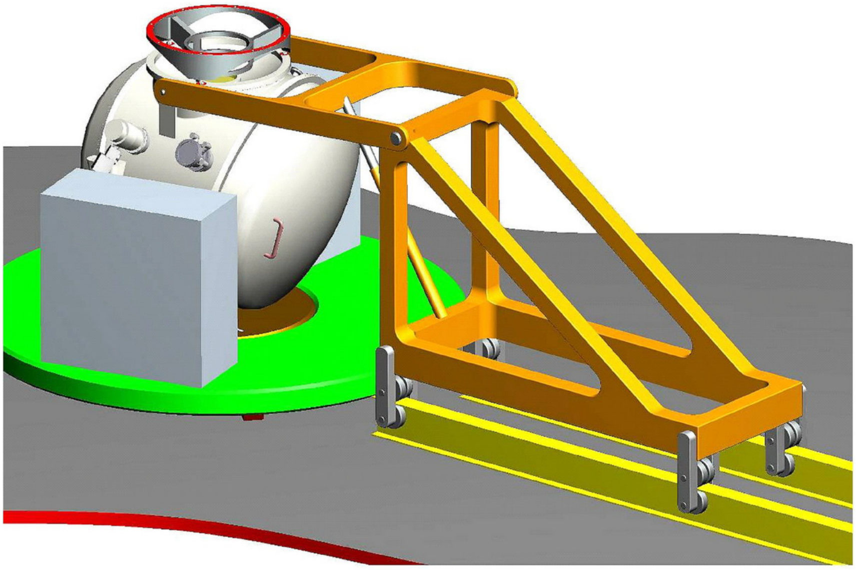


Figure 4: Illustration of the rolling trolley foreseen for handling the MICADO cryostat.. This can be used both in the lab and on the Nasmyth platform. The trolley runs on rails that are installed temporarily.

5.5.2 Assembly, test and integration general description

<u>ASSEMBLY</u>: Once parts are tested and accepted, they are assembled according to assembly drawings, design reports and procedures. It is assumed that every module can be assembled and tested "stand-alone". Parts are assembled with standards fasteners, combined with conical spring washers. These washers allows for sustaining mechanical connections while cooling (and thus shrinking) the instrument to operational temperature. All heaters, sensors and thermal switches are mounted to their structures with a layer of indium between. Solder connection are made with lead-free solder. Wiring is clamped to structural walls. Unshielded cabling is supposed to be routed closely over structural plating. The plating will act partial as shielding.

<u>ENVIRONMENT</u>: Mechanical parts undergo a surface treatment (chromated) and are packed in a clean environment. Until assembly, parts are stored in a protective environment and are only unpacked in a clean environment. Optics and witness samples are stored in a nitrogen flushed cupboard with restricted access. All parts are assembled in a clean environment, the cleanliness levels of which will need to be agreed. Assembled modules are treated as parts. When an assembled unit contains optics, the unit is stored in a nitrogen atmosphere. When the cold optics are under test and not mounted inside the cryostat, the covers of the cold optics box are closed.

<u>PROCEDURES</u>: An assembly procedure will be written to module level and added to the design description of the particular module. In general modules are assembled, tested and stored in a clean environment (packaging), waiting for integration. Details of the assemblies will become available at FDR since detailed designs of modules are not in the scope of PDR. All screws will be tightened with a prescribed torque. Torque tools are calibrated. Applied

mechanical assembly support tools will be described in the assembly procedure, as well as specific tools.

TESTING: Assembled modules will be tested or verified according to their specifications. In many cases the assembly is the only way to prove that the individual parts conform to their specification, by testing them in assembly.

5.6 MICADO integration and tests

This Section describes the principle behind the performed verifications and tests in the relevant disciplines. Most of the cold optics is aligned by design. It is expected that all sub-units can be tested 'stand-alone', but have to be integrated in order to verify the alignment with respect to the instrument.

5.6.1 Optical tests

Testing of integrated optics means the test of an integrated module in the same manner as a single component. In this part of the test sequence, the optics are aligned within the specific substructure, for example the camera. In cases where the mounting of the optics is identified as critical, the mount itself needs to be tested with optical methods. Additional optics may need to be designed in order to condition beams appropriately. Examples are null-lenses, baffling, and fiducially marks/points. Image quality at the operational wavelengths can only be recorded in the cold, because the camera is not transparent to visible light. Despite this, experience shows that optics can be positioned within the tolerances by design. Furthermore, focus and optimal image plane angle will be found by adjusting the detector focal plane array.

5.6.2 Opto-mechanical tests

Coldstop alignment is done to production accuracy. Roundness may be recorded with a profile projector. Intermediate distances are verified by design and 3D measurements.

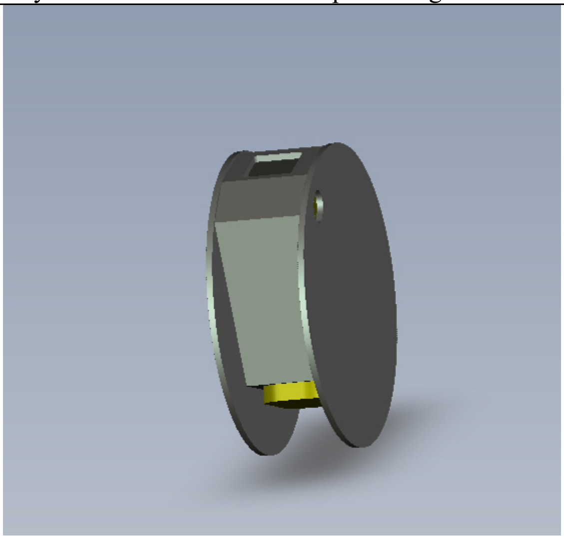
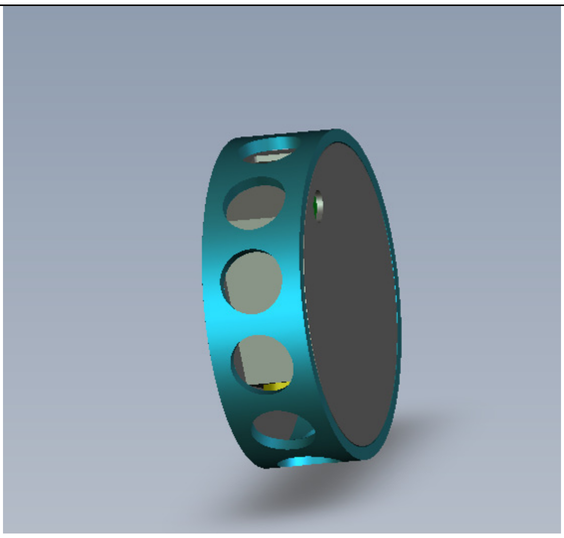
5.7 Deliverables

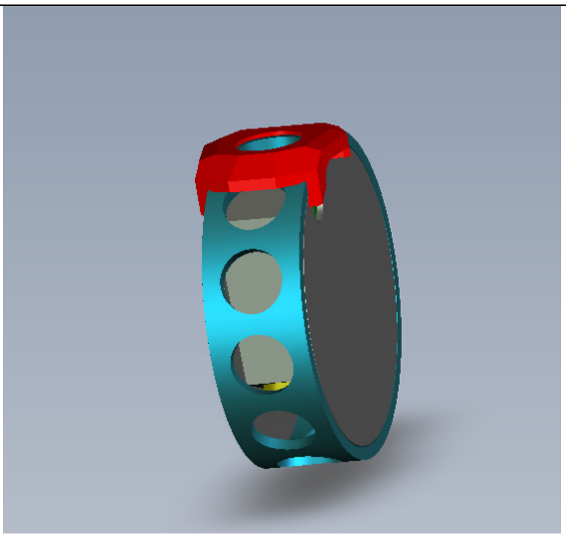
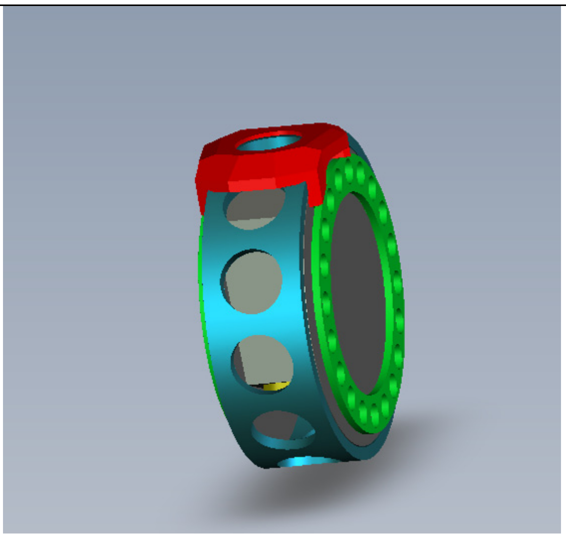
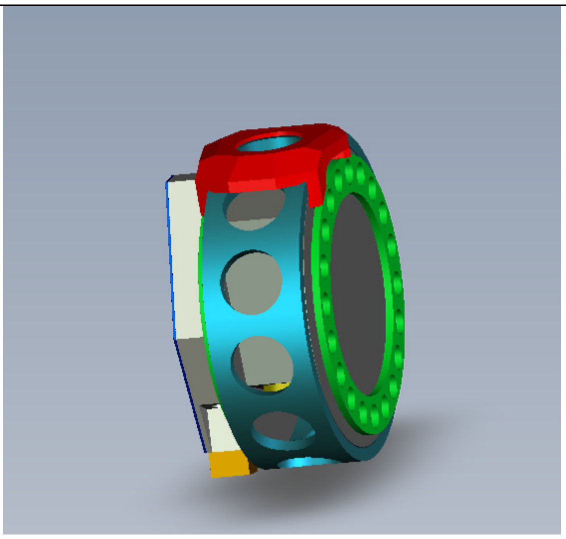
At the end of the MICADO assembly and integration phase, alignment in the operational wavelength is achieved. A cold aligned MICADO will be delivered. The remote devices will be tested and delivered functional. Finally, the intermediate structure, cable wrap, and rotating platform will also be delivered.

6 INTEGRATION STORYBOARD

In this section we outline the 'storyboard' for MICADO integration. The pre-condition is that all sub-systems are assembled and tested, ready for integration.

Table 1: storyboard for MICADO cold optics integration

1		Position the core structure on a temporary assembly structure. Assemble all optics, the Arm Selection Mechanism and all sensors, heaters and wiring. Verify functioning of mechanism
2		Assemble the Focal plane mechanism and the motors. Verify functioning.

3		Assemble the Transfer structure. The instrument can now be handled by the Transfer structure. (The temporary assembly structure can be removed.)
4		Mount the primary arm and auxiliary arm filter wheels. Mount their motors and verify their functions.
5		Mount the Auxiliary arm with the Zoom mechanism inside. Verify their function.

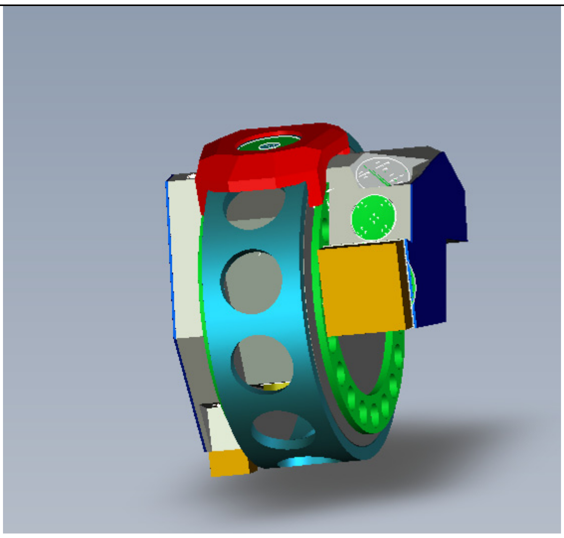
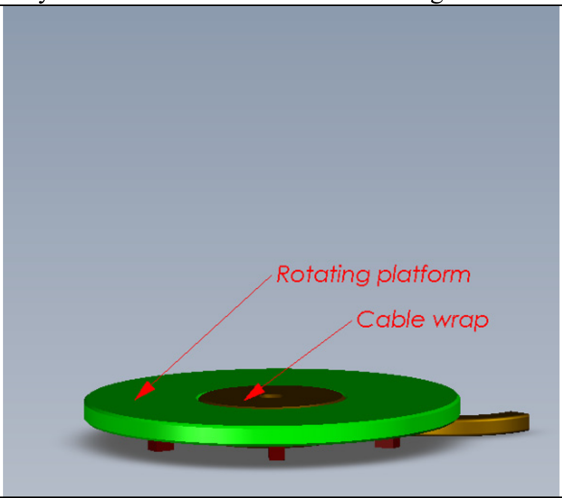
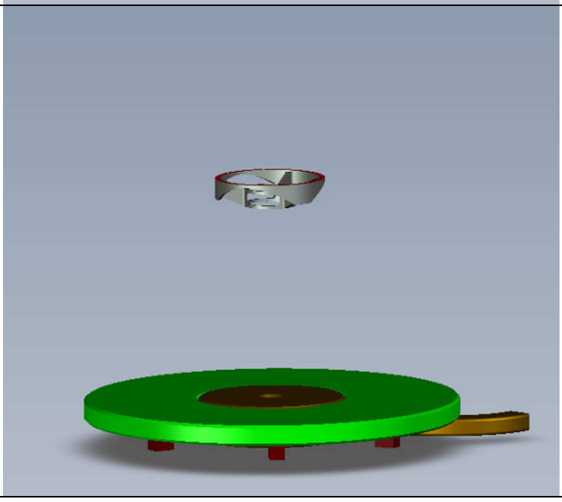
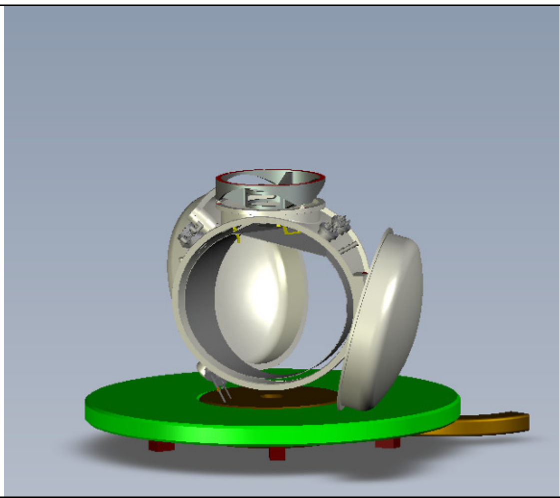
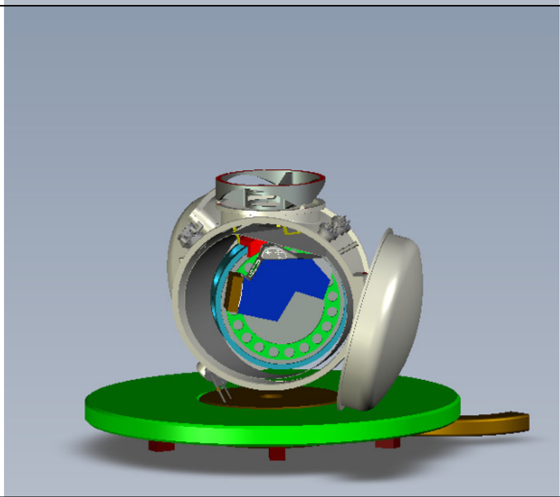
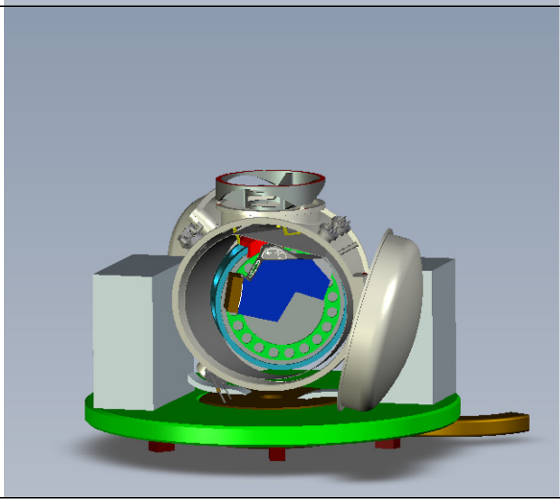
6		Mount the Primary arm and detectors.

Table 2: Storyboard for MICADO instrument integration

1		Mount rotating platform and Cable wrap on the Nasmyth platform.
(2)		*In the lab only*: Mount the intermediate Structure on SCAO / MAORY. Make sure the ADC is mounted. This step is not repeated at the observatory.

(3)		*In the lab only*: Mount the Cryostat with Radiation shield, Support rods, cryo-harness pumps and coolers to the Intermediate structure. Connect the cryostat to the cable wrap. This step is not repeated at the observatory.
4		*In the lab*: Mount the integrated instrument to the support rods. *On the observatory*: Mount the integrated instrument to the SCAO or MAORY interface *Both*: Connect all wiring to the cryo-harness and test connectivity. Close the doors.
5		Position the electronics rack and connect them to the cable wrap and to the instrument. Start Instrument verifications.

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