E-ELT PROGRAMME

# MICADO-EELT Phase A
# Interface Information and Requests

Document: E-SPE-MCD-561-0015

Issue: 1.0

Date: 19.10.09

Author(s) MICADO

Proj. Manager R. Davies

Name Date & Signature

## CHANGE RECORD

| ISSUE | DATE | SECTION/PAGE AFFECTED | REASON/ REMARKS |
|---|---|---|---|
| 0.1 | | All | First draft |
| 0.2 | | All | Input from BM, H-JH GVK, MD |
| 0.3 | | All | Input from MT, YC |
| | | | |
| | | | |
| | | | |

## TABLE OF CONTENTS

**1 SCOPE ........ 5**

**2 APPLICABLE AND REFERENCE DOCUMENTS ........ 5**

2.1 APPLICABLE DOCUMENTS ........ 5
2.2 REFERENCE DOCUMENTS ........ 5

**3 INSTRUMENT OVERVIEW ........ 6**

**4 TECHNICAL INTERFACES ........ 6**

4.1 OPTICAL INTERFACES REQUIREMENTS ........ 6
4.2 MECHANICAL INTERFACES INFORMATION ........ 7
4.3 JITTERING REQUIREMENTS ........ 10
4.4 LGS REQUIREMENTS ........ 11
4.5 REQUIREMENTS ON THE OBSERVATORY INFRASTRUCTURE ........ 11

**5 DETECTORS REQUIREMENTS ........ 13**

**6 STANDARDS ........ 13**

6.1 CONTROL ELECTRONICS ........ 13
6.2 INSTRUMENT CONTROL SOFTWARE ........ 14
6.3 CRYOGENIC EQUIPMENT ........ 15
6.4 VACUUM EQUIPMENT ........ 15
6.5 DATA REDUCTION SOFTWARE ........ 15

**7 OTHER REQUESTS ........ 15**

7.1 NASMYTH MOUNT ........ 15
7.2 CRYOGENIC REQUIREMENTS ........ 16
7.3 DETECTOR CONTROL ELECTRONICS & SOFTWARE ........ 16

## 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 |
| PLC | Programmable Logic Controller |
| PSF | Point Spread Function |
| RTD | Real Time Display |
| SCAO | single-conjugate adaptive optics |
| TMT | Thirty Meter Telescope |
| USM | Universitäts-Sternwarte München |
| WP | Workpackage |

# 1 SCOPE

This document is a response to the request from ESO in RD7 to provide information about the interfaces between the post-focal instruments and the E-ELT. To facilitate cross-referencing, the headings in Sections 4-7 are identically named and numbered to those in RD7.

The information contained in this document reflects the estimates relevant to the instrument concept developed during the Phase A study.

# 2 APPLICABLE AND REFERENCE DOCUMENTS

## 2.1 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

## 2.2 Reference Documents

RD1 MICADO Instrument Development and Management Plan, E-PLA-MCD-561-0020, v1.0

RD2 MICADO Scientific Analysis Report, E-TRE-MCD-561-0007, v2.0

RD3 MICADO System Overview, E-TRE-MCD-561-0009, v2.0

RD4 MICADO Design Trade-Off and Risk Assessment, E-TRE-MCD-561-0010, v2.0

RD5 MICADO Opto-Mechanical Design and Analysis, E-TRE-MCD-561-0011, v5.0

RD6 High Precision Astrometry with MICADO, Trippe et al., MNRAS submitted

RD7 Interface Information to be Provided by Instrument and Post-Focal AO Studies teams, issue 1.0

RD8 MICADO-MAORY Phase A Interface Specification, E-SPE-MCD-561-0014, v1.0

# 3 INSTRUMENT OVERVIEW

MICADO is the Multi-AO Imaging Camera for Deep Observations, which is being designed to work with adaptive optics on the European Extremely large Telescope. The instrument is intended to image, through selected wide and narrow-band near infrared filters, a wide 53”×53” field of view at the diffraction limit of the E-ELT. The goal of the consortium is to design a camera that will initially work with single conjugate adaptive optics (for which the wavefront sensing is provided by its own SCAO module) as well as, in principle, GLAO (provided by the E-ELT; although note that the instrument is far from optimised for this mode); and later to work with MCAO (specifically the MAORY concept).

In addition to the primary imaging field, MICADO will have an auxiliary arm that provides additional capabilities over a smaller (of order 10arcsec) field over view. In the current design, these capabilities will include imaging at different pixel scales, and simple long-slit spectroscopy for compact objects.

# 4 TECHNICAL INTERFACES

## 4.1 Optical Interfaces Requirements

MICADO interfaces to the telescope via an AO system (specifically MAORY). The requirements from the AO system may suffice.

1. Pupil motion: rotational, lateral and axial

TBD (during Phase B)

2. Pupil quality

TBD (during Phase B)

3. Focal plan motion: rotational, lateral and axial

TBD (during Phase B)

4. Transmission non-uniformity

A few percent (TBC). Note that non-uniformities can be removed with careful flatfielding as long as they are stable with time. The more critical requirement is therefore the *stability* rather than degree of transmission non-uniformity.

5. Calibration facilities

MICADO will provide an internal calibration facility that fulfils most of its needs. No external calibration facility is required during day time. During night time, twilight exposures will be required for flatfielding (specifically, illumination correction) and the usual standard star exposures are needed for telluric correction. See RD3 for a full summary of expected calibrations.

Calibration sources are required for the SCAO module:

- a visible point-like source at the E-ELT interface focus between M2 and M3,
- an infrared point-like source at the E-ELT interface focus between M2 and M3,
- visible light sources on M4,
- availability of windshake data for the SCAO wavefront sensor.

### 4.2 Mechanical Interfaces Information

MICADO is designed for gravity invariant rotation and therefore will not, at any stage, interface mechanically to the Nasmyth port. During an initial operational phase, MICADO will be mounted to its own SCAO module. This module will rest on the Nasmyth floor. In its final phase, MICADO will be mounted to the MCAO system MAORY. In both phases, the cryostat will hang underneath, and be supported by, the AO system. In addition, there will be a rotating platform directly underneath the cryostat that rests on the Nasmyth floor that provides a cable wrap and supports the electronics cabinets.

1. Sketch Layout

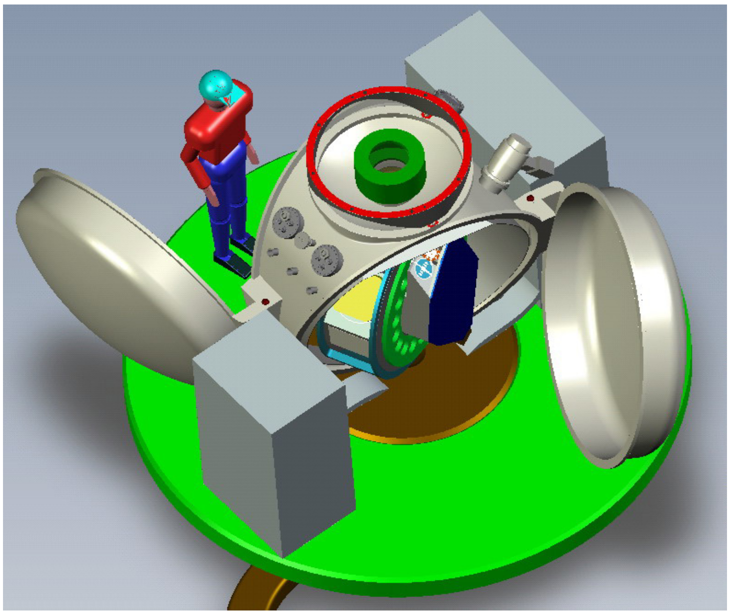

**Figure 1**: Overview of MICADO as it will be at the telescope. The mechanical interface to the AO systems is the red mounting ring on the top side. Access to all key systems is provided through 2 large doors in the cryostat, and facilitated because the optics mount is slightly rotated with respect to the cryostat. The electronics are mounted on a co-rotating platform that rests on the Nasmyth platform and also provides the cable-wrap for external supplies.

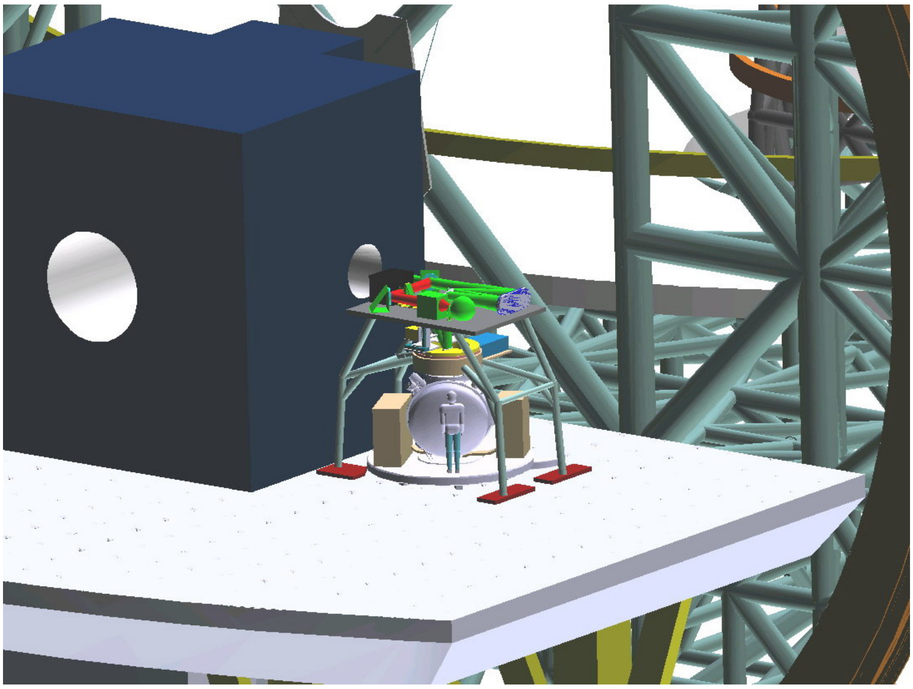

**Figure 2**: View of MICADO as it will be mounted in a gravity invariant orientation under the SCAO module and its support structure. The relay optics is mounted on the upper optical table together with the calibration unit. These will be covered. The yellow and red cylinders are the derotator, and the blue box houses the derotator motor. The WFS itself is hardly visible, located just above & to the side of the derotator in a yellow box.

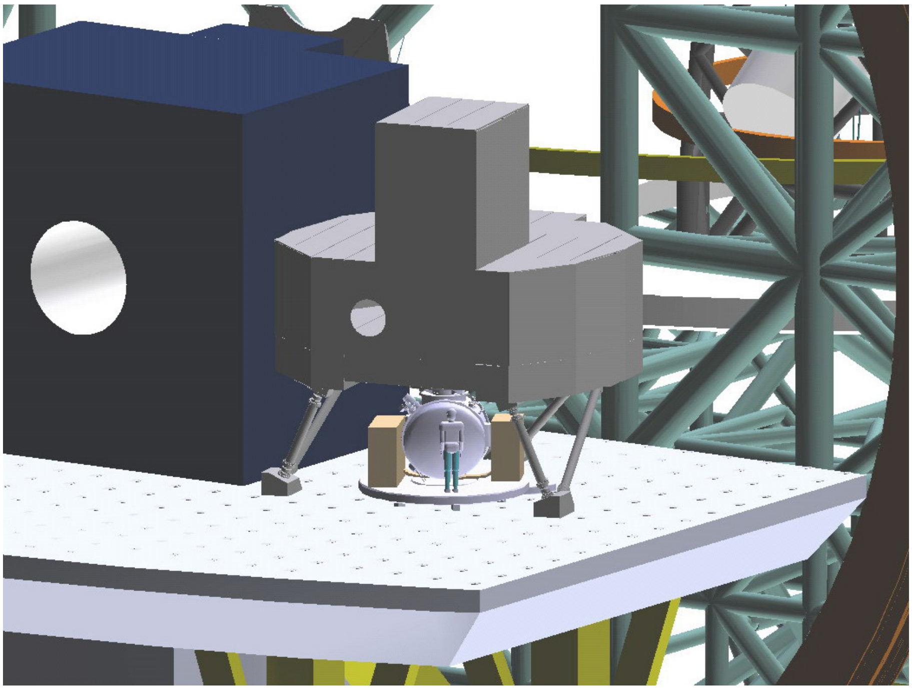

**Figure 3**: View of MICADO as it will be mounted in a gravity invariant orientation under MAORY.

2. Total mass and Centre of Gravity

Based on the current design, the expected masses as given in RD3 are:

(i) Rotating mass supported by derotator: 3000kg

(ii) Rotating mass supported on Nasmyth floor: 2500kg

(iii) Mass of calibration unit (statically mounted in AO system): 500kg

3. Total Volume

The total rotational volume is as shown in Figure 3 and summarised below. Note that the access volume (e.g. for mounting & maintenance) is necessarily larger.

(i) Rotational volume: cylinder diameter 3.8m, height 2.5m (tapered at the top)

(ii) Minimum access volume: cylinder diameter 5.0m, height 2.5m

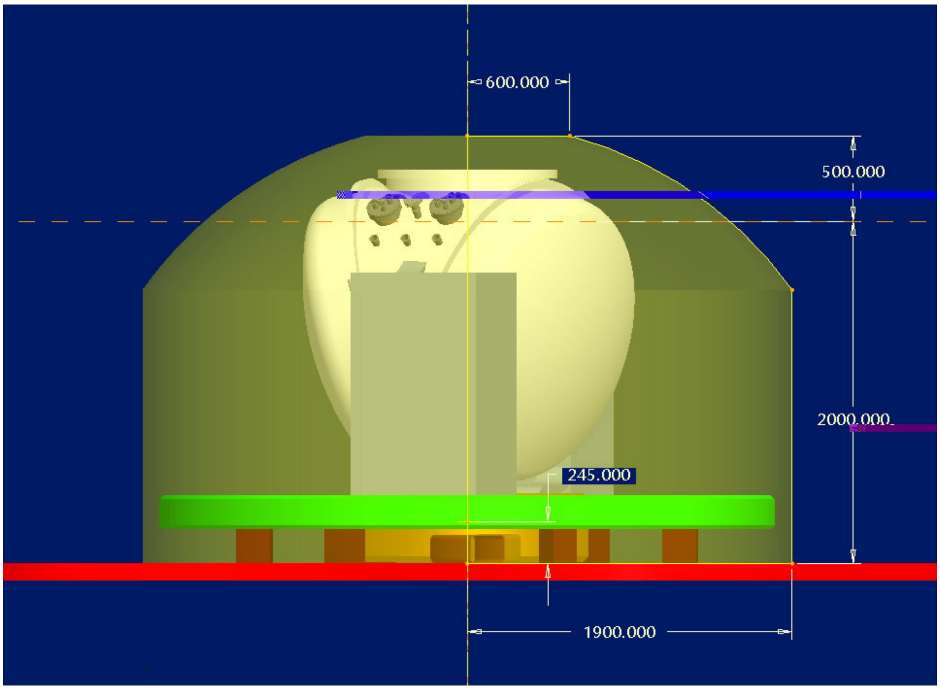


**Figure 4**: rotational volume of MICADO is shown in yellow: a tapered cylinder of height 2.5m and diameter 3.8m.

4. Rotational Torque

MICADO is not designed to be laterally mounted. The following figures are estimated for a gravity invariant rotation where MICADO is supported from above, and are as given in RD8:

(i) Torque on flange perpendicular to optical axis: 10kNm (15kNm leaves some margin)

(ii) Frictional torque on flange: 300Nm

(iii) Inertial torque: 300Nm

### 4.3 Jittering Requirements

The dithering and offsetting functionality required by MICADO needs to be shared between the AO system and telescope. There are currently 3 regimes foreseen (see RD8 and the operational concept described in RD3).

We note that the maximum sky offset of 60” indicated in the observatory top level requirements is insufficient for MICADO, which has a 53” field of view.

*Small dithers*

These are to allow efficient removal of systematic effects (e.g. bad pixels etc), and for nodding during spectroscopic observations. They are controlled by MAORY, and performed while keeping the AO loops closed (e.g. by defining a new centering position on the NGS sensors) so the overhead is small.

1. frequency: every 10-30secs
2. angular offset: ±1mas to ±300mas (goal 500mas) from the initial pointing along each of X and Y axes
3. exposure times at position: multiple exposures totalling 10-30sec (i.e. the full time spent at the dither position)
4. maximum time to preset at new position: 2 sec (i.e. no more than 10% of the time spent at that position).
5. offset repeatability & accuracy: <2mas (i.e. about 20% of the PSF FWHM)
6. AO needed at offset position: yes

*Large dithers*

These are to allow efficient estimation of the sky background (via median filtering) in more crowded fields or when observing more extended objects. These dithers will be controlled by MICADO and need to be performed in conjunction with the AO system and telescope. The AO loops will need to be opened while the offset is executed but need to be closed again at the new position.

1. frequency: every few minutes
2. angular offset: ±0.5 to ±10arcsec from the initial pointing along each of X and Y axes
3. exposure times at position: multiple exposures totalling a few minutes (perhaps with small dithers in between).
4. maximum time to preset at new position: 15sec (i.e. no more than 10% of the time spent at that position).
5. offset repeatability & accuracy: 0.1arcsec (no strong requirement)
6. AO needed at offset position: yes

*Sky Offsets*

These are for dedicated sky exposures when the target field is too full to allow sky estimation via median filtering of dithered exposures. A single set of sky exposures can be used for multiple sets of object exposures. Since the aim of the exposure at the offset position is to measure the sky background.

1. frequency: every ~20minutes (TBC); depends on overhead, and every ~10mins would be highly preferable

2. angular offset: up to 15arcmin (this is the largest offset identified in the MICADO science cases, and relates to the Galactic Center)

3. exposure times at position: multiple exposures totalling no more than a few minutes (perhaps with small or large dithers in between).

4. maximum time to preset at new position: 15sec (i.e. no more than 10% of the time spent at that position).

5. offset repeatability & accuracy: a few arcsec (no strong requirement) at the offset position; <1arcsec when returning to the original position

6. AO needed at offset position: no

## 4.4 LGS Requirements

Not directly applicable: MICADO will only make use of the LGS through another AO system (MAORY for MCAO or ATLAS for LTAO).

## 4.5 Requirements on the Observatory Infrastructure

1. Space need at the integration lab

*MICADO*:

The minimal access volume during integration should be at leased 1 meter around the rotational volume which results in a cylinder with a diameter of 5.8m. The minimum height should also be 1 meter more than the instrument once fully mounted to allow unrestricted manoeuvring space (noting that hardware is mounted sideways into the cryostat), i.e. 3.5m from the floor to the lifting hook. The lifting installation is expected to need an additional 1.5 meter height, which results in a total height from floor to ceiling of 5.0 meter.

Depending on optical measurement equipment for instance a telescope beam simulator which needs to be placed at the entrance port of the instrument the height may become even higher.

Additional 5x5m area is needed to place a work bench, computer and other measurement equipment.

In total an area of at least 60m$^2$ will be needed in the integration lab for MICADO

*SCAO*:

The support structure for SCAO requires the most room. It is approximately 5mx3m area and 5m high. Adding 1m access and mounting space all around, and an additional 1.5m height for the lifting installation, means that the space required is approximately 7mx5m in area and 7.5m high.

Adding space for a work bench etc. as above, means that total floor area required is at least $60m^2$.

*MICADO+SCAO:*

In the current integration scheme, MICADO will be mounted to SCAO only after SCAO has been installed on the Nasmyth platform. The consortium proposes a rolling trolley incorporating a suitable lifting device (see RD5).

2. Standard maintenance equipment for assembly, inspection, test, calibration, servicing

- Dummy backbone which represents the mounting structure of the telescope and/or MAORY
- Optical measurement/alignment equipment for instance telescope beam simulator
- Instrument and/or cryostat cover lifting equipment/tools
- Electro-Mechanical tool kit with fastener tools, etc
- Liquid Nitrogen (continuous) supply and return lines

3. Size and mass of modules that may be dismantled during an intervention

MICADO has been designed such that during standard interventions, access to all key components can be gained via the cryostat doors. The largest parts that will need to be dismantled and removed are the radiation shields. These are less then 2m across and weigh less than 1000kg.

4. Services (power, cooling, compressed air, etc)

(all numbers are initial estimates, and TBC)

Power Requirement on Uninterruptible Power Supply (UPS 230VAC): less than 3KW

Power Requirement on normal mains power (230VAC): 3KW

Power Requirement on three phase power 400 VAC: less than 8KW

Coolant requirement on liquid coolant: Minimum differential pressure 2 bar, thermal load max 6KW, feed 10 C° below ambient temperature

LN2 continuous supply required.

Max flow rate (start of cool down): 80 l/h (TBC)

Continuous flow rate (steady state): 3 l/h (TBC)

5. Cleanliness needs in integration lab(s)

Minimal cleanliness during integration shall be ISO class 7 (TBC).

6. Thermal control needs in integration lab

22 ±2°C (TBC)

# 5 DETECTORS REQUIREMENTS

1. Detector type

MICADO's baseline design has assumed that HAWAII-4RG (4k×4k arrays with 15micron pixel pitch) are available. We have also assumed that these are 2-edge buttable; and that the minimum gaps required between neighbouring detectors are 3mm between 2 buttable edges and 9mm between 2 non-buttable edges.

We are willing to consider alternative arrays. However, the large format is a requirement to avoid excessive workpower to characterise, mount, and test the individual detectors.

2. Number of engineering & science arrays

The primary imaging field requires 16 such detectors; the auxiliary arm design currently uses just 1. Therefore 17 science grade arrays are needed for the instrument.

It is expected that 1 engineering grade array, and 1 spare should be sufficient as extras.

3. Schedule for procurement

In the current baseline, the initial phase (corresponding to first light on the E-ELT) requires 5 detectors. An upgrade during which the remaining 12 detectors will be mounted will occur when MAORY is available. The procurement schedule will take this into account.

# 6 STANDARDS

## 6.1 Control electronics

Our preferences include:

- Based on SIMATIC Programmable Logic Controller (PLC), Realtime Ethernet or other Realtime architectures
- Also for cryogenic housekeeping (cryogenics control) and safety relevant functions PLC SIMATIC S7 in fail safe version is a possible standard

- Realtime LabView and PXI controller from National Instruments could also be used as implementation for control electronic

We note that the initial time/effort for development with new control architecture is much higher/complex than would be if design developed on existing standards.

It would be useful to decide on some (likely) standards to allow the consortia to become familiar with them, and also to provide meaningful estimates of workpower required for instrument development.

## 6.2 Instrument control software

*General assumptions*:

1. It is assumed that the data flow concept is the same as for VLT observations: Phase 1/Phase 2 Proposal Preparation - Execution of Observation Blocks in either Service or Visitor Mode - Archiving - Data reduction. The OBs shall be prepared in a standardised way using a dedicated tool. They shall be the only way of interaction with the instrument for normal observation, calibration and maintenance scenarios. A direct interaction with individual hardware components shall be possible only in exceptional, i.e. engineering cases.
2. The communication between MICADO and all other relevant E-ELT subsystems (TCS, DCS, AO modules, Archive etc.) is expected to be accomplished through the same standardised interface to the (yet to be defined) E-ELT Common Software Layer.
3. A standard for the communication between the high level MICADO Instrument Software and the MICADO hardware components to be controlled by Local Control Units is expected to be set by ESO.

Furthermore, it is expected that the following *software components* will be *provided by ESO*:

1. A generic E-ELT Common Software framework providing basic services for the communication between E-ELT subsystems (Instrument SW, TCS, DCS, AO modules, Archive etc.).
2. The Detector Control Software (DCS).
3. An online archive system for archiving of the raw image data.

*Preferences* regarding possible software platforms and programming languages:

1. Given the timeline of the project it will be necessary to maintain a certain development infrastructure (possibly including licenses for operating systems and/or software development kits) for many years. Therefore Open Source solutions are strongly preferred over proprietary commercial ones. For the same reason Linux as operating system will be favoured.
2. Because of good experiences with C++, Python and XML these could be imagined as a suitable set of standard programming languages.

### 6.3 Cryogenic equipment

TBD

### 6.4 Vacuum equipment

TBD

### 6.5 Data reduction software

The Astro-WISE system is well suited for reduction of MICADO data. Astro-WISE is an integrated system where users cannot only perform data reduction but also data archiving, post-reduction analysis and publishing of the raw, intermediate and final data products.

A salient feature for the data reduction relevant for MICADO is that it performs 'global' astrometry and photometry. Astrometric and photometric corrections and calibrations by combining the information from overlapping observations improving on calibrations based on individual pointings. Data reduction can take place in fully automated fashion or in a more manual fine-tuning manner.

There are three key features of Astro-WISE in general relevant for MICADO. First one is full data lineage linking from final catalog back to raw data. Users can trace pixels in processed data all the way back to the contributing pixels in input products. This includes tracing back metadata such as process configuration parameters and informational attributes. Second one is the fact that Astro-WISE is a federated infrastructure. The system allows the use and sharing of geographically distributed resources for computation, storage and thus also human resources. At the moment institutes in the Netherlands (Groningen, Leiden, Nijmegen), Germany (Munich, Bonn/Bochum) and Italy (Naples) operate Astro-WISE for collaborative projects, sharing their resources.Third one is the fact that Astro-WISE is scalable up to the regime of very large datasets. Astro-WISE will be used for data reduction and post-calibration analysis of very large surveys from VST and VISTA wide-field imagers. ESO has been partner in Astro-WISE since the start of its design.

More information on Astro-WISE can be found on the Astro-WISE homepage (www.astro-wise.org). The following ADASS proceedings paper gives a detailed technical overview of the system: www.astro-wise.org/Public/2007ASPC..376..491V.pdf.

## 7 OTHER REQUESTS

### 7.1 Nasmyth Mount

MICADO has been designed for gravity invariant rotation. With both MAORY and its own SCAO module, this is provided via an optical relay. An alternative that could simplify the SCAO design would be if there were a gravity invariant port on (under) the Nasmyth adaptor. MICADO would only need to use this during the first few years of operation.

## 7.2 Cryogenic Requirements

In order to minimise the risk & impact on AO performance due to vibrations from cryo-coolers, it is foreseen that MICADO should be cooled with continuous flow LN2.

## 7.3 Detector Control Electronics & Software

We prefer that ESO should provide the detector control system and control software, as is currently done for VLT instruments.

---oooOOOooo---