E-ELT PROGRAMME

MICADO-MAORY Phase A Interface Specification

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CHANGE RECORD

ISSUE	DATE	SECTION/PAGE AFFECTED	REASON/ REMARKS
0.5	09.01.09	All	Input from MICADO consortium
0.6	20.01.09	All	Input from MAORY consortium
0.7	22.01.09	All	Input from ESO
0.8	27.01.09	All	Updated during ESO-MICADO-MAORY interface meeting on 27.01.09
0.9	18.02.09	4.1, 4.3	Added acceptance of field curvature, and expected communications & listed out actions from meeting
0.91	09.07.09	4.1, 4.2, 4.3, 4.7	Updated mechanical interfaces, field distortions from AO, communication, & operations; added handling
0.92	15.07.09	4.3	Minor update to communication following email from Emiliano
0.93	21.07.09	all	Reformatted to portrait page; merged MICAOD & MAORY columns into a single specification, highlighting where there is a discrepancy
0.94	30.07.09	4.3	Minor changes based on comments from Bernard
0.95	28.09.09	4.2	Updated torque specs after discussion with ESO & MAORY
1.0	22.10.09	4.2	Updated figures, final iteration with MAORY

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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 SCOPE

This document describes the interfaces that exist between MICADO and MAORY, as identified during the Phase A studies. It is not intended to define a final and definitive detailed specification for these interfaces, but should indicate where the interfaces are compatible, as well as to highlight where there might be potential discrepancies. All interfaces are subject to revision during later phases of the instrument projects.

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 Phase A Science Analysis Report, E-TRE-MCD-561-0007, v2.0

RD3 MICADO Phase A 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 MICADO Phase A Top Level Data Reduction User Requirements, E-TRE-MCD-561-0024, v1.0

3 PROJECT OVERVIEW

MICADO is the Multi-AO Imaging Camera for Deep Observations, which has been designed to work with adaptive optics on the European Extremely large Telescope. The instrument has been optimised for the multi-conjugate adaptive optics module MAORY; but it is also able to work with other adaptive optics systems, and includes a separate module to provide a single conjugate adaptive optics capability during the early operational phase.

The instrument is able to image, through selected wide and narrow-band near infrared filters, a wide (nearly 60") field of view at the diffraction limit of the E-ELT. In addition to a high throughput imaging camera with a fixed 3mas pixel scale, MICADO will have an auxiliary arm to provide an increased degree of flexibility. In the current design, this arm provides (i) a finer 1.5mas pixel scale over a smaller field, and (ii) a simple, medium resolution, longslit spectroscopic capability.

MAORY is the multi-conjugate adaptive optics system that will make use of laser and natural guide stars to provide diffraction limited image quality across the full MICADO science field with a good sky coverage.

4 INTERFACES

In the following tables, the columns are as follows:

Interface: the interface to be specified

specification: the preference/requirement from the MICADO consortium, which has been agreed, as far as is possible, during Phase A with the MAORY consortium. If there is a discrepancy, this has been noted and the ID number marked in yellow.

Notes: any relevant comments that should be borne in mind, or other explanations to help understand the interface & its purpose.

4.1 Optical Interfaces

ID	*interface*	*specification*	*notes*
0101	Transmitted field size	53x53arcsec for main imaging field; 16x16arcsec for auxiliary arm; both on-axis	FoV as defined in E-TRE-MCD-561-0009 (MICADO System Overview); specifying smaller area for auxiliary arm enables larger NGS search area.
0102	F/#	17.7	
0103	Field curvature	1.29m from MAORY, (centre of curvature on MICADO side of input plane). Note: revised MAORY interface is 1.43m.	MICADO is optimised for MAORY interface, but will work fine over smaller field with telescope interface.

0104	Scale	3.605mm/arcsec	
0105	Scale stability	No specific requirement	Telescope specification is for 0.01% over 1 hr
0106	Exit pupil location	-43.3m	Telescope exit pupil is between M4 and M5
0107	Back focal distance	500mm	750mm (+/-50mm) for telescope interface.
0108	Transmitted wavelength range	optimised for 0.78-2.4um	
0109	Transmitted optical quality	Diffraction limited	Strehl is specified in E-SPE-ESO-528-0091 issue 2.0 (MAORY Tech Spec)
0110	geometrical distortions from instrument optics	MAORY geometrical optical distortions should be stable to 1 part in 10^6 across the full MICADO field of view, on short (i.e. seconds) and long (i.e. months) timescales; TBC	To enable astrometric calibrations using a mask in the instrument without excessive (day-to-day) calibration overheads. Note that MAORY distortion of 0.0018% is ~1 part in 5×10^4; these distortions need only be stable to ~5% to meet this requirement. It would be very useful to know the impact of thermal changes in this respect. It may be possible to reduce this spec to cover only distortions higher than 3rd order.
0111	Field warping from AO	Geometrical distortions higher than 3rd order should be less than 1 part in 10^6 across the full MICADO field of view; TBC	To enable astrometric calibration on sky. We assume distortions up to 3rd order can be corrected from each data frame itself.
0112	Optical throughput	80% across full MICADO bandpass	As specified in E-SPE-ESO-528-0091 issue 2.0 (MAORY Tech Spec)

4.2 Mechanical Interfaces

4.2.1 Mass

ID	*interface*	*specification*	*notes*
0211	Rotating mass of MICADO supported by MAORY	5000kg	
0212	Torque on flange, perpendicular to optical axis	10kNm (goal 15kNm)	Assumes 5000kg is 200mm off-axis; the goal gives some margin for being up to 300mm off-axis.
0213	Frictional torque on flange due to MICADO	300Nm	matches ESO's spec for Nasmyth flange; MICADO expects inertia torque also to be less than (an additional) 300Nm.
0214	Static mass of MICADO supported by MAORY	~500kg	currently this is expected to include only the calibration unit
0216	Location of NGS WFS module	Mounted on opposite side (i.e. inside) of derotator.	MICADO & NGS WFS will rotate together on same derotator; interface is still at the

			derotator flange.

4.2.2 Volume

ID	interface	MICADO preference	notes
0221	Total design (i.e. rotational) volume of MICADO	Cylinder of height 2.5m and diameter 3.8m, tapering towards the top (see Figure 1 for more details and Figure 3 for an illustration).	The rotational volume specified here includes the rotating platform and electronics cabinets (which are supported by the Nasmyth platform). The 3D models indicate this volume fits under MAORY.
0222	Minimum access volume around MICADO	The goal is a cylinder of diameter 5.0m, height 2.5m (see Figure 2 for more details, and Figure 3 for an illustration of the available space). This can be partially intersected, as long as space remains for people to move around relatively unhindered.	Ideally there should be about 1m around MICADO for maintenance and handling. Access needs to be assessed further (e.g. in most instances it may be possible to rotate MICADO to an orientation that provides localised optimal access).

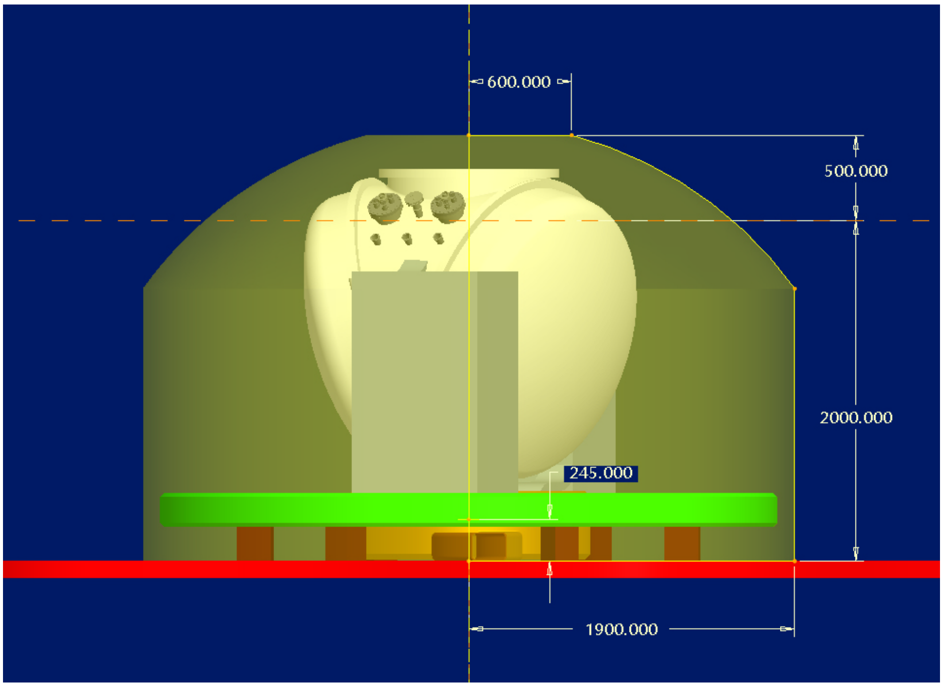

Figure 1: Rotational symmetric operational volume envelope of MICADO, shown as transparent yellow. Dimensions are given in millimeters with respect to the centre of the focal plane, the mounting interface, and the Nasmyth platform.

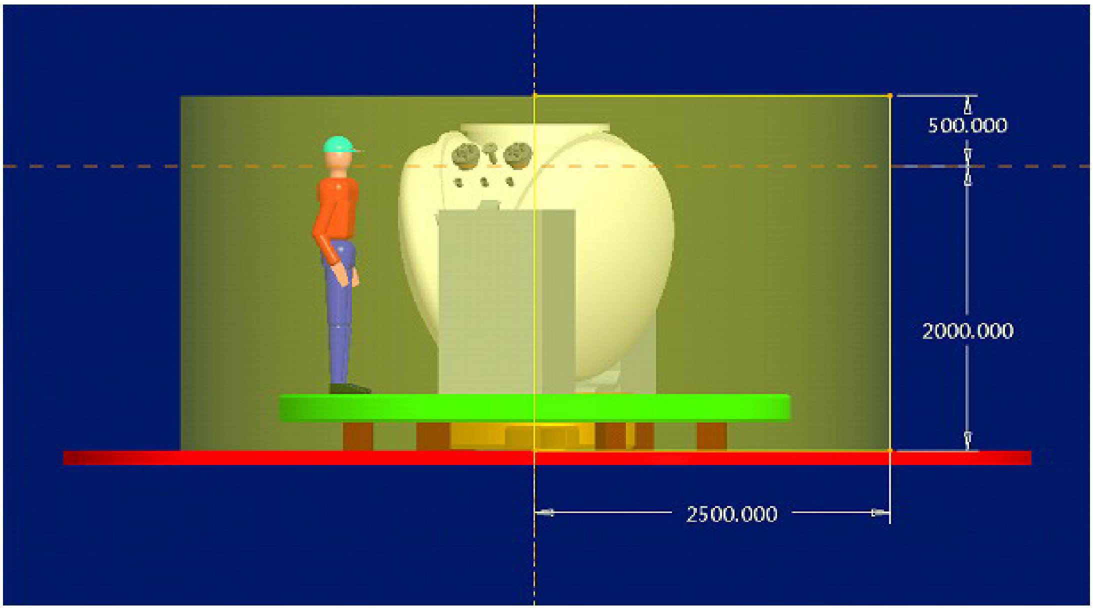

Figure 2: the Access volume around MICADO is a cylinder 5m diameter and 2.5m high. This is to enable personnel to reach every part of the instrument while it is mounted, and also to enable the cryostat doors to open fully. If the full volume is not available, one might consider scenarios where the instrument has to be rotated to an appropriate orientation before opening the cryostat doors, etc.

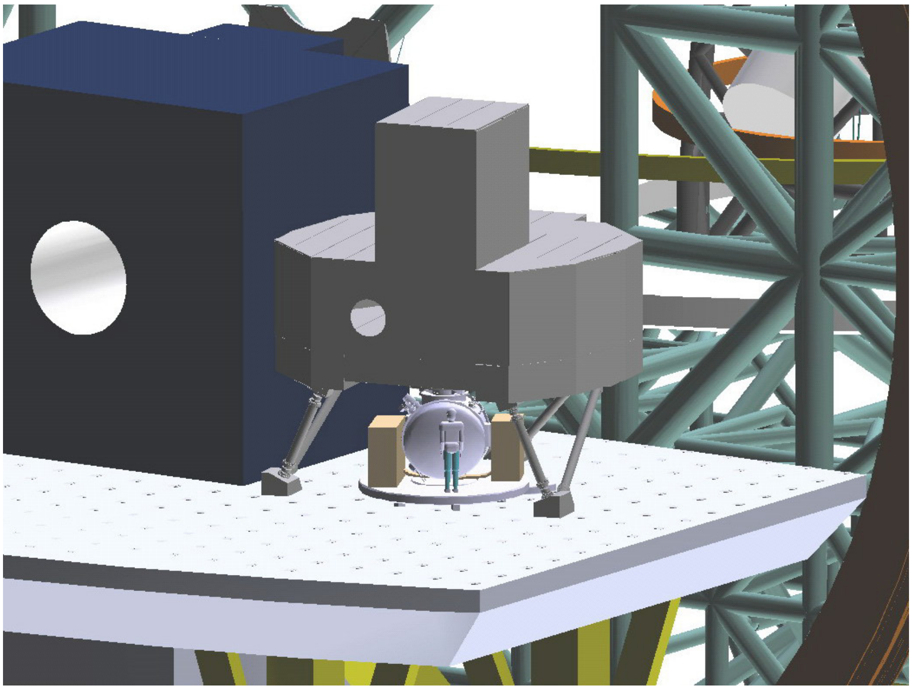

Figure 3: Illustration of MICADO mounted under MAORY, showing that there is good access from several directions, both for mounting and for maintenance.

4.2.3 Attachment

ID	*interface*	*specification*	*notes*
0231	general	MICADO will use a MAORY derotator port	
0232	Adapter port	Gravity invariant	
0233	Adapter location	Below	
0234	Adapter diameter and attachment points	Horizontal circular contact plane 0.95-1.05m diameter concentric with exit beam (see Figure 2); 8 equally spaced M20 bolts on 1m diameter circle, bolt mounting from below; alignment via 2 16mm dowel pins, hollow M8 thread inside, locked with 2 M6 bolts from below.	Note that telescope adapter diameter will be larger.
0235	Derotation	Provided by MAORY	
0236	Derotation accuracy: runout[1]	<2mas at a distance 30arcsec off axis in a 1-2min period	This specification is after correction of any lateral shift by NGS WFS.
0237	Derotation accuracy: wobble[2]	TBD; similar to above	Bear in mind that telescope pupil will shift (by a few cm over the 42m) Be careful that wobble moves also the pupil and this specification should be given as tilt w.r.t. derotation axis and not as image motion
0238	Derotation accuracy: angular	<2mas at a distance 30arcsec off axis in a 1-2min period (TBC)	

1 Wobble = angular pointing shift of optical axis, causing a field dependent defocus
2 Runout = misalignment of optical axis & rotation axis

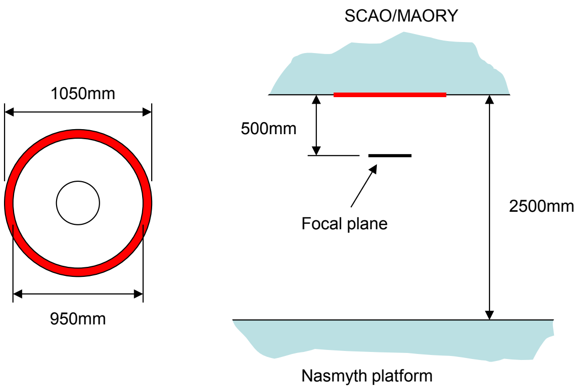

Figure 4: The interface between MICADO and MAORY is a mounting ring 1000mm diameter and 100mm wide located 2500mm above the Nasmyth platform.

4.2.4 Vibrations

ID	*interface*	*specification*	*notes*
0241	Vibrations from MICADO to MAORY	TBD	MICADO does not plan to use cryo-coolers. Note: MAORY is responsible for coping with the Nasmyth platform vibrations to the level needed to meet their TLR.
0242	Vibration from MAORY to MICADO	no specific requirement	This is implicit in requirement 0109 on optical quality.

4.2.5 Handling

ID	*interface*	*specification*	*notes*
0251	Mounting MICADO	The exact mounting method is not yet finalised. The current proposal is to use a handling trolley which moves on rails that are temporarily mounted to the Nasmyth platform (Figure 5). The access volume required to mount MICADO is shown in Figure 6	This is currently a proposal.

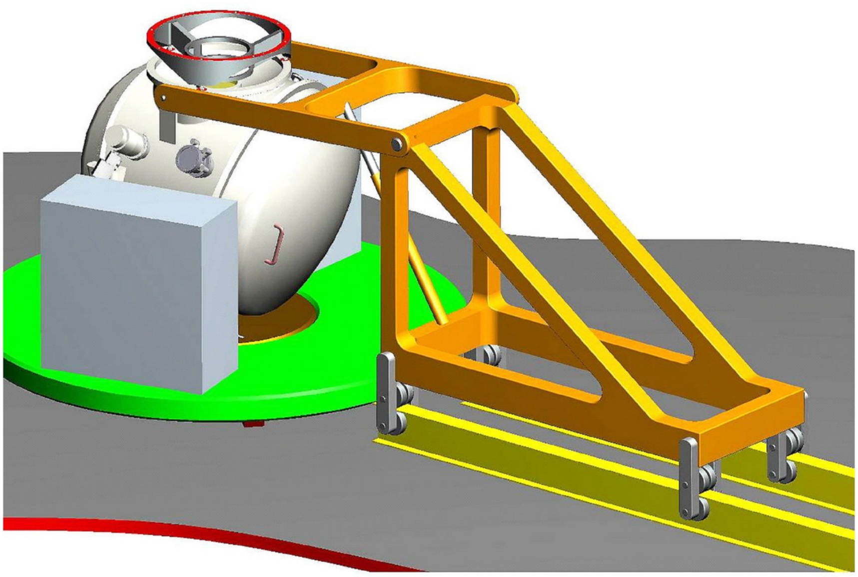

Figure 5: Illustration of a trolley that runs on temporary rails, proposed for the (dis-)mounting of MICADO. This has the minimum impact on MAORY, reducing overall complexity, and is simple and safe.

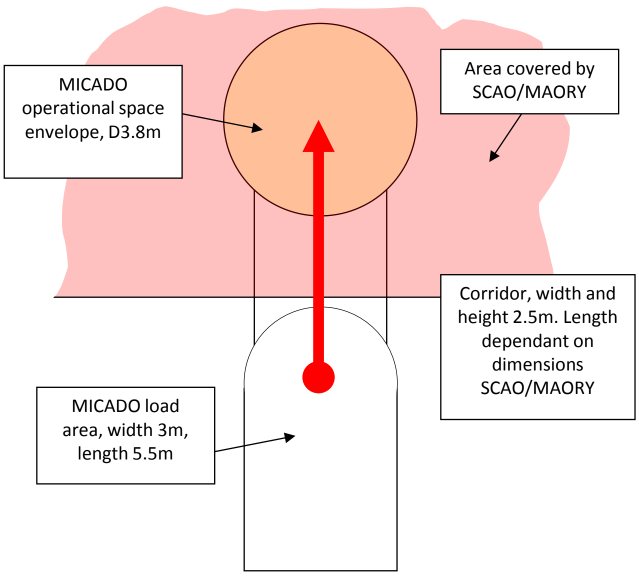

Figure 6: Access volume required to mount MICADO under MAORY (and also under SCAO).

4.3 Communication, Software, Control

ID	*interface*	*specification*	*notes*
0301	Communication interface	The observatory communication software (provided by ESO – Mario Kiekebusch) will be used	Need to wait until observatory SW architecture is clearer.
0302	Communication functionality: sign on/off	MICADO will be able to set and unset itself as the MAORY client instrument	When MICADO is set as the client, MAORY will use gravity invariant port.
0303	Communication functionality: instrument setup	MICADO will pass MAORY the following information in a setup command: (a) target position (b) derotator offset (c) guide stars (d) MCAO mode (e) monitor star(s) (f) waveband (g) time at position	This information is for: (a) on-axis coordinates (b) angular offset for MICADO FoV (e.g. to set slit angle) (c) coordinates of 3 NGS for tip-tilt sensing (the size of the science field is taken into account when selecting these beforehand) (d) to optimise MCAO for small or large field (e) coordinates for 1 (more?) faint truth sensor stars (f) for differential optical-IR tracking (g) the estimated time needed to execute the observation block; for MAORY optimisation
0304	Communication functionality: operations	The following commands to MAORY will be available for MICADO: (a) go to specific configuration	This information is for: (a) put MAORY (e.g. DMs flat, derotator offset, etc) in specific state while calibration unit is used

		(b) start AO (c) pause AO (d) stop AO (e) apply offset (x,y) (f) apply small dither (x,y)	(b) close AO loops (or re-close after pause) (c) pause AO (while offset or dither is applied) (d) open AO loops (e.g. at end of observing block) (e) so MAORY can compensate (by offsetting –x,-y) when the telescope is offset by x,y (f) Execute a small dither while keeping AO loops closed (e.g. by changing the centering position of the NGSs).
0305	Communication functionality: responses	MAORY will reply to any MICADO communication to indicate whether it is accepted or rejected.	
0306	Communication functionality: error tracking	MAORY will implement a way to clarify, in case of failure, the source of the error	For example, in the VLT environment this is done through error messages and error stacks, which are displayed to the user
0307	Metrology (for flexure compensation)	Active metrology using fast guiding at 10Hz-100Hz on the MICADO detectors is foreseen.	Without feedback, tilt will be compensated to the accuracy of the NGS WFS. Non-common path tilt is not corrected.
0308	AO performance metrics	MAORY should provide appropriate estimates of AO performance to be included in headers of data files	
0309	Atmospheric conditions	MAORY should provide appropriate metrics of atmospheric conditions that can be included in headers of data files	MAORY can make use of metrics provided by the telescope, and pass them on.
0310	AO system status	MAORY should provide complete information about its status (e.g. of devices) for inclusion on data file headers.	This is useful for debugging etc.

4.4 Calibration

ID	*interface*	*specification*	*notes*
0401	Calibration unit	MAORY should include provision for a calibration unit to be inserted at its input focal plane. The calibration unit is expected to have a volume 1m×1m×1m offset laterally from the optical axis (TBC).	Calibration unit for MICADO is under the responsibility & control of MICADO. MAORY have indicated the need for a focal plane pinhole mask. During Phase B, MICADO & MAORU will work to incorporate this in the calibration unit.

4.5 Services, Utilities

No interfaces currently foreseen

4.6 Thermal

ID	*interface*	*specification*	*notes*
0601	Temperature	Background from MAORY should not exceed 50% of that from telescope+sky; Goal: 20% of telescope+sky	See also E-SPE-ESO-528-0091 issue 2.0 (MAORY Tech Spec). Calculation indicates that up to about 20deg C ambient, this requirement is anyway fulfilled.

4.7 Operations

ID	*interface*	*specification*	*notes*
0701	Acquisition	It should be possible to perform blind offsets using a combination of large and small dithers	i.e. acquire on a brighter target; and then offset to a science target which cannot be seen in a short exposure. MICADO will control the offsetting, using a reference object in the field.
0702	Non-sidereal tracking	Currently no specific requirement from MICADO	Telescope requirement is 10000arcsec/hour (10mm/sec in focal plane)
0703	Seeing limited mode	Should be available	Currently foreseen only for sky subtraction (see 0707)
0704	Small dither	MAORY should be able to perform a small dither of +/-0.3arcsec (goal +/-0.5arcsec) in each of X and Y from the initial pointing, with an accuracy of <2mas, within 2sec (TBC)	This is controlled by MAORY, and performed while keeping the AO loops closed (e.g. by defining a new centering position on the NGS sensors). The overhead is small. Small dithers are useful for removing systematic effects. Small dithers will be used for nodding during spectroscopic observations.
0705	Large dither	MAORY should be able to perform a large dither of up to 10 arcsec (TBC) from the initial pointing, with overhead <2sec (TBC) more than that required by the telescope offset; accuracy is TBD	This is controlled by MICADO and involves the following steps: 1. MAORY Pause AO 2. telescope apply offset (maintaining optical quality) 3. MAORY apply offset 4. MAORY start AO
0706	Sky offset	MAORY should be able to perform an offset of up to	This offset to take sky exposures is controlled by MICADO and involves the

		15arcmin from the initial pointing, with overhead <2sec (TBC) more than that required by the telescope offset; accuracy is TBD	following steps: 1. MAORY pause AO 2. telescope apply offset (note: if the offset is very large, a preset may be needed; TBC) We have to be careful here: it is not clear if the E-ELT wavefront control is fully taken over by the instruments or it maintains at least a supervision of it. It is possible that it is required for instruments to close in any case the minimal loops to guarantee the telescope's safety.
0707	Sky return	Following a sky offset (and possible subsequent dithers), MAORY should be able to return to the initial pointing, with overhead <2sec (TBC) more than that required by the telescope offset; accuracy is TBD	This return from a sky offset is controlled by MICADO and involves the following steps: 1. telescope apply offset (opposite to the sky offset) 2. MAORY start AO

5 ACTIONS FROM 27 JAN 09 INTERFACE MEETING

AI	Action	Owner	Due date	Status
IF-0101	Provide MICADO with optical design	MAORY	10.02.2009	done
IF-0103	Look into a possible design for exchangeable collimator	MICADO	28.02.2009	done
IF-0105	Provide/confirm specification values for 0105	MAORY	28.02.2009	done
IF-0110	Provide MAORY with a number to define “negligible distortion”	MICADO	28.02.2009	done
IF-0111a	Provide MAORY with an estimate for acceptable warping spectrum for different spatial frequencies	MICADO	28.02.2009	done
IF-0111b	Evaluate impact of MCAO in astrometry at high spatial frequencies	MAORY	Phase 2 review	initial analysis done; detailed calculation in progress
IF-0210	Provide/confirm specification values for 0212, 0213, 0214	MAORY	28.02.2009	done
IF-0233a	Check if 2.5m vertical space is sufficient (location below MAORY)	MICADO	28.02.2009	done
IF-0233b	Check whether a 4.5m diameter volume can be accommodated	MAORY	28.02.2009	done
IF-0237	Provide/confirm specification values for 0237	MAORY	28.02.2009	done
IF-0238	Provide/confirm specification values for 0238	MAORY	28.02.2009	done
IF-0401a	Specify volume required for the calibration unit	MICADO	28.02.2009	done
IF-0401b	Assess what functionalities are needed from calibration unit	MAORY	28.02.2009	Done
IF-0700a	Provide initial list of functions required	MICADO	28.02.2009	Done
IF-0700b	Provide initial list of functions required	MAORY	28.02.2009	Done
IF-0700c	Look into the mechanical apposition accuracy of NGS WFS positioning	MAORY	28.02.2009	Done (N/A for current dither scenarios)

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