E-ELT PROGRAMME

MICADO Phase A
Compliance Matrix

Document: E-TRE-MCD-561-0008

Issue: 2.0

Date: 19.10.09

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CHANGE RECORD

ISSUE	DATE	SECTION/PAGE AFFECTED	REASON/ REMARKS
1		All	First issue
2	19.10.09	All	Revised based on Phase A design & updated Technical Specs

TABLE OF CONTENTS

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 contains the compliance matrix for the MICADO instrument study. See AD1 for the requirements and RD5 for an overview of MICADO.

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 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

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

2.2 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 Executive Summary, E-PLA-MCD-561-0006, v2.0

RD3 MICADO Instrument Development and Management Plan, E-PLA-MCD-561-0020, v1.0

RD4 MICADO Scientific Analysis Report, E-TRE-MCD-561-0007, v2.0

RD5 MICADO System Overview, E-TRE-MCD-561-0009, v2.0

RD6 MICADO Design Trade-Off and Risk Assessment, E-TRE-MCD-561-0010, v2.0

RD7 MICADO Opto-Mechanical Design and Analysis, E-TRE-MCD-561-0011, v5.0

RD8 MAORY System Overview and Design Trade-Off, E-TRE-INA-528-0004, v1.0

RD9 High Precision Astrometry with MICADO, Trippe et al., MNRAS submitted

RD10 MICADO SCAO module, E-TRE-MCD-561-0022, v1.0

RD11 MICADO Photometric Study, E-TRE-MCD-561-0023, v1.0

RD12 MICADO-MAORY Interface Specification, E-SPE-MCD-561-0014, v1.0

RD13 MICADO Top Level Instrument Software User Requirements, E-TRE-MCD-561-0021, v1.0

RD14 MICADO Top Level Data Reduction User Requirements, E-TRE-MCD-561-0024, v1.0

3 INTRODUCTION

MICADO is the Multi-AO Imaging Camera for Deep Observations, which is being designed to work with adaptive optics on the E-ELT. 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 using natural guide stars during the early operational phase.

The MICADO concept appears in RD5. This document reports compliance with the specifications laid out in AD1.

4 COMPLIANCE MATRIX

The following table summarizes the compliance of the MICADO concept with the enumerated requirements laid out in AD1.

Requirement	Compliant (Y/N)	Comment	Reference
2.1 Instrument Concept, Wavelength Range			
Direct Camera	Y	The camera performs direct imaging via fixed-mirror, all-reflective optics	RD7, Sec 4.2
Diffraction Limited	Y	Diffraction limited and properly sampled for J-K bands in a 53” field. Tolerance analysis is performed to a specification of 70% Strehl at 1μm	RD7, Sec 4.2
Widest FoV delivered	Y	Diffraction-limited 53” field in primary imaging field. Higher resolution (1.5 mas sampling, 6” Field of View) in auxiliary arm.	RD7, Sec 4.2
NIR Wavelengths	Y	Slots for 20 filters, including broad and narrow-band. Design optimized for 0.8 - 2.4μm	RD7, Sec 6.6.3
I Band	Y	Optimized for 0.8 - 2.4μm. Science tradeoff indicates 0.6 μm cut-off has some value, but AO performance is insufficient	RD7, Sec 4.2
2.2 Observing Modes			
Primary Mode	Y	Direct imaging with filters, properly sampled at the E-ELT diffraction limit for J-K bands	RD7, Sec 4.2
Study of Optional Mode – Visible Wavelengths	Y	MICADO is optimized for 0.8-2.4 μm. Operation to 0.6 μm has been studied, but AO performance is poor. Implementation would have an adverse impact on primary wavelengths.	RD4, Sec 6

Study of Optional Mode – GLAO Operation	Y	This has been studied, but there are few compelling science drivers for this mode, since JWST will out-perform MICADO with GLAO. Also, providing the necessary 10x zoom capability would increase the cost and complexity of MICADO well beyond the value of scientific return.	RD4, Sec 5.1.2
Study of Optional Mode - SCAO	Y	We have studied and adopted a strategy of early use of MICADO with SCAO. A conceptual design of the support structure, relay optics, and WFS system for SCAO has been performed.	RD10
Study of Optional Mode - spectroscopy	Y	Spectroscopy was identified by the science team as an important capability to include in the MICADO design. It has been studied as part of the Auxiliary Arm.	RD4, Sec 5.1.3 RD7, Sec 4.3 & 6.5.3
2.3 Pixel Scale, Sampling			
Science Trade-off	Y	Phase A includes a science trade-off on pixel scales. The importance of a fixed, stable focal plane for JHK astrometry, coupled with the desirability of a finer scale for shorter wavelengths and thorough sampling of single targets has led to the two-arm design.	RD6, Sec 4.2.1 RD4, Sec 6
2.4 Filters			
Wide and Narrow Band, Trade-off	Y	The science trade-off addressed the issue of number and type of filters. There is space for 20 filters in each arm, although the exact specifications have not yet been decided.	RD4, Sec 6 RD7, Sec 6.6.3
2.5 Performance			
2.5.1 Throughput>60%	Y	The total throughput of MICADO exceeds 60% over its operational bands. This throughput, the AO performance, and the thermal background of the EELT and MAORY optics determine the final sensitivity of MICADO.	RD7, Sec 9 (Appendix 3)
2.5.2 Instrument thermal background	Y	MICADO will increase the thermal background above that of the telescope *alone* by approximately 13% in the H and K bands, which is close to the 10% specification. MICADO's contribution relative to the telescope + MAORY (for which it was designed) is below 10% wavelengths and filters. If the sky is included MICADO's	RD5, Sec 6 (Appendix 1)

			thermal contribution is negligible.	
2.5.3 Scattered Light, Ghosts		Y	Reflective optics and the option of tilting filters and windows place ghosts below the requirements. The initial estimate is that scattered light will be <0.5% of the background and ghosts from focussed sources $<10^{-5}$ of the original intensity.	RD7, Sec 4.2
2.5.4 Image Quality		Y	Tolerance analysis is performed to a specification of 70% Strehl at 1μm.	RD7, Sec 4.2.2
2.5.5 Photometric Accuracy		Y	Photometric accuracy of 0.03 mag, dominated by PSF fitting. The ultimate accuracy will be limited by knowledge and field variations of the PSF delivered by MAORY rather than distortion and/or image quality of MICADO.	RD4, Sec 4.2 & 6 RD11
2.5.5 Astrometric Accuracy		Y	A detailed study of the sources of error wrt astrometry leads to a relative accuracy of 50 μas over the full field in a single, well-calibrated exposure. This allows proper motion studies at the level of 40 μas/year for a single observing epoch and 10 μas/year for a 3-4 year campaign.	RD9
2.6 Instrument Location and Associated AO Systems				
Location		Y	Detailed study, collaboration with the MAORY group, and a trade-off analysis, has led to a gravity-stable location underneath the MAORY system. This configuration is compatible with early use of MICADO with the SCAO system / ATLAS.	RD7, Sec 6.1 RD12, Sec 4.2.3
2.7 Interfaces, Cost, and FTE Estimates				
E-ELT Interface Compliance (as in AD2)	Volume	Y	Rotating diameter 3.8 m. Height 2.5 m, including support structure	RD7, Sec 3.2.4
	Weight	Y	Weight of instrument & cryostat is ~3000 kg; additional weight on Nasmyth platform (electronics & cable-wrap) is 2500kg; calibration unit is 500kg.	RD7, Sec 3.2.3
	other	Y	The integration and transport, control hardware, cryogenics, control software, data reduction software, operations: telescope interfaces are compliant with AD2 as far as this can currently be assessed.	RD5 RD7 RD13 RD14
Cost		Y	The total cost of MICADO, including the SCAO module for early operations, is 10.8M€ (zero contingency), which is close to the preliminary estimate for target cost in AD1.	RD3, Sec 7

		This cost can be broken down into: MICADO initial phase: 5.1M€ SCAO module: 0.6M€ MICADO upgrade for MCADO: 5.1M€	
FTEs	N/A	Workpower estimate is 189 FTE, including a 20% contingency. AD1 did not specify a manpower requirement.	RD3, Sec 7

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