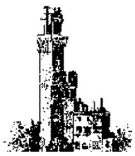


E-ELT PROGRAMME

MICADO Phase A
Top Level Instrument Software User Requirements

Document: E-TRE-MCD-561-0021
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Date: 2009-10-21

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CHANGE RECORD

ISSUE	DATE/AUTHOR	SECTION AFFECTED	REASON/ REMARKS
1.0	2009-10-21	all	Phase A review version.

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1 INTRODUCTION

1.1 Purpose

The purpose of this document is to describe the set of *user requirements* towards the MICADO Instrument Software. Such requirements are both of scientific and technical nature and come from:

1. The instrument characteristics as described in [AD 01], [AD 02] and [AD 03].
2. The operational scenarios as described in [AD 01].
3. External requirements on software imposed by ESO:
   - E-ELT top level observatory requirements as described in [AD 04],
   - E-ELT interface requirements to scientific instruments as described in [AD 05] and
   - requirements related to the actually not yet precisely defined E-ELT Common Software Framework provided by ESO and to the technology used for the implementation of control systems, respectively. See for reference [AD 07].

This is the first document entirely dedicated to software for MICADO. It shall be applicable to all the documents which will follow it.

In order to trace more easily all requirements and related solutions in the next software documents, all requirement described here have a numbered tag: [**REQ 001**]. Section 7 lists all these tagged requirements again in tabular form.

1.2 Scope

This document defines the user requirements towards the *MICADO Instrument Software (INS)* only. The *MICADO top level data reduction user requirements* are described in [AD 06].

Furthermore, it is assumed that an E-ELT Common Software Framework for the communication between instruments, AO modules, telescope and detector control software will be provided by ESO[1]. Requirements on this Middleware layer are not part of this document. Other packages delivered by ESO are the Archive for storing of the acquired images and the Detector Control Software (DCS). These are not in the scope of this document either.

1.3 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.

Ref.	Document Number	Issue	Date	Title
AD 01	E-TRE-MCD-561-0009	2.0	2009-10	MICADO System Overview
AD 02	E-TRE-MCD-561-0011	5.0	2009-10	MICADO Opto-Mechanical Design and Analysis
AD 03	E-TRE-MCD-561-0013	1.0	2009-10	MICADO Control

[1] Discussion on 2009-07-23 with Mario Kiekebusch.

				Electronics Design
AD 04	E-SPE-ESO-079-0260	1	2008-06-04	Observatory Top Level Requirements
AD 05	E-TRE-ESO-586-0252	1	2008-06-20	E-ELT Interfaces for Scientific Instruments
AD 06	E-TRE-MCD-561-0024	1.0	2009-10	MICADO Top Level Data Reduction User Requirements
AD 07	INS-09/03	1	2009-08-09	Technological options under consideration for the E-ELT Instrument Control Systems

1.4 Reference Documents

The following documents and books are referenced in this document:

Ref.	Document Number	Issue	Date	Title
RD 01	E-SPE-MCD-561-0014	1.0	2009-10	MICADO – MAORY Phase A Interface Specification
RD 02	E-TRE-MCD-561-0022	1.0	2009-10	MICADO Single Conjugate Adaptive Optics Module
RD 03	VLT-SPE-ESO-17240-3221	2	2007-02-16	VLT Instrument Software Template for User Requirements Specification
RD 04	UML 2.0 Superstructure Specification			
RD 05	Cockburn, A.: Writing Effective Use Cases. , Addison Wesley, 2001			

1.5 Abbreviations and Acronyms

This document employs several abbreviations and acronyms to refer concisely to an item, after it has been introduced. The following list is aimed to help the reader in recalling the extended meaning of each short expression:

ADC	Atmospheric Dispersion Compensator
AO	Adaptive Optics
DCS	Detector Control Software
Dec	Declination
DRS	Data Reduction Software
E-ELT	European Extremely Large Telescope
ESO	European Southern Observatory
FITS	Flexible Image Transport System
FoV	Field of view
GUI	Graphical User Interface
GS	Guide Star
HW	Hardware
ICS	Instrument Control Software
INS	(MICADO) Instrument Software

IWS	Instrument Workstation
LGS	Laser Guide Star
MAORY	Multi-conjugate Adaptive Optics Relay for the E-ELT
mas	milli arcsecond
MCAO	Multiconjugate Adaptive Optics
MICADO	The Multi-AO Imaging Camera for Deep Observations
MoS	Monitoring Star
MS	Maintenance Software
N/A	Not Applicable
NGC	New General Detector Controller
NGS	Natural Guide Star
OB	Observation Block
OS	Observation Software
OSS	Observer Support Software
P2PP	Phase 2 Proposal Preparation
RA	Right ascension
RTD	Real Time Display
SCAO	Single Conjugated Adaptive Optics
SGS	Secondary Guide Star
TBC	To Be Clarified
TBD	To Be Defined
TCS	Telescope Control Software
UC	Use Case
UIF	User Interface
VLT	Very Large Telescope
WS	Workstation

1.6 Glossary

Observation Block (OB): The smallest schedulable unit for any observation, calibration or maintenance operation. An OB contains each and every information necessary to perform the operation and has to be prepared by the observer in advance. Furthermore, it is assumed that *all standard operations with MICADO will be done by means of observation blocks* and hence an OB is the usual way for an observer to interact with the instrument.

Science OB: An OB dedicated to the observation of astronomical targets on sky, including such targets which are of pure reference purpose (photometric standard stars, sky flats etc.). This definition follows the one from the VLT Data Flow concept.

Calibration OB: An OB dedicated to the acquisition of reference data without the necessity to observe an astronomical target on sky (including bias, internal flat field, wavelength calibrations by means of arc lamps etc.). This definition again follows the one from the VLT Data Flow concept.

Template: A functional unit executing parts of the OB functionality and implemented as program scripts. Whether OBs for E-ELT observations will be composed of templates as for VLT observations is still to be defined.

Small Dither: An offset of less than ±0.3 arcsec (goal 0.5 arcsec) from the initial pointing in X and Y direction with an accuracy of ~2 mas. Such a move will be performed and controlled by

the AO System alone and does not require a telescope offset. The *AO loops* will be kept *closed* during the dither operation.

Large Dither: An offset of up to 10 arcsec from the initial pointing. Such a move is controlled by MICADO and requires a telescope offset and interaction with the AO System. The *AO loops* will be *open* during the dither operation and closed again at the new pointing.

Sky Offset: An offset of more than 10 arcsec but less than 15 arcmin from the initial pointing. Requires an appropriate telescope offset or preset operation, respectively. The *AO loops* will be *opened* and, unlike as for large dithers, not closed at the new pointing.

Sky Return: The return operation from a pointing which was reached by a sky offset. After a sky return the *AO loops* will be *closed again*.

2 OVERALL DESCRIPTION

2.1 Instrument Overview

MICADO is the imaging camera for the 42-m European Extremely Large Telescope (E-ELT).

It is designed to work with two AO systems – with the Single Conjugated Adaptive Optics (SCAO) module and with the Multi-conjugate Adaptive Optics Relay (MAORY). This section briefly describes the characteristics of the MICADO instrument that are relevant for the definition of the user requirements. The sketches below (Figure 1 and Figure 2) show very schematically the main components of MICADO. The instrument has two light paths. The *primary path* is destined for imaging with a FoV of 53x53 arcsec with pixel scale equal 3 mas/pixel. With the *auxiliary path* imaging with pixel scale of 1.5 mas/pixel over a smaller field and spectroscopy with resolution 3000-5000 and 4mas pixel scale will be made. MICADO has 17 detectors (16 in primary, 1 in auxiliary path). The calibration unit is under control of MICADO but located in the AO system.

MICADO has interfaces to the E-ELT Software Framework, Archive, the AO Systems (MAORY/SCAO), TCS and DCS. The interfaces to MAORY and SCAO are kept almost identical. This interface to MAORY is described in [RD 01].

2.2 Modes

MICADO will be operated in two modes [**REQ 002**]:

1. Imaging
2. Spectroscopy

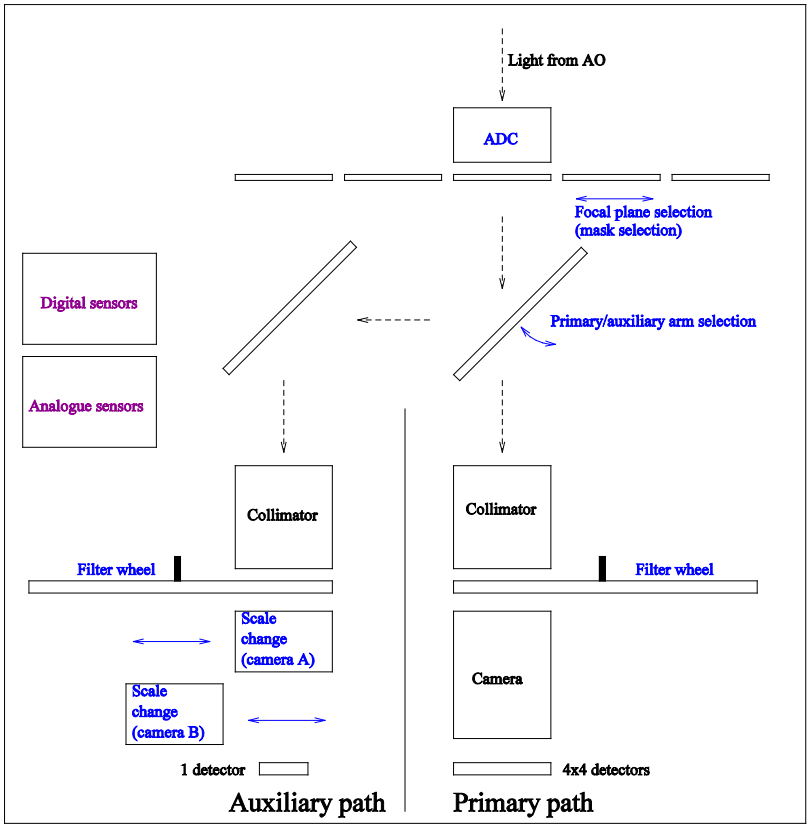

Figure 1: Schematic sketch of the instrument part of MICADO. Moved components are described in blue, monitored devices in magenta. For simplicity refractive optics was assumed in this sketch. In reality the collimators and cameras are reflective.

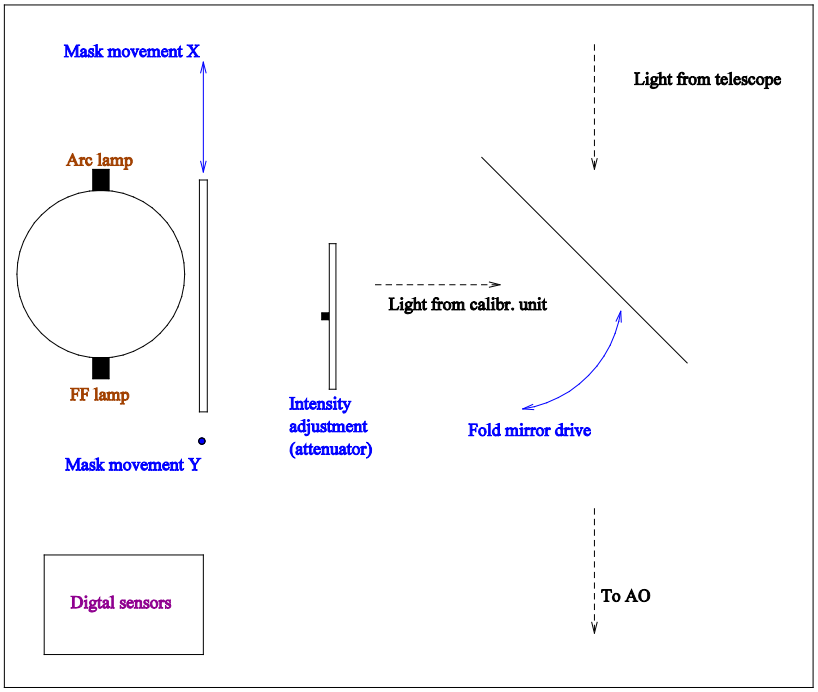

Figure 2: Schematic sketch of the calibration unit. Moved components are described in blue, lamps in brown and monitored devices in magenta. The calibration unit is located in the AO system.

2.3 Devices

The following table describes the devices seen by the control electronics and related software i.e. those devices that are to be controlled or sensors whose output is to be monitored.

#	Device	Remarks	Values
1	Focal plane selection	1. Selection of mask to be inserted in light path (located in instrument). 2. Stepper motor 3. With resolver	6 positions (field stops for primary and auxiliary arms, 2 long slits, closed position, hole array)
2	Selector primary / auxiliary path	1. Move fold mirror 2. Stepper motor 3. With resolver	PRIMARY/AUXILIARY position
3	Filter wheel / primary	1. Filter wheel in the primary path 2. Stepper motor 3. With resolver	Several positions
4	Filter wheel / auxiliary	1. Filter wheel in the auxiliary path 2. Stepper motor 3. With resolver	Several positions
5	Auxiliary channel A selection	1. Moveable camera to select channel A. 2. When camera A is in light path camera B must be in “OUT” position. 3. Stepper motor 4. With resolver	IN/OUT
6	Auxiliary channel B selection	1. Moveable optics (camera) to select channel B 2. When camera B is in light path camera A must be in “OUT” position. 3. Stepper motor 4. With resolver	IN/OUT
7	Fold mirror drive	1. Directs light from calibration unit to optical path of the AO system. 2. DC motor 3. With encoder	IN/OUT
8	Calibration mask x	1. Shifts calibration mask into field and positions it in x direction 2. DC motor 3. With encoder	Several positions
9	Calibration mask y	1. Positions mask in y direction 2. DC motor 3. With encoder	Several positions
10	Adjustment of intensity of lamps (attenuator)	1. Rotational drive 2. DC motor 3. With encoder	3 – 4 positions
11	ADC (2 motors)	1. Positioning of ADC drives depending on zenith distance	

		2. Frequency about 2 per minute. 3. DC motor 4. With encoders	
12	Flat field lamp		ON/OFF
13	Arc lamp		ON/OFF
14	DIGIO signals	Acquisition, logging and generation of alarms	Interlocks, warnings and alarms e.g. over temperatures, too high pressure, etc
15	Analogue signals	Acquisition, logging and generation of for analogue signals	Temperatures, pressure, position information from resolvers, coolant flow, etc
16	Detectors	17 detectors with 4k x 4k pixels	

Table 1: MICADO Devices.

In total there are 2 lamps, 12 motors to be controlled and about 50 analogue and 50 digital signals to be monitored [**REQ 003**]. The detailed list of signals is given in **[AD 03].**

3 FUNCTIONAL REQUIREMENTS

3.1 Preparation of observations

According to the Observatory Top Level Requirements [AD 04] all observations with the E-ELT will take place by means of *Observation Blocks (OBs)* [**REQ 004**] as it is the case already for VLT observations. Accordingly, these smallest schedulable observation units have to be prepared in advance by the observer using a dedicated piece of preparation software, hereafter referred to as *Observer Support Software (OSS)*, *OSS tool* or simply *OSS*. Besides the specification of the usual parameters like target position, exposure time, wavelength band etc. the following MICADO specific tasks have to be performed here:

1. The Natural Guide Stars (NGS) and a Monitor Star (MoS) for the AO system and a Secondary Guide Star (SGS) to support secondary guiding for MICADO have to be selected.
2. If the science target for imaging or spectroscopy is too faint a bright reference star shall be defined for accurate acquisition.
3. The Field of View (FoV) for imaging has to be chosen in such a way that bright stars unwanted for observation are located outside of and in the gaps between the detectors, respectively.

Essentially, the OSS tool will resemble very much the P2PP tool used for VLT observations.

3.2 Science operations

A typical observation consists of one or more exposures on the target and on sky and is accompanied by a set of calibration exposures which may be taken directly before or after the science exposure or during daytime.

3.3 Maintenance operations

Besides the scientific operation at the telescope, the MICADO Instrument Software needs to support the testing activities in Europe and at the E-ELT Observatory, the commissioning phase and the maintenance of the instrument [**REQ 005**]. Actually there is only one task related to software – taking a series of images and determination of telescope focus.

3.4 Use cases

The following section analyses the main functionality of the MICADO Instrument Software in terms of *use cases* as a medium to cover the *behavioural requirements*.

Each use case describes an interaction of at least one of the interacting entities (persons, external systems, etc., in general called *external actors*) with the system under consideration (here: MICADO Instrument Software) while regarding the latter one as a black box. Interactions within the system are not considered as far as they don't affect any external actor.

The following (external) actors can interact with the MICADO Instrument Software (INS):

- *Observer*: Can be any person who is able to prepare an observation with MICADO.
- *E-ELT Operator*: Any person with general permissions at the instrument, in particular with the permission to execute observation blocks and to perform maintenance operations. In

general, this person will be a member of E-ELT staff. An E-ELT Operator (or simply *Operator*) has the authority to do all operations a normal observer can perform and therefore he is a 'special observer'. This is expressed in the UML diagrams by a generalization relation.

- *Image Server*: An online source of images possibly to be used during observation preparation.
- *Catalogue Server*: An online catalogue of potential Natural Guide Stars (NGS), Secondary Guide Stars (SGS) and Monitoring Stars (MoS).
- *ESO Database*: The repository where OBs are stored.
- *MICADO Hardware:* Any MICADO devices driven by the instrument control electronics.
- *AO System:* The Adaptive Optics module (either MAORY or SCAO) which MICADO is connected to.
- *Telescope Control Software (TCS)*: Standard component of ESO E-ELT software. Delivered by ESO.
- *Detector Control Software (DCS)*: Standard component of ESO E-ELT software. Delivered by ESO.
- *Archive Server*: The software component archiving the raw FITS frames. Delivered by ESO.

Only *Observer* and *E-ELT Operator* are *primary actors* in the sense that they are able to trigger any use case.

Two different levels of detail are considered:

- *User goal level use cases*: These higher level use cases describe more or less complete and independent scenarios to achieve a user goal, i.e. a result which in the general system behaviour only slightly depends on other user goals.
- *Subfunction use cases*: These are of lower level and are required to carry out the functionality of user goal level use cases. They can essentially be considered as functional steps which are included in the higher level ones. Use cases of subfunction level are hyperlinked in the main success scenario step of the user goal level use case where they are included in.

Although use cases are primarily a text description the overview of their mutual dependency and their connection with external actors can be improved by use case diagrams according to the Unified Modelling Language (UML). In the following only the top level view with all the user goal level use cases is shown. Regarding the drawing standard, the UML 2.0 Superstructure definition [RD 04] was applied.

As far as the format of the use case description itself is concerned, a template similar to the "fully dressed" one introduced by A. Cockburn [RD 05] is used. The different entries have the following meanings:

- *Characteristic Information*: Essential information belonging to each use case and defining the frame in which the use case behaviour runs.

- *Main Success Scenario*: Describes the sequence of steps from an initial trigger event to the successful achievement of the use case goal. Executed under 'usual' conditions without any exceptions and without consideration of less usual special modifications.
- *Scenario Extensions*: Description of possible deviations from the Main Success Scenario due to exceptions or certain external conditions, respectively. A particular extension has the same numbering as the corresponding step in the Main Success Scenario.
- *Scenario Variations*: Alternatives to the steps in the Main Success Scenario. A certain Scenario Variation with the numbering of the corresponding Main Success Scenario step describes a different way to achieve the same goal.
- *Related Information*: Any external information which is either necessary or complementary for understanding of the use case behaviour.

Furthermore, a use case may depend on certain (e.g. setup) *parameters*, the detailed list/description of which are moved and hyperlinked to section Data.

Figure 3 and Figure 4 below show the most important (user goal level) use cases whose descriptions are subject of the following subsections. Here, the scope of the MICADO software as a whole is subdivided into the actual MICADO Instrument Software, consisting of the Observer Support Software (OSS), Observation Software (OS), Instrument Control Software (ICS) and Maintenance Software (MS) and into the MICADO Data Reduction Pipeline which is subject of [AD 06].

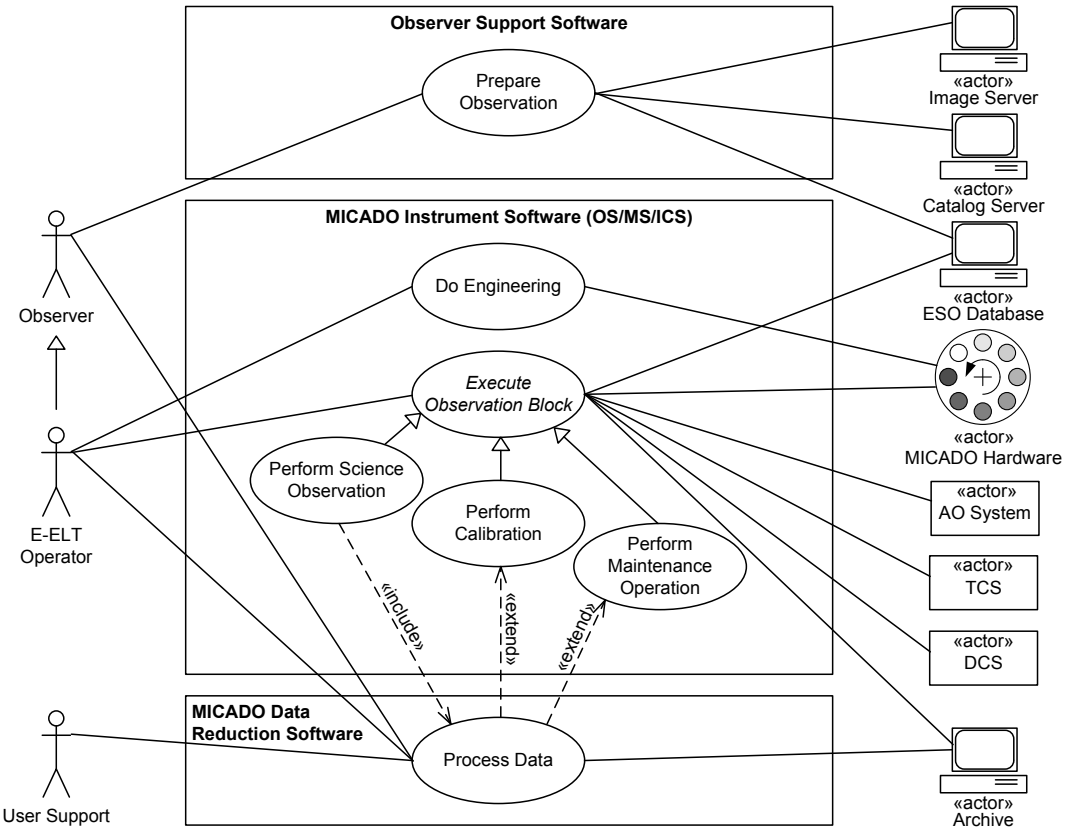

Figure 3: User goal level use cases within the scope of MICADO Software together with all external actors. The MICADO Data Reduction Software is not within the scope of this document.

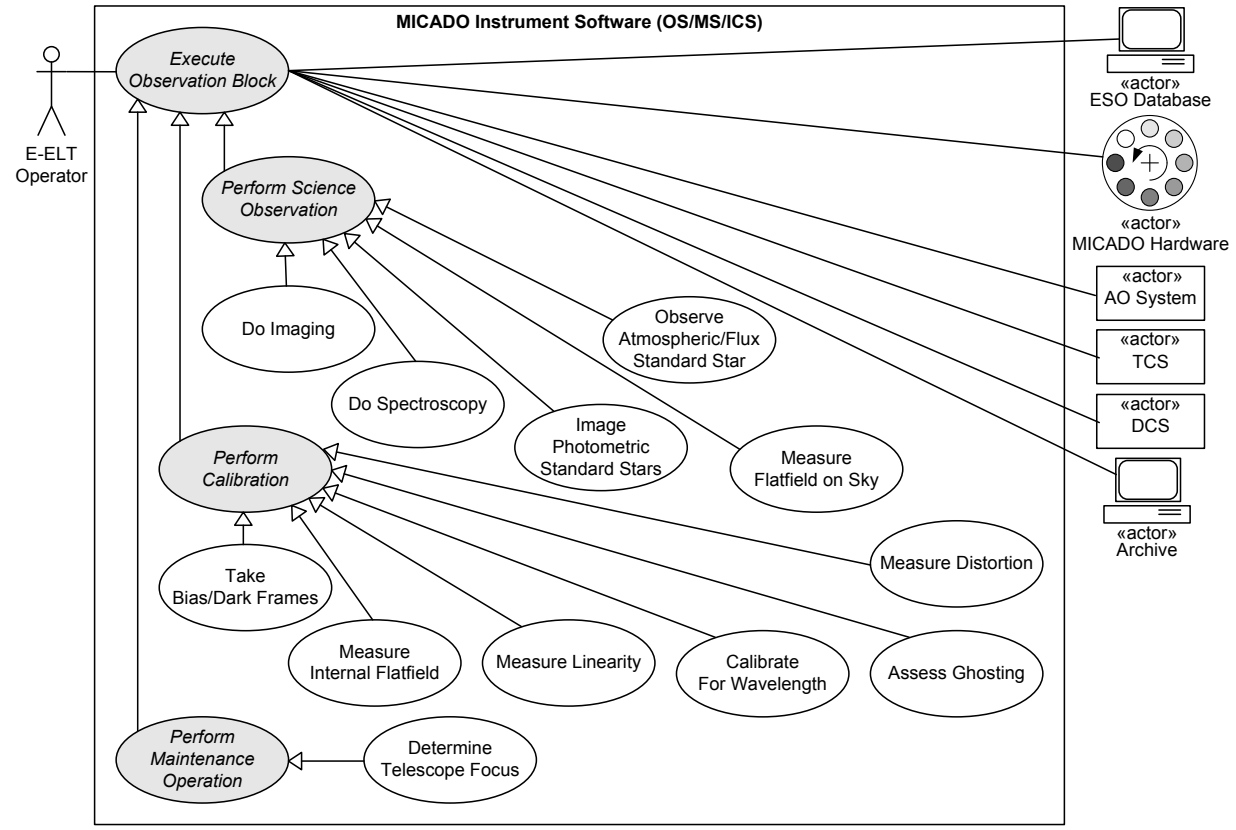

Figure 4: The science, calibration and maintenance use cases actually corresponding to Observation Blocks. Note that calibration operations on sky are classified as "Science" observations according to the definition from the VLT data flow concept.

Use case 1: Prepare Observation

Characteristic Information

Goal in Context:	Create executable Observation Block (OB) by specifying parameters for any scientific or calibration operation [**REQ 006**].
Scope:	Observer Support Software.
Level:	User Goal.
Preconditions:	Observer has been assigned observing time. Observer is logged on to the OSS tool.
Success End Condition:	Observer has prepared at least one valid OB which can be executed by the MICADO Instrument Software. The OB has been locally saved or submitted to ESO.
Failed End Condition:	No valid OB could be created.
Primary Actor:	Observer.
Trigger Event:	Observer creates new OB from scratch by means of the appropriate OSS GUI element.

Main Success Scenario

1. Observer creates new OB from scratch.
2. Observer selects type of intended observation/operation and defines which basic functional parts the OB consists of[2] [**REQ 007**].
3. Observer specifies values for the mandatory parameters of the selected observation:
   - Instrument Setup Parameters
   - Telescope Setup Parameters
   - AO System Setup Parameters
   - Detector Setup Parameters
   - Observing Sequence

   OSS tool provides reasonable default values for less important parameters, observer accepts or modifies these and gives the more critical parameters explicitly. OSS tool supports user input by a graphical display that shows the FoV of MICADO and of the AO System, the detector outlines and their orientation with respect to RA and Dec [**REQ 008**].
4. OSS tool displays suitable Natural Guide Stars (NGS) and Monitor Stars (MoS) for AO System and Secondary Guide Stars (SGS) for MICADO in the vicinity of the target graphically as symbols. Observer selects a sufficient number (3NGS, 1MoS for MAORY, 1 SGS for MICADO, 1 NGS for SCAO) of each category [**REQ 009**].
5. Observer enters additional information: supplementary target information, constraint set, allowed time interval for observation, calibration requirements etc. [**REQ 010**]
6. OSS tool verifies the content of the just created OB and ensures that it is executable at the telescope [**REQ 011**].
7. Observer saves OB for further processing [**REQ 012**].

[2] The organisation of OBs as sets of observation *templates* like for VLT observations can not be taken for granted, although it is very likely.

Scenario Extensions

***a** Observer aborts OB creation:
OSS tool asks for confirmation and discards the incomplete OB.

***b** Observer aborts OSS tool:
OSS tool asks for confirmation, discards the incomplete OB and exits.

1a An already existing OB (created previously) shall be copied or modified:
Observer imports OB either from file or from ESO Database.

1b Preparation shall be supported by a previously taken image of the sky region of interest:
Observer loads image from image server.

3a Celestial coordinates of some or all required targets have been prepared beforehand:
Observer loads predefined catalogue.

3b Non-standard exposure time required (usually for all science observations):
Observer calculates exposure time.

4a Not enough suitable NGS/MoS/SGS:
The intended observation is impossible. Observer changes target.

4b Faint target shall be observed (accurate acquisition necessary):
OSS tool presents a selection of suitable bright reference targets. Observer selects one.

5a Observation in Service Mode shall be supported by a finding chart:
Observer loads image from image server and appends finding chart.

6a OSS tool detects an error or invalid parameter:
The OB will be prevented from reaching the ESO database. Observer has to modify the invalid settings.

Scenario Variations

1 Observer creates either *Science* or *Calibration* OB. *Maintenance* OBs shall not be created by means of the OSS tool but provided as ready-to-use units along with INS.

2 The following operations (each of which corresponding to a dedicated use case) are possible:
Science:
- Imaging
- Spectroscopy
- Flatfield measurement on sky
- Telluric/flux standard star observation
- Photometric standard star observation

Calibration:
- Bias/dark frame exposures
- Internal flatfield measurement
- Distortion measurement
- Wavelength calibration
- Ghosting assessment
- Linearity measurement

4 The coordinates of all required celestial positions can be
- retrieved either from an online Catalogue Server,
- provided by a previously defined user catalogue or
- defined interactively.

7 Observer saves valid OB either in local cache or submits it to ESO database.

Related Information

Performance Target:	The retrieval of any celestial positions (NGS, SGS, MoS) from the Catalogue Server shall not exceed 1 minute [**REQ 013**].
Required Accuracy:	The accuracy of celestial positions provided by OSS shall not degrade the accuracy achievable by the instrument (2mas). In particular it shall not depend on the resolution of the GUI display [**REQ 014**].
Frequency:	Once for every valid OB.
Superordinate Use Case:	None.
Subordinate Use Cases:	None.
Channel to Primary Actor:	The dedicated Observer Support Software (P2PP-like) tool.
Secondary Actors:	Image Server Catalogue Server ESO Database
Channels to Secondary Actors:	OSS tool/network connection.

Use case 2: Do Imaging

Relations to subfunction use cases and to external actors

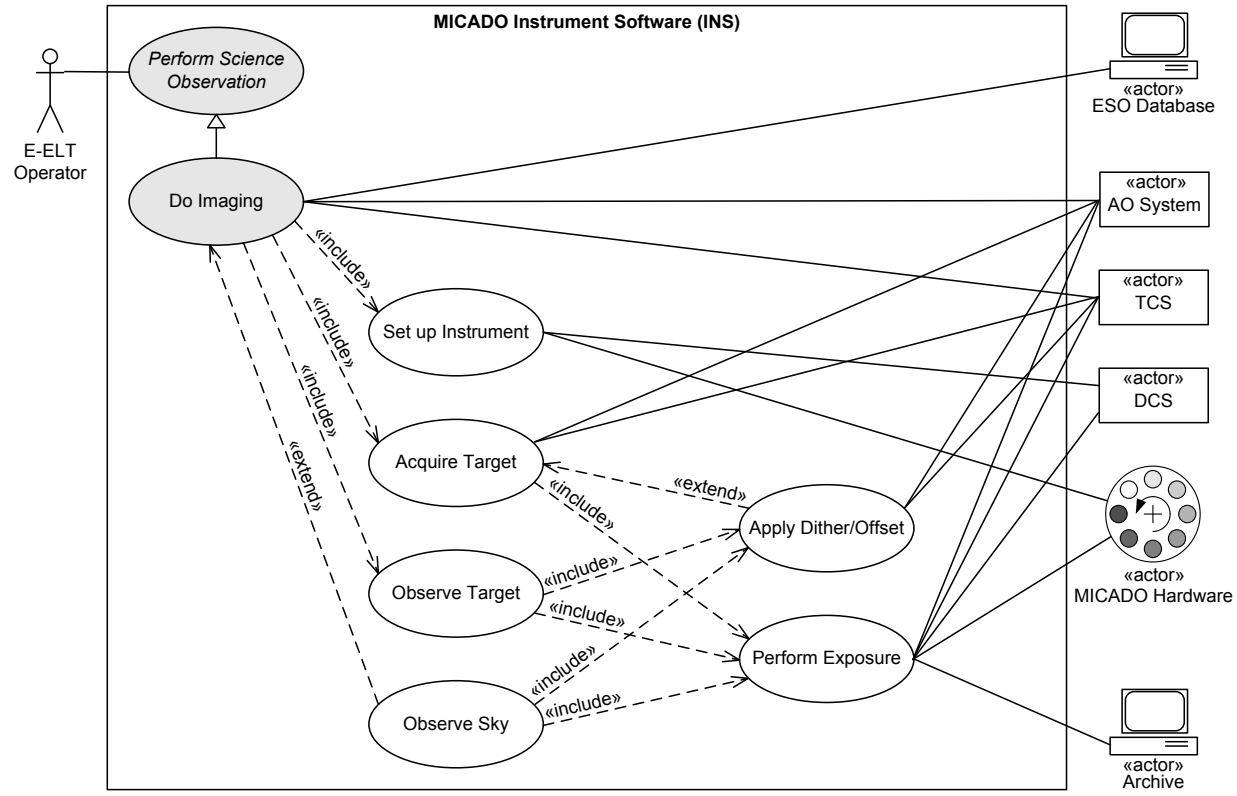

Figure 5: Actors and subfunction use cases involved in "Do Imaging". Note that the particular arrangement of use case symbols does not necessarily indicate a sequence of execution and that the involved subfunction use cases are the same as for "Do Spectroscopy".

Characteristic Information

Goal in Context:	Perform a MICADO observation in imaging mode [**REQ 015**].
Scope:	MICADO Instrument Software (INS).
Level:	User goal.
Preconditions:	Instrument Software, TCS, DCS and the AO System control software are online and idle. Archive System is ready to store science frames.
Success End Condition:	All science data required for a successful completion of the OB have been archived.
Failed End Condition:	Part of the required science data could not be obtained.
Primary Actor:	E-ELT Operator.
Trigger Event:	Operator loads science OB from ESO Database into the appropriate INS application.

Main Success Scenario

1. Operator starts OB.
2. INS registers itself at TCS and AO System.

3. INS sets up instrument for imaging.
4. Operator lets INS acquire the target.

Steps 3 and 4 can be performed in parallel.

5. INS extracts observing sequence parameters from OB and calculates number and duration of cycles with large dithers and sky frames from OB length and given dither patterns.
6. INS observes target.
7. INS observes sky.

Steps 6 and 7 can be repeated for a number of cycles to be calculated by INS.

8. INS makes AO System stop AO.
9. INS signs off from AO system and TCS.

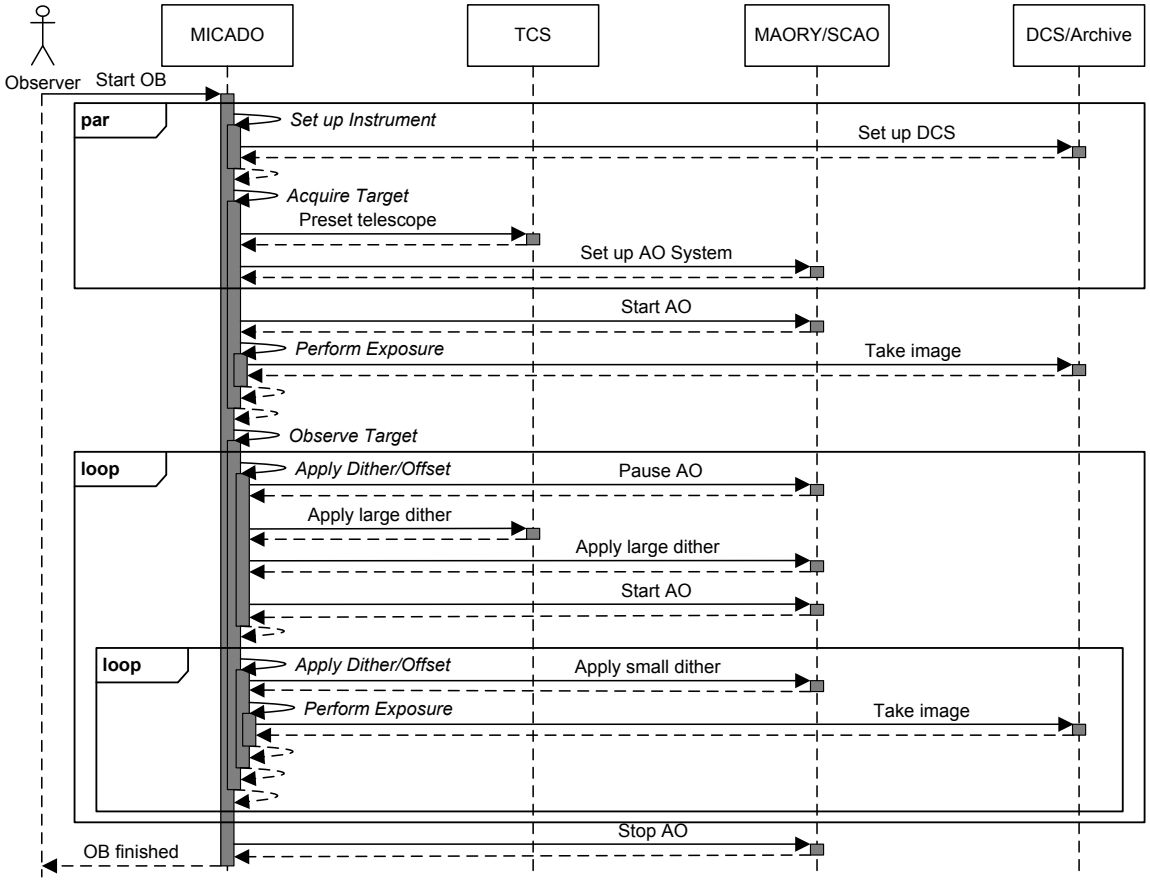

Figure 6: The simplest possible main success scenario of "Do Imaging" and the involved subfunction use cases. Only the most important steps are depicted (e.g. no sky images are taken).

Scenario Extensions

***a** Operator aborts OB execution:
INS makes operator confirm, aborts operations on all involved secondary actors and logs the incident.

***b** INS detects an unexpected failure:
- *b1 INS displays an error message, aborts OB execution and logs the error.
- *b2 Operator determines cause of error and tries to execute OB again.
  - ***b2a** Failure cannot be handled:

Operator terminates the instrument operation.

7a Extra sky frames not required:
Step will be skipped.

7b Sky offset larger than the maximum allowed telescope offset of 60 arcsec [AD 04]:
INS acquires target again after returning from sky position.

Scenario Variations

***a** Imaging can be performed with primary field or with auxiliary path.

Related Information

Performance Target:	It is expected that the ratio of pure exposure time to the total duration of the OB will be better than 60 percent. MICADO Instrument Software shall not increase the non-observing time by more than 3% (SW overhead for setup, writing image to disk etc.) [**REQ 016**].
Required Accuracy:	Accuracy requirements are covered by subordinate use cases Set up Instrument (UC #4), Acquire Target (UC #5) and Apply Dither/Offset (UC #8)
Frequency:	Several times per night.
Superordinate Use Case:	None.
Subordinate Use Cases:	Set up Instrument (UC #4) Acquire Target (UC #5) Observe Target (UC #6) Observe Sky (UC #7) Apply Dither/Offset (UC #8) Perform Exposure (UC #9)
Channel to Primary Actor:	OB executing application.
Secondary Actors:	ESO Database, MICADO Hardware, AO System, TCS, DCS, Archive.
Channels to Secondary Actors:	E-ELT Common Software.

Use case 3: Do Spectroscopy

Relations to subfunction use cases and to external actors

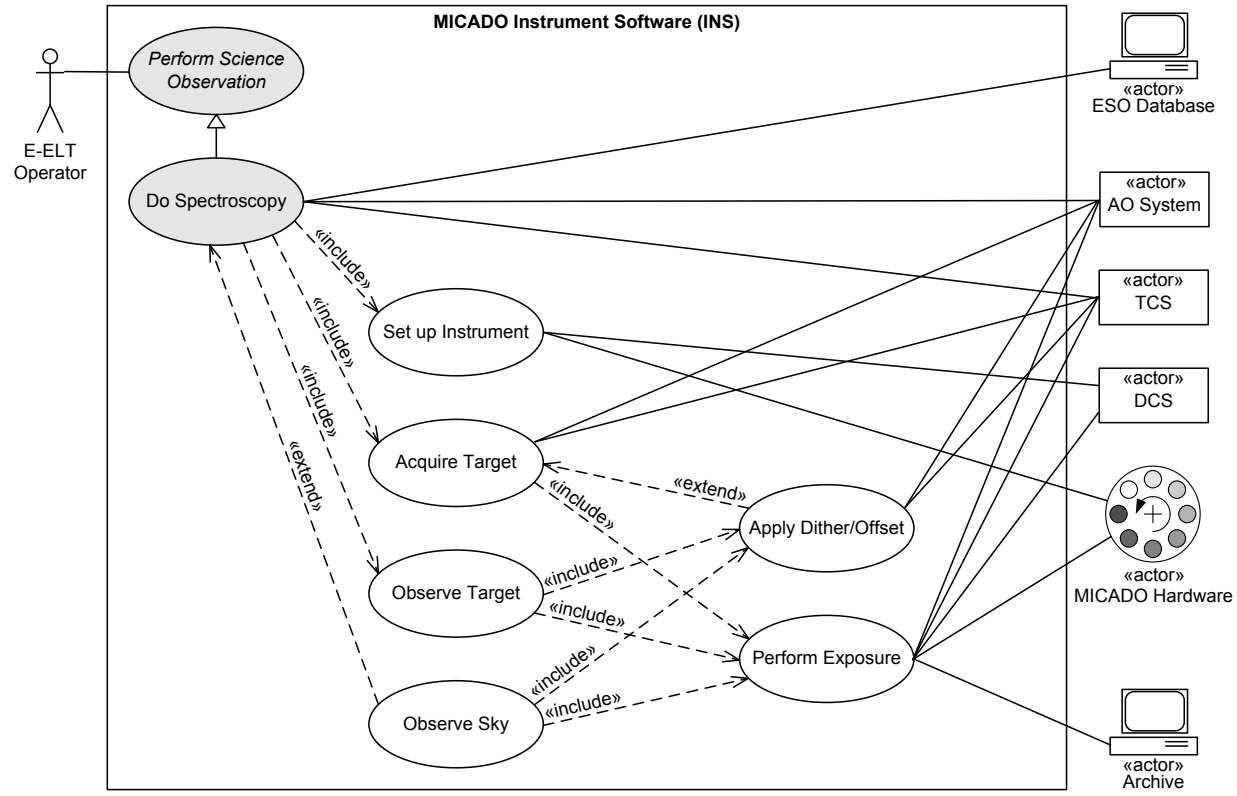

Figure 7: Actors and subfunction use cases involved in "Do Spectroscopy". Note that the particular arrangement of use case symbols does not necessarily indicate a sequence of execution and that the involved subfunction use cases are the same as for "Do Imaging".

Characteristic Information

Goal in Context:	Perform a MICADO observation in spectroscopy mode [**REQ 017**].
Scope:	MICADO Instrument Software (INS).
Level:	User goal.
Preconditions:	Instrument Software, TCS, DCS and the AO System control software are online and idle. Archive System is ready to store science frames.
Success End Condition:	All science data required for a successful completion of the OB have been archived.
Failed End Condition:	Part of the required science data could not be obtained.
Primary Actor:	E-ELT Operator.
Trigger Event:	Operator loads science OB from ESO Database into the appropriate INS application.

Main Success Scenario

1. Operator starts OB.

2. INS registers itself at TCS and AO System.
3. INS sets up instrument for imaging.
4. Operator lets INS acquire the target.

Steps 3 and 4 can be performed in parallel.

5. INS sets up instrument for spectroscopy.
6. INS extracts observing sequence parameters from OB and calculates number and duration of cycles with small dithers (nods) and possibly sky frames from OB length.
7. INS observes target for the calculated number of cycles.
8. INS observes sky.

Steps 7 and 8 can be repeated for a number of cycles to be calculated by INS.

9. INS makes AO System stop AO.
10. INS signs off from AO system and TCS.

Scenario Extensions

***a** Operator aborts OB execution:
INS makes operator confirm, aborts operations on all involved secondary actors and logs the incident.

***b** INS detects an unexpected failure:
*b1 INS displays an error message, aborts OB execution and logs the error.
*b2 Operator determines cause of error and tries to execute OB again.
***b2a** Failure cannot be handled:
Operator terminates the instrument operation.

8a Extra sky frames not required:
Step will be skipped.

8b Sky offset larger than the maximum allowed telescope offset of 60 arcsec [AD 04]:
INS acquires target again after returning from sky position.

Related Information

Performance Target:	It is expected that the ratio of pure exposure time to the total duration of the OB will be better than 60 percent. MICADO Instrument Software shall not increase the non-observing time by more than 3% (SW overhead for setup, writing image to disk etc.) [**REQ 018**].
Required Accuracy:	Accuracy requirements are covered by subordinate use cases Set up Instrument (UC #4), Acquire Target (UC #5) and Apply Dither/Offset (UC #8)
Frequency:	Several times per night.
Superordinate Use Case:	None.
Subordinate Use Cases:	Set up Instrument (UC #4) Acquire Target (UC #5) Observe Target (UC #6) Observe Sky (UC #7) Apply Dither/Offset (UC #8) Perform Exposure (UC #9)
Channel to Primary Actor:	OB executing application.

Secondary Actors:	ESO Database, MICADO Hardware, AO System, TCS, DCS, Archive.
Channels to Secondary Actors:	E-ELT Common Software.

Use case 4: Set up Instrument

Characteristic Information

Goal in Context:	Configure MICADO Hardware and DCS for the upcoming science or calibration operation [**REQ 019**].
Scope:	MICADO Instrument Software.
Level:	Subfunction.
Preconditions:	Instrument Software and DCS are online and idle.
Success End Condition:	MICADO hardware and DCS are properly configured for the upcoming science or calibration operation.
Failed End Condition:	One of the MICADO hardware components or DCS not ready.
Primary Actor:	E-ELT Operator.
Trigger Event:	An appropriate command within the currently running OB is executed.

Main Success Scenario

1. INS sets instrument mode to either *Imaging* or *Spectroscopy*.
2. INS selects primary or auxiliary arm.
3. INS sets filter wheel to required position.
4. INS inserts appropriate focal plane mask.
5. INS extracts detector setup parameters from OB and transfers setup information to DCS. DCS sets up itself for the upcoming operation.

Steps 1 – 5 can be performed in parallel.

6. INS sets initial ADC position and starts semi-continuous ADC correction.
7. INS reports on successful setup completion.

Scenario Extensions

***a** Operator aborts OB execution:
INS makes operator confirm, aborts operations on all involved secondary actors and logs the incident.

3a Calibration unit required:
- 3a1 INS inserts calibration unit into light path.
- 3a2 INS selects arc or flatfield calibration lamp and adjusts intensity.
- 3a3 INS sets calibration mask to required position.

Scenario Variations

3 For imaging: INS selects filter.
For spectroscopy: INS selects grism and slit.

6 The initial ADC position can be determined in the following ways:
- Calculated by INS from actual observation time.
- Calculated by INS from actual zenith distance delivered by TCS on request.
- Fixed by definition to a zenith-equivalent position (for calibrations).

Related Information

Performance Target:	The duration of instrument setup is expected to be in the order of 150 seconds. MICADO Instrument SW shall not contribute to the total setup time by more than 5% [**REQ 020**]. Parallel setup of devices is to be implemented as much as possible to increase the efficiency [**REQ 021**]. Calibration lamps which require warm-up time should be switched on at the start of any set-up [**REQ 022**].
Required Accuracy:	MICADO Instrument SW shall not degrade the achievable positioning accuracy of individual hardware components (grisms, slits, etc.) given by their intrinsic properties [**REQ 023**].
Frequency:	For spectroscopy observations on sky two consecutive instrument setups (for imaging and spectroscopy) are required. Otherwise once per OB.
Superordinate Use Case:	Do Imaging (UC #2) Do Spectroscopy (UC #3) Take Dark Frames (UC #10) Measure Internal Flatfield (UC #11) Measure Flatfield on Sky (UC #12) Observe Atmospheric/Flux Standard Star (UC #13) Image Photometric Standard Stars (UC #14) Measure Distortion (UC #15) Calibrate for Wavelength (UC #16) Determine Telescope Focus (UC #17) Assess Ghosting (UC #18) Measure Linearity (UC #19) Do Engineering (UC #20)
Subordinate Use Cases:	None.
Channel to Primary Actor:	OB executing application.
Secondary Actors:	MICADO Hardware, DCS.
Channel to Secondary Actors:	E-ELT Common Software.

Use case 5: Acquire Target

Characteristic Information

Goal in Context:	Point the telescope to a predefined target region and adjust the AO System accordingly [**REQ 024**].
Scope:	MICADO Instrument Software.
Level:	Subfunction.
Preconditions:	Instrument Software, TCS, DCS and the AO System control software are online and idle.
Success End Condition:	Telescope is at required position, AO loop closed, instrument is ready for target observation.
Failed End Condition:	At least one setting of either telescope, MICADO, or the AO system is not compliant with the intended observation.
Primary Actor:	E-ELT Operator.
Trigger Event:	An OB requiring an acquisition has been started.

Main Success Scenario

1. INS extracts telescope setup parameters from OB and transfers setup information to TCS. TCS presets telescope and starts tracking/guiding and derotating.
2. TCS returns remaining tracking time on request of INS. INS verifies that remaining tracking time is sufficient to execute the remaining OB parts.
3. INS extracts AO system setup parameters from OB and transfers setup information to AO System. AO System sets up itself for the upcoming operation but leaves the AO loop open.

Steps 1/2 and 3 can be performed in parallel.

4. INS verifies that setup of MICADO Hardware and DCS is successfully completed in order to synchronise acquisition with instrument setup.
5. INS makes AO System close the AO loop.
6. INS performs exposure.
7. Operator confirms successful acquisition.

Scenario Extensions

***a** Operator aborts OB execution:
INS makes operator confirm, aborts operations on all involved secondary actors and logs the incident.

2a Remaining tracking time shorter than expected OB length:
INS makes operator confirm, aborts operation and logs the incident.

5a Acquisition is performed for sky flats where no AO is required:
AO loop remains open.

6a Secondary guiding required (only for imaging):
INS determines position of Secondary Guide Star (SGS) and transfers position to AO System as well as position and size of enclosing window to DCS.

7a Exact acquisition required:

- 7a1 INS displays a magnified section of the just taken image which contains the science or reference target, respectively.
- 7a2 INS determines the actual target position automatically from the image.

7a2a INS doesn't find the science or reference target, respectively:
Operator defines target position by clicking on the image.

7a3 Operator accepts the offset to expected science target position calculated by INS.

7a3a Offset unacceptable:
INS makes operator confirm, aborts OB and logs the incident.

7a4 INS applies a dither in order either to move the science target to the expected pixel (for imaging) or to the slit position (for spectroscopy).

7a5 INS performs exposure.

Steps 7a1 – 7a5 can be repeated until operator is happy with the acquisition accuracy.

Related Information

Performance Target:	The maximum telescope preset time will be in the order of 5 min [AD 04]. a) In case of *simple acquisition* MICADO SW shall not contribute more than 1% to the duration of the whole acquisition process [**REQ 025**] . b) In case of *accurate acquisition* (determination of positions, calculation of necessary offsets/dithers etc.) MICADO SW shall not contribute more than 5% to the duration of the whole acquisition process [**REQ 026**].
Required Accuracy:	a) For *simple acquisition* the achievable accuracy is equal to the blind pointing accuracy of the telescope of 3 arcsec [AD 04]. b) In case of accurate acquisition MICADO SW shall not degrade the 2mas pointing accuracy achievable by the AO System [RD 01] by more than 1%[3] [**REQ 027**].
Frequency:	Once per OB.
Superordinate Use Case:	Do Imaging (UC #2) Do Spectroscopy (UC #3)
Subordinate Use Cases:	Apply Dither/Offset (UC #8) Perform Exposure (UC #9)
Channel to Primary Actor:	OB executing application.
Secondary Actors:	AO System, TCS.
Channel to Secondary Actors:	E-ELT Common Software.

[3] Excluding the accuracy of position determination made by online data processing.

Use case 6: Observe Target

Characteristic Information

Goal in Context:	Perform a sequence of dithered science target exposures [**REQ 028**].
Scope:	MICADO Instrument Software.
Level:	Subfunction.
Preconditions:	Telescope is at "Science" position, AO loop closed, instrument is ready for exposure.
Success End Condition:	All target frames are successfully archived.
Failed End Condition:	At least one of the exposures could not be finished successfully.
Primary Actor:	E-ELT Operator.
Trigger Event:	An appropriate command within the currently running OB is executed.

Main Success Scenario

INS repeats steps 1 – 3 for the number of dithers in large dither pattern:
1. INS applies large dither.
   INS repeats steps 2 – 3 for the number of dithers in small dither pattern:
   2. INS applies small dither.
   3. INS performs exposure

Scenario Extensions

***a** Operator aborts OB execution:
INS makes operator confirm, aborts operations on all involved secondary actors and logs the incident.

1a Zero dither size for large dither was specified (usually only for the first step and for spectroscopy):
Large dither will be skipped.

2a Zero dither size for small dither/nod was specified (usually only for the first step):
Small dither/nod will be skipped.

Scenario Variations

1 Possible *large dither* patterns:
- For imaging, there are fixed, user defined and random dither patterns available.

2 Possible *small dither* patterns:
- For imaging, there are fixed, user defined and random dither patterns available.
- For spectroscopy only nodding along the slit is necessary and possible. The INS nods along the slit by applying a small dither of given nod length plus an additional small random amount and in opposite directions for two consecutive nods.

Related Information

Performance Target:	Performance requirements are covered by subordinate use cases Apply Dither/Offset (UC #8) and Perform Exposure (UC #9).
Required Accuracy:	Accuracy requirements are covered by subordinate use case Apply Dither/Offset (UC #8).
Frequency:	Several times per OB if required.
Superordinate Use Case:	Do Imaging (UC #2) Do Spectroscopy (UC #3) Measure Flatfield on Sky (UC #12) Observe Atmospheric/Flux Standard Star (UC #13) Image Photometric Standard Stars (UC #14)
Subordinate Use Cases:	Apply Dither/Offset (UC #8) Perform Exposure (UC #9)
Channel to Primary Actor:	OB executing application.
Secondary Actors:	None. Communication via subordinate use cases.
Channel to Secondary Actors:	E-ELT Common Software.

Use case 7: Observe Sky

Characteristic Information

Goal in Context:	Perform sky exposures at a sufficiently large distance (~15arcmin) from the science target [**REQ 029**].
Scope:	MICADO Instrument Software.
Level:	Subfunction.
Preconditions:	Telescope is at "Science" position, AO loop closed, instrument is idle and ready for exposure.
Success End Condition:	All sky frames are successfully archived.
Failed End Condition:	At least one of the exposures could not be finished successfully.
Primary Actor:	E-ELT Operator.
Trigger Event:	An appropriate command within the currently running OB is executed.

Main Success Scenario

1. INS makes AO System pause AO.
2. TCS applies a sky offset on request of INS.
3. AO System applies a small dither on request of INS.
4. INS performs exposure.

Steps 3 - 4 will be repeated for the specified number of exposures and the specified dither pattern, respectively.

5. TCS returns to previous position on request of INS.
6. INS makes AO System start AO again.

Scenario Extensions

***a** Operator aborts OB execution:
INS makes operator confirm, aborts operation and logs the incident.

Scenario Variations

3 Possible *small dither* patterns:

- For imaging, there are fixed, user defined and random dither patterns available.
- For spectroscopy only nodding along the slit is necessary and possible. The INS nods along the slit by applying a small dither of given nod length plus an additional small random amount and in opposite directions for two consecutive nods.

Related Information

Performance Target:	Performance requirements are covered by subordinate use cases Apply Dither/Offset (UC #8) and Perform Exposure (UC #9).
Required Accuracy:	Accuracy requirements are covered by subordinate use case Apply Dither/Offset (UC #8).
Frequency:	A few (1 – 6) times per OB if required.

Superordinate Use Case:	Do Imaging (UC #2) Do Spectroscopy (UC #3)
Subordinate Use Cases:	Apply Dither/Offset (UC #8) Perform Exposure (UC #9)
Channel to Primary Actor:	OB executing application.
Secondary Actors:	AO System.
Channel to Secondary Actors:	E-ELT Common Software.

Use case 8: Apply Dither/Offset

Characteristic Information

Goal in Context:	Adjust the pointing or move the centre position of the MICADO FoV by applying dithers and offsets to the AO System and telescope, respectively [**REQ 030**].
Scope:	MICADO Instrument Software.
Level:	Subfunction.
Preconditions:	Telescope is tracking, guiding and derotating at old position. AO System is in the initial state according to the offset type (see Table 2). Instrument SW is idle and ready for exposure.
Success End Condition:	Telescope is tracking, guiding and derotating at new position. AO System is in the final state according to the offset type (see Table 2). Instrument SW is idle and ready for exposure.
Failed End Condition:	Telescope, Instrument SW or AO System not ready for exposure at new position.
Primary Actor:	E-ELT Operator.
Trigger Event:	An appropriate command within the currently running OB is executed.

Main Success Scenario

1. INS makes AO System assume the state required *during* the offset according to the offset type (Table 2).
2. INS makes TCS perform an offset if required for the actual type (Table 2).
3. INS makes AO System perform an offset if required for the actual type (Table 2).
4. INS makes AO System assume the state required *after* the offset according the offset type (Table 2).

	Offset size	*Telescope offset*	*AO System offset*	*AO loop*		
				before offset	*during offset*	*after offset*
Small Dither	< 0.3”	no	yes	closed	closed	closed
Large Dither	0.3” … 10”	yes	yes	closed	open	closed
Sky Offset	10” … 15’	yes	no	closed	open	open
Sky Return	10” … 15’	yes	no	open	open	closed

Table 2: The different offset types and how they affect telescope and AO System operations.

Scenario Extensions

***a** Operator aborts OB execution:
INS makes operator confirm, aborts operations on all involved secondary actors and logs the incident.

***b** Zero offset size specified:
Steps 1 -3 will be skipped.

2a Offset size too large to perform it incrementally:
INS requires a new telescope preset via TCS.

Related Information

Performance Target:	It is expected that a small dither/large dither/sky offset will be completed within 2/20/300 seconds. MICADO SW shall not contribute more than 30%/3%/5% to the small dither/large dither/ sky offset time due to offset calculations and communication overhead [**REQ 031**].
Required Accuracy:	Several successive dither/offset operations shall not degrade the initial pointing accuracy (2mas achievable by MAORY) by more than 0.1% due to the specification of dithers/offsets [**REQ 032**].
Frequency:	Several times per OB.
Superordinate Use Case:	Acquire Target (UC #5) Observe Target (UC #6) Observe Sky (UC #7)
Subordinate Use Cases:	None.
Channel to Primary Actor:	OB executing application.
Secondary Actors:	AO System, TCS.
Channel to Secondary Actors:	E-ELT Common Software.

Use case 9: Perform Exposure

Characteristic Information

Goal in Context:	Perform a single exposure in Imaging or Spectroscopy mode [**REQ 033**].
Scope:	MICADO Instrument Software.
Level:	Subfunction.
Preconditions:	Instrument software and DCS are idle and ready for exposure, the Archive System is ready to store images. For observations on sky the telescope points to the specified target position. If required, the AO loop is closed.
Success End Condition:	Exposure successfully performed, FITS frame(s) archived.
Failed End Condition:	Exposure not performed, FITS frame(s) not archived.
Primary Actor:	E-ELT Operator.
Trigger Event:	An appropriate command within the currently running OB is executed.

Main Success Scenario

1. Operator starts exposure via an appropriate command within the OB.
2. DCS starts exposure on request of INS.
3. DCS stops exposure after specified exposure time.
4. INS adds FITS header info delivered by TCS, AO System and by the INS components itself to the FITS frame(s) delivered by DCS and saves it (them) to disk.
5. INS informs Archive System about new data. Archive System stores raw FITS frame(s) for further processing.
6. DCS delivers Secondary Guiding information (x/y position of SGS) directly to AO System with a frequency of about 10 Hz on request of INS.
7. INS reports and logs the successful completion of the exposure**.**

Scenario Extensions

***a** Operator aborts OB execution:
INS makes operator confirm, aborts operations on all involved secondary actors and logs the incident.

4a Not enough space left on disk:
INS displays an error message, aborts OB execution and logs the error.

Related Information

Performance Target:	There is no formal requirement on time necessary to complete the exposure life cycle i.e. time between start of bias exposure and when complete FITS file is available on IWS for being archived. The actual performance of the ESO New General Detector Controller (NGC) is sufficient. The overhead (writing header) introduced by MICADO INS shall not exceed 2 seconds [**REQ 034**].
Required Accuracy:	MICADO Instrument SW shall not degrade the achievable accuracy of the different instrument parameters when writing the corresponding information into FITS header [**REQ 035**].

Frequency:	Many times per OB.
Superordinate Use Case:	Acquire Target (UC #5) Observe Target (UC #6) Observe Sky (UC #7) Take Dark Frames (UC #10) Measure Internal Flatfield (UC #11) Measure Distortion (UC #15) Calibrate for Wavelength (UC #16) Determine Telescope Focus (UC #17) Assess Ghosting (UC #18) Measure Linearity (UC #19)
Subordinate Use Cases:	None.
Channel to Primary Actor:	OB executing application.
Secondary Actors:	MICADO Hardware, TCS, AO System, DCS, Archive.
Channel to Secondary Actors:	E-ELT Common Software.

Use case 10: Take Bias/Dark Frames

Characteristic Information

Goal in Context:	Provide calibration frames for determination of detector bias/dark current [**REQ 036**].
Scope:	MICADO Instrument Software.
Level:	User goal.
Preconditions:	Instrument software and DCS are online and idle, Archive System is ready to store calibration frames.
Success End Condition:	All exposures belonging to the OB are successfully archived.
Failed End Condition:	At least one of the exposures could not be finished successfully.
Primary Actor:	E-ELT Operator.
Trigger Event:	Observer loads calibration OB into the appropriate INS application.

Main Success Scenario

1. Operator starts OB.
2. INS extracts instrument setup parameters from OB and sets up instrument.
3. INS extracts observing sequence parameters from OB and performs exposure until the specified number of exposures is reached.

Scenario Extensions

***a** Operator aborts OB execution:
INS makes operator confirm, aborts operations on all involved secondary actors and logs the incident.

***b** INS detects an unexpected failure:
*b1 INS displays an error message, aborts OB execution and logs the error.
*b2 Operator determines cause of error and tries to execute OB again.
***b2a** Failure cannot be handled:
Operator terminates the instrument operation.

3a Bias frames required:
INS sets exposure time to minimum value.

Related Information

Performance Target:	Performance requirements are covered by subordinate use cases Set up Instrument (UC #4) and Perform Exposure (UC #9).
Required Accuracy:	Accuracy requirements are covered by subordinate use cases Set up Instrument (UC #4) and Perform Exposure (UC #9).
Frequency:	Once per day for bias and dark frames.
Superordinate Use Case:	None.
Subordinate Use Cases:	Set up Instrument (UC #4) Perform Exposure (UC #9)
Channel to Primary Actor:	OB executing application.
Secondary Actors:	None. Communication via subordinate use cases.
Channel to Secondary Actors:	E-ELT Common Software.

Use case 11: Measure Internal Flatfield

Characteristic Information

Goal in Context:	Provide calibration frames for the determination of detector pixel-to-pixel sensitivity variations [**REQ 037**].
Scope:	MICADO Instrument Software.
Level:	User goal.
Preconditions:	Instrument software and DCS are online and idle, Archive System is ready to store calibration frames.
Success End Condition:	All exposures belonging to the OB are successfully archived.
Failed End Condition:	At least one of the exposures could not be finished successfully.
Primary Actor:	E-ELT Operator.
Trigger Event:	Observer loads calibration OB into the appropriate INS application.

Main Success Scenario

1. Operator starts OB.
2. INS registers itself at AO System. AO System confirms availability for MICADO calibration.
3. INS extracts instrument setup parameters from OB and sets up instrument either for imaging or spectroscopy.
4. INS extracts observing sequence parameters from OB and performs exposure until the specified number of exposures is reached.
5. INS signs off from AO System.

Scenario Extensions

***a** Operator aborts OB execution:
INS makes operator confirm, aborts operations on all involved secondary actors and logs the incident.

***b** INS detects an unexpected failure:
- *b1 INS displays an error message, aborts OB execution and logs the error.
- *b2 Operator determines cause of error and tries to execute OB again.
  - ***b2a** Failure cannot be handled:
    Operator terminates the instrument operation.

Related Information

Performance Target:	Performance requirements covered by subordinate use cases Set up Instrument (UC #4) and Perform Exposure (UC #9).
Required Accuracy:	Accuracy requirements are covered by subordinate use cases Set up Instrument (UC #4) and Perform Exposure (UC #9).
Frequency:	Once per day.
Superordinate Use Case:	None.
Subordinate Use Cases:	Set up Instrument (UC #4) Perform Exposure (UC #9)
Channel to Primary Actor:	OB executing application.
Secondary Actors:	AO System (calibration unit), DCS, Archive.
Channel to Secondary Actors:	E-ELT Common Software.

Use case 12: Measure Flatfield on Sky

Characteristic Information

Goal in Context:	Provide calibration frames for the determination of telescope and instrument vignetting effects [**REQ 038**].
Scope:	MICADO Instrument Software.
Level:	User goal.
Preconditions:	Instrument software, TCS, DCS and the AO System control software are online and idle, Archive System is ready to store science frames. The AO loop is open.
Success End Condition:	All exposures belonging to the OB are successfully archived.
Failed End Condition:	At least one of the exposures could not be finished successfully.
Primary Actor:	E-ELT Operator.
Trigger Event:	Observer loads calibration OB into the appropriate INS application.

Main Success Scenario

1. Operator starts OB.
2. INS registers itself at TCS.
3. INS extracts instrument setup parameters from OB and sets up instrument for imaging or spectroscopy.
4. INS acquires target.
5. INS extracts observing sequence parameters from OB.
6. INS performs exposure.
7. INS calculates illumination level and new exposure time.
8. Operator confirms continuation of exposures.
9. INS applies a dither/offset.

Steps 6 – 10 are executed in a loop

10. INS signs off from TCS.

Scenario Extensions

***a** Operator aborts OB execution:
INS makes operator confirm, aborts operations on all involved secondary actors and logs the incident.

***b** INS detects an unexpected failure:
- *b1 INS displays an error message, aborts OB execution and logs the error.
- *b2 Operator determines cause of error and tries to execute OB again.
  - ***b2a** Failure cannot be handled:
    Operator terminates the instrument operation.

7a Too bright sky for twilight flats:
INS makes operator confirm, waits for a sufficient (to be calculated) time and tries again.

7b Next exposure time is outside the allowed range:
INS makes operator confirm, signs off from TCS and terminates the OB normally.

8a Operator terminates OB:
INS makes operator confirm, signs off from TCS and terminates the OB normally.

Related Information

Performance Target:	Performance requirements are covered by subordinate use cases Set up Instrument (UC #4), Acquire Target (UC #5) and Perform Exposure (UC #9).
Required Accuracy:	Accuracy requirements are covered by subordinate use cases Set up Instrument (UC #4), Acquire Target (UC #5) and Perform Exposure (UC #9).
Frequency:	Once per month.
Superordinate Use Case:	None.
Subordinate Use Cases:	Set up Instrument (UC #4) Acquire Target (UC #5) Observe Target (UC #6)
Channel to Primary Actor:	OB executing application.
Secondary Actors:	MICADO Hardware, TCS, DCS, Archive.
Channel to Secondary Actors:	E-ELT Common Software.

Use case 13: Observe Atmospheric/Flux Standard Star

Characteristic Information

Goal in Context:	Provide a reference spectrum of a featureless star of known magnitude to allow the removal of telluric atmospheric features as well as flux calibration for spectroscopy [**REQ 039**].
Scope:	MICADO Instrument Software.
Level:	User goal.
Preconditions:	Instrument software, TCS, DCS and the AO System control software are online and idle, Archive System is ready to store science frames.
Success End Condition:	All exposures belonging to the OB are successfully archived.
Failed End Condition:	At least one of the exposures could not be finished successfully.
Primary Actor:	E-ELT Operator.
Trigger Event:	Observer loads calibration OB into the appropriate INS application.

Main Success Scenario

1. Operator starts OB.
2. INS registers itself at AO System and TCS.
3. INS extracts instrument setup parameters from OB and sets up instrument for imaging.
4. INS acquires target.
5. INS sets up instrument for spectroscopy.
6. INS extracts observing sequence parameters from OB.
7. INS observes target.
8. INS makes AO System stop AO.
9. INS signs off from AO system and TCS.

Scenario Extensions

***a** Operator aborts OB execution:
INS makes operator confirm, aborts operations on all involved secondary actors and logs the incident.

***b** INS detects an unexpected failure:
- *b1 INS displays an error message, aborts OB execution and logs the error.
- *b2 Operator determines cause of error and tries to execute OB again.
  - ***b2a** Failure cannot be handled:
    Operator terminates the instrument operation.

Related Information

Performance Target:	Performance requirements are covered by subordinate use cases Set up Instrument (UC #4), Acquire Target (UC #5) and Perform Exposure (UC #9).
Required Accuracy:	Accuracy requirements are covered by subordinate use cases Set up Instrument (UC #4), Acquire Target (UC #5) and Perform Exposure (UC #9).

Frequency:	Once per night.
Superordinate Use Case:	None.
Subordinate Use Cases:	Set up Instrument (UC #4) Acquire Target (UC #5) Observe Target (UC #6)
Channel to Primary Actor:	OB executing application.
Secondary Actors:	MICADO Hardware, AO System, TCS, DCS, Archive.
Channel to Secondary Actors:	E-ELT Common Software.

Use case 14: Image Photometric Standard Stars

Characteristic Information

Goal in Context:	Allow flux calibration by taking calibration frame(s) from photometric standard stars of known magnitude [**REQ 040**].
Scope:	MICADO Instrument Software.
Level:	User goal.
Preconditions:	Instrument software, TCS, DCS and the AO System control software are online and idle, Archive System is ready to store science frames.
Success End Condition:	All exposures belonging to the OB are successfully archived.
Failed End Condition:	At least one of the exposures could not be finished successfully.
Primary Actor:	E-ELT Operator.
Trigger Event:	Observer loads calibration OB into the appropriate INS application.

Main Success Scenario

1. Operator starts OB.
2. INS extracts instrument setup parameters from OB and sets up instrument for imaging.
3. INS registers itself at AO System and TCS.
4. INS acquires target.
5. INS extracts observing sequence parameters from OB.
6. INS observes target.
7. INS makes AO System stop AO.
8. INS signs off from AO system and TCS.

Scenario Extensions

***a** Operator aborts OB execution:
INS makes operator confirm, aborts operations on all involved secondary actors and logs the incident.

***b** INS detects an unexpected failure:
- *b1 INS displays an error message, aborts OB execution and logs the error.
- *b2 Operator determines cause of error and tries to execute OB again.
  - ***b2a** Failure cannot be handled:
    Operator terminates the instrument operation.

Related Information

Performance Target:	Performance requirements are covered by subordinate use cases Set up Instrument (UC #4), Acquire Target (UC #5) and Perform Exposure (UC #9).
Required Accuracy:	Accuracy requirements are covered by subordinate use cases Set up Instrument (UC #4), Acquire Target (UC #5) and Perform Exposure (UC #9).
Frequency:	Once per 2 months.
Superordinate Use Case:	None.

Subordinate Use Cases:	Set up Instrument (UC #4) Acquire Target (UC #5) Observe Target (UC #6)
Channel to Primary Actor:	OB executing application.
Secondary Actors:	MICADO Hardware, AO System, TCS, DCS, Archive.
Channel to Secondary Actors:	E-ELT Common Software.

Use case 15: Measure Distortion

Characteristic Information

Goal in Context:	Provide calibration frames for the determination of the distortion introduced by optical path components of MICADO and AO System [**REQ 041**].
Scope:	MICADO Instrument Software.
Level:	User goal.
Preconditions:	Instrument Software, DCS and the AO System control software are online and idle, Archive System is ready to store calibration frames.
Success End Condition:	All exposures belonging to the OB are successfully archived.
Failed End Condition:	At least one of the exposures could not be finished successfully.
Primary Actor:	E-ELT Operator.
Trigger Event:	Observer loads calibration OB into the appropriate INS application.

Main Success Scenario

1. Operator starts OB.
2. INS registers itself at AO System. AO System confirms availability for MICADO calibration.
3. INS extracts instrument setup parameters from OB and sets up instrument for imaging.
4. INS extracts observing sequence parameters from OB.
5. INS performs exposure until the specified number of exposures is reached.
6. INS signs off from AO System.

Scenario Extensions

***a** Operator aborts OB execution:
INS makes operator confirm, aborts operations on all involved secondary actors and logs the incident.

***b** INS detects an unexpected failure:
- *b1 INS displays an error message, aborts OB execution and logs the error.
- *b2 Operator determines cause of error and tries to execute OB again.
  - ***b2a** Failure cannot be handled:
    Operator terminates the instrument operation.

Related Information

Performance Target:	Performance requirements are covered by subordinate use cases Set up Instrument (UC #4) and Perform Exposure (UC #9).
Required Accuracy:	Accuracy requirements are covered by subordinate use cases Set up Instrument (UC #4) and Perform Exposure (UC #9).
Frequency:	Once per 3 months.
Superordinate Use Case:	None.

Subordinate Use Cases:	Set up Instrument (UC #4) Perform Exposure (UC #9)
Channel to Primary Actor:	OB executing application.
Secondary Actors:	MICADO Hardware, AO System (calibration unit), DCS, Archive.
Channel to Secondary Actors:	E-ELT Common Software.

Use case 16: Calibrate for Wavelength

Characteristic Information

Goal in Context:	Provide calibration frames for the wavelength calibration by taking reference spectra of arc lamp [**REQ 042**].
Scope:	MICADO Instrument Software.
Level:	User goal.
Preconditions:	Instrument software, DCS and the AO System control software are online and idle, Archive System is ready to store calibration frames.
Success End Condition:	All exposures belonging to the OB are successfully archived.
Failed End Condition:	At least one of the exposures could not be finished successfully.
Primary Actor:	E-ELT Operator.
Trigger Event:	Observer loads calibration OB into the appropriate INS application.

Main Success Scenario

1. Operator starts OB.
2. INS registers itself at AO System. AO System confirms availability for MICADO calibration.
3. INS extracts instrument setup parameters from OB and sets up instrument for spectroscopy.
4. INS extracts observing sequence parameters from OB.
5. INS performs exposure until the specified number of exposures is reached.
6. INS signs off from AO System.

Scenario Extensions

***a** Operator aborts OB execution:
INS makes operator confirm, aborts operations on all involved secondary actors and logs the incident.

***b** INS detects an unexpected failure:
- *b1 INS displays an error message, aborts OB execution and logs the error.
- *b2 Operator determines cause of error and tries to execute OB again.
  - ***b2a** Failure cannot be handled:
    Operator terminates the instrument operation.

Related Information

Performance Target:	Performance requirements are covered by subordinate use cases Set up Instrument (UC #4) and Perform Exposure (UC #9).
Required Accuracy:	Accuracy requirements are covered by subordinate use cases Set up Instrument (UC #4) and Perform Exposure (UC #9).
Frequency:	Once per night.
Superordinate Use Case:	None.

Subordinate Use Cases:	Set up Instrument (UC #4) Perform Exposure (UC #9).
Channel to Primary Actor:	OB executing application.
Secondary Actors:	MICADO Hardware, AO System (calibration unit), DCS, Archive.
Channel to Secondary Actors:	E-ELT Common Software.

Use case 17: Determine Telescope Focus

Characteristic Information

Goal in Context:	Measure the telescope focus position [**REQ 043**].
Scope:	MICADO Instrument Software.
Level:	User goal.
Preconditions:	Instrument Software, DCS, TCS and AO System Control SW are online and idle.
Success End Condition:	Focus position measured and stored.
Failed End Condition:	Focus determination not successfully completed.
Primary Actor:	E-ELT Operator.
Trigger Event:	Operator loads maintenance OB into the appropriate INS application.

Main Success Scenario

1. Operator starts OB.
2. INS extracts instrument setup parameters from OB and sets up instrument for imaging.
3. INS registers itself at AO System and TCS.
4. INS acquires target.
5. TCS adjusts the entrance focal plane of AO System with respect to the telescope focal plane on request of INS.
6. INS performs exposure.

Steps 5 and 6 will be repeated for the requested number of steps and within a specified range.

7. INS calculates and displays focus curve, determines best focus position and logs it.
8. INS makes AO System stop AO.
9. INS signs off from AO system and TCS.

Scenario Extensions

***a** Operator aborts OB execution:
INS makes operator confirm, aborts operations on all involved secondary actors and logs the incident.

***b** INS detects an unexpected failure:
- *b1 INS displays an error message, aborts OB execution and logs the error.
- *b2 Operator determines cause of error and tries to execute OB again.
  - ***b2a** Failure cannot be handled:
    Operator terminates the instrument operation.

Related Information

Performance Target:	No requirement since this operation will be performed only during commissioning.
Required Accuracy:	MICADO Instrument SW will determine the maximum error of focus position along with the focus position itself [**REQ 044**].
Frequency:	Once during commissioning.
Superordinate Use Case:	None.

Subordinate Use Cases:	Set up Instrument (UC #4) Acquire Target (UC #5) Perform Exposure (UC #9)
Channel to Primary Actor:	OB executing application.
Secondary Actors:	MICADO Hardware, AO System, TCS, DCS.
Channel to Secondary Actors:	E-ELT Common Software.

Use case 18: Assess Ghosting

Characteristic Information

Goal in Context:	Provide calibration frames for the elimination of detector ghosting artefacts [**REQ 045**].
Scope:	MICADO Instrument Software.
Level:	User goal.
Preconditions:	Instrument software and DCS are online and idle, Archive System is ready to store calibration frames.
Success End Condition:	All exposures belonging to the OB are successfully archived.
Failed End Condition:	At least one of the exposures could not be finished successfully.
Primary Actor:	E-ELT Operator.
Trigger Event:	Observer loads calibration OB into the appropriate INS application.

Main Success Scenario

1. Operator starts OB.
2. INS registers itself at AO System. AO System confirms availability for MICADO calibration.
3. INS extracts instrument setup parameters from OB and sets up instrument for imaging.
4. INS extracts observing sequence parameters from OB.
5. INS performs exposure.

Steps 4 and 5 will be repeated until the specified number of exposures is reached.

6. INS signs off from AO System.

Scenario Extensions

***a** Operator aborts OB execution:
INS makes operator confirm, aborts operations on all involved secondary actors and logs the incident.

***b** INS detects an unexpected failure:
- *b1 INS displays an error message, aborts OB execution and logs the error.
- *b2 Operator determines cause of error and tries to execute OB again.
  - ***b2a** Failure cannot be handled:
    Operator terminates the instrument operation.

Related Information

Performance Target:	Performance requirements covered by subordinate use cases Set up Instrument (UC #4) and Perform Exposure (UC #9).	
Required Accuracy:	Accuracy requirements are covered by subordinate use cases Set up Instrument (UC #4) and Perform Exposure (UC #9).	
Frequency:	Once per month.	
Superordinate Use Cases:	None.	
Subordinate Use Cases:	Set up Instrument (UC #4) Perform Exposure (UC #9)	
Channel to Primary Actor:	OB executing application.	
Secondary Actors:	MICADO Hardware, AO System (calibration unit), DCS, Archive.	
Channel to Secondary Actors:	E-ELT Common Software.	

Use case 19: Measure Linearity

Characteristic Information

Goal in Context:	Provide calibration frames for the determination of the linearity of the detector response [**REQ 046**].
Scope:	MICADO Instrument Software.
Level:	User goal.
Preconditions:	Instrument software and DCS are online and idle, Archive System is ready to store calibration frames.
Success End Condition:	All exposures belonging to the OB are successfully archived.
Failed End Condition:	At least one of the exposures could not be finished successfully.
Primary Actor:	E-ELT Operator.
Trigger Event:	Observer loads calibration OB into the appropriate INS application.

Main Success Scenario

1. Operator starts OB.
2. INS registers itself at AO System. AO System confirms availability for MICADO calibration.
3. INS extracts instrument setup parameters from OB and sets up instrument for imaging.
4. INS extracts observing sequence parameters from OB and performs exposure until the specified number of exposures is reached. The exposure times will vary according to the defined sequence.
5. INS signs off from AO System.

Scenario Extensions

***a** Operator aborts OB execution:
INS makes operator confirm, aborts operations on all involved secondary actors and logs the incident.

***b** INS detects an unexpected failure:
- *b1 INS displays an error message, aborts OB execution and logs the error.
- *b2 Operator determines cause of error and tries to execute OB again.
  - ***b2a** Failure cannot be handled:
    Operator terminates the instrument operation.

Related Information

Performance Target:	Performance requirements covered by subordinate use cases Set up Instrument (UC #4) and Perform Exposure (UC #9).
Required Accuracy:	Accuracy requirements are covered by subordinate use cases Set up Instrument (UC #4) and Perform Exposure (UC #9).
Frequency:	Once per month.
Superordinate Use Cases:	None.
Subordinate Use Cases:	Set up Instrument (UC #4) Perform Exposure (UC #9)
Channel to Primary Actor:	OB executing application.
Secondary Actors:	AO System (calibration unit), DCS, Archive.
Channel to Secondary Actors:	E-ELT Common Software.

Use case 20: Do Engineering

Characteristic Information

Goal in Context:	Perform any engineering operation which can not be done by means of an Observation Block [**REQ 047**].
Scope:	MICADO Instrument Software.
Level:	User goal.
Preconditions:	Instrument software is running (i.e. either in state OFF, STANDBY or ONLINE).
Success End Condition:	Instrument Software and MICADO Hardware are online, in a clear state, idle and ready for execution of the next OB.
Failed End Condition:	Either Instrument Software or MICADO Hardware are not ready for the upcoming OB.
Primary Actor:	E-ELT Operator.
Trigger Event:	Operator starts Engineering GUI.

Main Success Scenario

1. Operator starts Engineering GUI.
2. Operator stops all currently moving hardware devices.
3. Operator performs the intended operation.

Scenario Extensions

3a Operator detects a severe problem:
Operator shuts down Instrument Software and asks engineering staff for advice.

Related Information

Performance Target:	Performance requirements are covered by subordinate use case Set up Instrument (UC #4).
Required Accuracy:	Accuracy requirements are covered by subordinate use case Set up Instrument (UC #4).
Frequency:	Only if required.
Superordinate Use Cases:	None.
Subordinate Use Cases:	None.
Channel to Primary Actor:	Dedicated engineering tool.
Secondary Actors:	MICADO Hardware.
Channel to Secondary Actors:	E-ELT Common Software.

3.5 Software framework components to be delivered by MICADO consortium

At time of writing of this document the extent of an E-ELT Software Framework (throughout this document referred to as *E-ELT Common Software*) provided by ESO is still to be defined. The actual assumption agreed with ESO is that only software for communication between processes, Image Archive and Detector Control Software will be delivered by ESO. For this reason the following software subsystems/applications have to be provided by the MICADO Consortium in addition to the MICADO-specific parts:

1. An Observer Support Software (OSS) tool which combines a similar functionality as provided by the P2PP tool for VLT instruments and the MICADO-specific tasks necessary for observation preparation [**REQ 048**].
2. A tool for the execution of OBs which resembles the Broker of Observation Blocks (BOB) provided with the VLT SW [**REQ 049**].
3. A software tool for the real-time display of images similar to RTD provided with VLT SW [**REQ 050**].
4. A logging system [**REQ 051**].
5. An event handling system [**REQ 052**].
6. A software alarm system [**REQ 053**].

3.6 States

The States of MICADO Instrument Software, particularly those of Instrument Control Software (ICS) and Observation Software (OS) shall be either [**REQ 054**]:

1. **OFF**: Part of the Software is not running and part of devices can be powered off.
2. **LOADED**: The whole hardware is powered on, the whole Software is running, but the interfaces to the hardware are not initialized.
3. **STANDBY**: the software and the hardware interfaces are initialized; the hardware cannot be initialized.
   a. Lamps are off.
   b. Shutters are closed.
   c. Motors current is off.
   d. Sensors monitoring is active.
4. **ONLINE**: All software and hardware is loaded, initialized and active. This is the normal state during operations.

3.7 Simulation

The Control Software shall support *degraded operations* in case of problems with devices hardware. In such cases, the behaviour of the device hardware shall be simulated by software in the most realistic way as possible and at the lowest level as possible [**REQ 055**].

For training and test purposes, it shall be possible to simulate the complete instrument hardware, thus giving the possibility to run and test observations also at locations where the hardware is not available [**REQ 056**].

4 EXTERNAL INTERFACES

4.1 User Interfaces

4.1.1 User Station

During normal operations following user interfaces shall be available on the Instrument Workstation [**REQ 057**]:

1. BOB-like tool.
2. Display for taken images (former RTD).
3. OS Control with a summary of status (instrument, detector, AO, telescope).
4. Alarm display.

4.1.2 Graphical User Interface / OS display of images

For the display of acquired images a dedicated tool will be provided which is an integral part of the Observation Software (OS) [**REQ 058**]. Its functionality will very much resemble the one of the Real Time Display (RTD) application available with the VLT Common Software. Whether this tool will be part of a possible E-ELT Common Software Framework or a proprietary MICADO application remains to be decided. In particular the following requirements shall be fulfilled:

Every acquired image shall be displayed [**REQ 059**]. Positions and intensities shall be measurable at mouse driven cursor positions [**REQ 060**].

The maximum delay between end of image acquisition and end of image display shall not exceed 5 sec [**REQ 061**]**.**

4.1.3 Graphical User Interface / OSS

The OSS GUI shall be a combination of the functionality provided with the P2PP tool for VLT observations and the MICADO specific tasks [**REQ 062**]. In particular it shall contain:

1. An overview of all necessary parameters for Observation Block creation with appropriate entry fields for user input [**REQ 063**].
2. A FITS viewer to support the target selection by images obtained through pre-imaging or retrieved from an image server [**REQ 064**].
3. Appropriate GUI elements to establish and display the state of connections to external image and catalogue servers as well as to the ESO OB database [**REQ 065**].

4.1.4 Graphical User Interface / OS

The following information shall be continuously displayed in the User GUI [**REQ 066**]:

1. Instrument state, substate, simulation, mode
2. AO state, substate, simulation
3. TCS state, substate, simulation, position on sky
4. DCS state, substate, simulation
5. Calibration unit:
    a. Calibration unit in light path?
    b. Calibration mask in light path

c. Status of lamps
d. Position of attenuator (intensity adjustment)

6. Instrument
    a. Mask in light path
    b. Filter or grism in light path
    c. Camera in light path
    d. Used detector (4x4 or single)
    e. Positions of ADC motors
    f. Values of most important sensors (e.g. temperature of detector, pressure in the cryostat)
7. Image related
    a. Status of running exposure
    b. Available disk space
    c. Name of last saved FITS file
    d. Detector read-out main characteristics (windowing, binning, clock rate)
8. Any alarm issued?

4.1.5 Graphical User Interface / ICS

The following information shall be continuously displayed in the User GUI [**REQ 067**]:

1. ICS state, substate, simulation
2. Position of all devices
3. Status of interlocks
4. Status of DIGIO lines
5. Values of all sensors

In addition this GUI will allow performing any setup of the instrument devices as well as changes of the states. To support these activities appropriate input fields, selection and action buttons will be provided.

4.1.6 Graphical User Interface / Alarm System

Active alarms and warnings shall be displayed in a dedicated GUI. When alarm/warning is issued then this panel shall pop-up. For alarms/warnings related to analogue signals the actual value of the signal and the alarm/warning boundaries shall be displayed [**REQ 068**].

4.1.7 Graphical User Interface / Logging System

The logging information shall be displayed in a dedicated GUI. The following additional functionality shall be provided [**REQ 069**]:

1. Display logs from a specified node.
2. Display logs from a specified process.

4.2 Interface to ESO Repository for storage of OBs (Data Flow System)

The OBs created by OSS have to be stored in the ESO Repository [**REQ 070**]. The details have to be defined by ESO.

4.3 Interface to MICADO Hardware

The communication between INS in general and in particular the Instrument Control Software (ICS) with the different MICADO Hardware components (Table 1) will be accomplished by one of the technological solutions currently being evaluated by ESO [AD 07].

4.4 Interface to E-ELT Common Software Framework

The very preliminary information about this interface is given in [AD07]. The requirements on this framework and on the architecture for instrument control systems will be defined by ESO until the end of 2010. It is, however, expected that software communication between MICADO and all external actors (TCS, AO System, DCS, Archive) will be carried out in the same coherent way according to a standard communication protocol which has to be defined by the E-ELT Common Software.

4.5 Interface to Telescope

Any communication with the telescope control software (TCS) will be accomplished through the E-ELT Common Software [**REQ 071**].

The following actions will be requested by MICADO [**REQ 072**]:

1. Preset - positioning the target in the defined instrument aperture.
2. Offset.
3. Auto-guiding using an off-axis guide star or tracking only.
4. Provide the information for FITS header.

4.6 Interface to MAORY and SCAO

The communication with MAORY (e.g. SETUP, OFFSET) is described in [RD 01]. It is assumed that the interface to SCAO will be very similar to that of MAORY. As for the other external systems also the communication with the AO System will be accomplished through the E-ELT Common Software [**REQ 073**].

The AO systems have to provide the information for FITS header [**REQ 074**].

4.7 Interface to DCS

Command interface, information exchange, how header information has to be written, etc have to be defined by ESO.

MICADO specific requirement:

1. Handling of different sizes of the mosaic (initially only 4 chips will be mounted) [**REQ 075**].
2. Position determination of a target (window on detector for SGS) during an exposure and forwarding this information to AO. This has to be done 10 times per second. [**REQ 076**].

4.8 Interface to Archive

This interface covers the communication between OS and the ESO Archive for images at the Observatory. The details have to be defined by ESO.

5 DATA

5.1 Observation Parameters

The values for all parameters needed to characterize the type and actual sequence of an Observation Block shall be specified during the preparation of the observation using the OSS tool [**REQ 077**].

Below these parameters are listed in tabular form for all those user goal use cases which correspond actually to OBs (Observation preparation and Engineering are not comprised). For mandatory parameters the appropriate columns are marked.

	Do Imaging (UC #2)	Do Spectroscopy (UC #3)	Take Bias/Dark Frames (UC #10)	Measure Internal Flatfield(UC #11)	Measure Flatfield on Sky (UC #12)	Observe Atmospheric/Flux Standard Star (UC #13)	Image Photometric Standard Stars (UC #14)	Measure Distortion (UC #15)	Calibrate for Wavelength (UC #16)	Determine Telescope Focus (UC #17)	Assess Ghosting (UC #18)	Measure Linearity (UC #19)
Instrument Setup Parameters [**REQ 078**]:												
Mode: *Imaging* or *Spectroscopy*	X	X	X	X	X	X	X	X	X	X	X	X
Selection: *Primary* or *Auxiliary* arm	X	X	X	X	X	X	X	X	X	X	X	X
Filter	X		X	X	X		X	X	X	X	X	X
Grism		X		X	X	X			X			
Slit		X		X	X	X			X			
Lamp: *flatfield/arc*				X				X	X		X	X
Calibration mask								X			X	
ADC	X	X		X	X	X	X	X	X	X	X	X
Telescope Setup Parameters [**REQ 079**]:												
Target information (science target): RA, Dec, Equinox, Epoch, Proper motion	X	X			X	X	X			X		
Derotator offset	X	X			X	X	X			X		
Start guiding: *yes/no*	X	X				X	X			X		
Focus position	X	X			X	X	X			X		
AO System Setup Parameters [**REQ 080**]:												
Target information (RA, Dec, Equinox, Epoch, Proper motion) for NGS (1 for SCAO, 3 for MAORY)	X	X				X	X			X		

Target information (RA, Dec, Equinox, Epoch, Proper motion) for Monitor	X						X			X		
Derotator offset	X	X				X	X			X		
MCAO correction mode	X	X				X	X			X		
Time at position	X	X				X	X			X		
Detector Setup Parameters [**REQ 081**]:												
Readout mode	X	X	X	X	X	X	X	X	X	X	X	X
Exposure time	X	X	X	X	X	X	X	X	X	X	X	X
Number of sub-integrations	X	X	X	X	X	X	X	X	X	X	X	X
Observing Sequence [**REQ 082**]:												
Number of Large Dither Cycles	X											
Large Dither Pattern	X											
Small Dither Pattern	X	X			X	X	X			X	X	
Number of Small Dither cycles at "Sky" position	X	X										
Sky offset relative to "Science" target or absolute "Sky" position	X	X										
Exposure time for a single exposure	X	X	X	X	X	X	X	X	X	X	X	X
Maximum duration of the whole observation/number of exposures	X	X	X	X	X	X	X	X	X	X	X	X

Remarks:

- Each *Large Dither Cycle* comprises the execution of the complete set of exposures belonging to a particular Large Dither Pattern.
- The *Large Dither Pattern* (including the number of large dithers, i.e. the size of the pattern) can be either
  a. Predefined,
  b. random within a box or
  c. defined by user.
  The first large dither in (x,y) direction always has to be (0,0).
  If the number of large dithers is 1 then the dither pattern degenerates to a single Small Dither Pattern.
- The *Small Dither Pattern* (including the number of small dithers, i.e. the size of the pattern) can be either
  d. Predefined,
  e. random within a box or
  f. defined by user.
  The first small dither in (x,y) direction always has to be (0,0).
  If the number of small dithers is 1 then the dither pattern degenerates to a single exposure.

The nod length for dithers (nods along the slit) in case of Spectroscopy are a special kind of small dither pattern.

The number of *Small Dither Cycles* at "Sky" position is 0 if no sky frames are required.

5.2 Acquirement of images

Image files from the primary and auxiliary paths will have maximum formats of 16kx16k and 4kx4k respectively. The sizes of image file will be 1 GB and 67 MB respectively.

The SW overhead, including data transfer to the IWS, shall not exceed 2 sec [**REQ 083**]**.**

5.3 Storage

Calibration and Observation data shall be stored in FITS files [**REQ 084**]**.** The header standards will be defined by ESO**.**

The header information consists of the following parts [**REQ 085**]:

1. Detector part – it is expected that this information will be already attached to the image by DCS.
2. TCS part will be attached after readout.
3. AO part will be attached after readout.
4. Instrument part will be attached after readout.

All monitored values provided by different sensors (temperatures, pressure, flow rates, etc) shall be included in the image file FITS header [**REQ 086**]**.**

The typical amount of data produced and stored on disk during an observing night is in the order of 1 TB [**REQ 087**]**.** The maximum amount is 7 GB [**REQ 088**]**.**

5.4 Archive

The Archive will be provided by ESO.

All stored FITS files shall be archived [**REQ 089**].

The archiving operations shall not affect the duty cycle of the instrument, i.e. the archiving task shall run in background while the instrument is doing the next observations [**REQ 090**].

5.5 Online Processing on the Instrument Workstation

The following data processing tasks have to be performed on the Instrument Workstation:

1. Determination of position of a target for alignment process to put target in a given pixel position or on the slit [**REQ 091**].
2. Determination of half widths (x, y) of a star for focus determination [**REQ 092**].
3. Determination of intensity of sky for calculation of exposure time for sky flats [**REQ 093**].

5.6 Logging

The following shall be logged [**REQ 094**]:

1. Any unrecoverable error occurring during the execution of a command.
2. Every change of status for all devices (e.g. lamp on/off, filter moved to position RED).
3. Every change of the state for all devices (e.g. from standby to online with related HW initialization).
4. Every periodical read-out of sensors values.
5. Any warning and alarm.

6 OTHER NONFUNCTIONAL REQUIREMENTS

6.1 Configuration

The whole MICADO Instrument Software shall be developed under configuration control [**REQ 095**]. All possibly changing parameters shall preferably be stored at a central location and in a suitable format instead of being hardcoded [**REQ 096**]. The entire set of these parameters forms the *Instrument Configuration*.

It must be possible at any time to save and retrieve the current Instrument Configuration [**REQ 097**]**.**

Only authorized users can modify the Instrument Configuration [**REQ 098**]. Observers shall never be able to accidentally modify or corrupt configuration parameters (detector clock voltages, limits, temperatures,..) however they might be interested to display them.

6.2 Documentation

The documentation to be delivered along with the MICADO Instrument SW will be specified by the (not yet existing) E-ELT Software Management Plan. A software process similar to that established for VLT instruments with similar deliverable documents (Functional Specification, Design Description, User and Maintenance Manual etc.) is assumed [**REQ 099**].

6.3 Test

Test software has to be a part of the delivered packages [**REQ 100**]. The detailed list of tests will be prepared during the preliminary design phase.

6.4 Safety

6.4.1 Interlocks

Serious alarm conditions, which may leave the instrument in a hazardous condition, shall be avoided by appropriate hardware design, e.g. by mean of hardware interlocks. In such cases software alarms shall help to warn the user that the environmental conditions (e.g. temperature) is approaching the limits [**REQ 101**].

6.4.2 Warnings

Warnings shall be part of the operational logs [**REQ 102**]. They shall be treated as low priority alarms, using the same display tool as for any other alarm [**REQ 103**].

6.4.3 Alarms

Alarms shall be clearly shown to the user/operator [**REQ 104**]**.** The Alarms display GUI shall be permanently running in the User Station [**REQ 105**]**.**

The preliminary list of serious hardware alarms is given [AD 03]. These alarms will be implemented in software too. In addition deviations from normal conditions like detector temperatures or cryostat pressure will be handled in software [**REQ 106**].

All alarms shall be logged as operational logs [**REQ 107**]**.**

Monitoring of alarm conditions shall be active also when the instrument is in the STANDBY state (e.g. during daytime) [**REQ 108**].

7 REQUIREMENTS TRACEABILITY

To allow for a convenient backtracking of requirements which possibly will be referenced by follow-up documents the traceability matrix below lists all tagged requirements appearing throughout this document along with a short description and their section number. The tags themselves are hyperlinked to the place of their first appearance.

Label	Requirement	MICADO Software User Requirements E-TRE-MCD-561-0021
REQ 001	Requirements have numbered tags.	1.1
REQ 002	MICADO modes: Imaging and Spectroscopy.	2.2
REQ 003	MICADO has to control/monitor 2 lamps, 12 motors, 50 analogue and 50 digital signals.	2.3
REQ 004	Interaction of users with telescope and instrumentation will take place by means of Observation Blocks.	3.1
REQ 005	MICADO Instrument SW shall support testing, commissioning and maintenance activities.	3.3
REQ 006	OSS shall provide functionality for OB creation.	3.4
REQ 007	Observer can select OB type and assemble OB from parts.	3.4
REQ 008	OSS shall provide default parameter values and graphical display.	3.4
REQ 009	OSS shall allow NGS, MoS, SGS selection.	3.4
REQ 010	OSS shall allow for specification of additional information.	3.4
REQ 011	OSS shall verify each OB.	3.4
REQ 012	OBs shall be saved.	3.4
REQ 013	Retrieval of target positions from catalogue server shall not exceed 1 minute.	3.4
REQ 014	OSS shall not degrade accuracy of celestial positions achievable by instrument.	3.4
REQ 015	INS shall provide for observations in imaging mode.	3.4
REQ 016	INS shall not increase non-observing time by more than 3% in imaging mode.	3.4
REQ 017	INS shall provide for observations in spectroscopy mode.	3.4
REQ 018	INS shall not increase non-observing time by more than 3% in spectroscopy mode.	3.4
REQ 019	INS shall configure MICADO hardware and DCS.	3.4
REQ 020	INS shall not contribute more than 5% to total setup time.	3.4
REQ 021	If possible, parallel setup of devices shall be implemented.	3.4
REQ 022	Calibration lamps shall be switched on as early as possible.	3.4
REQ 023	INS shall not degrade the achievable pointing accuracy of individual hardware components.	3.4

REQ 024	INS shall allow for target acquisition.	3.4
REQ 025	In case of simple acquisition INS shall not contribute more than 1% to the duration of the whole acquisition process.	3.4
REQ 026	In case of accurate acquisition INS shall not contribute more than 5% to the duration of the whole acquisition process.	3.4
REQ 027	In case of accurate acquisition INS shall not degrade the 2mas pointing accuracy achievable with the AO System.	3.4
REQ 028	INS shall enable dithered target observations.	3.4
REQ 029	INS shall enable dithered sky observations.	3.4
REQ 030	INS shall control dithers/offsets to be performed by telescope and AO System.	3.4
REQ 031	INS shall not contribute more than 30%/3%/5% to small dither/large dither/sky offset time due to offset calculations and communication overhead.	3.4
REQ 032	Successive dithers shall not degrade the initial pointing accuracy by more than 0.1%.	3.4
REQ 033	INS shall provide control functionality for exposures.	3.4
REQ 034	The exposure time overhead introduced by MICADO SW shall not exceed 2 seconds.	3.4
REQ 035	INS shall not degrade achievable accuracy of instrument parameters when writing FITS header data.	3.4
REQ 036	INS shall provide functionality for bias/dark OBs.	3.4
REQ 037	INS shall provide functionality for internal flatfield measurements.	3.4
REQ 038	INS shall provide functionality for flatfield measurements on sky.	3.4
REQ 039	INS shall provide functionality for flux/standard star observations.	3.4
REQ 040	INS shall provide functionality for photometric standard star observations.	3.4
REQ 041	INS shall provide functionality for distortion measurements.	3.4
REQ 042	INS shall provide functionality for wavelength calibration measurements.	3.4
REQ 043	INS shall provide functionality for telescope focus determination.	3.4
REQ 044	INS will determine maximum error of focus position.	3.4
REQ 045	INS shall provide functionality for ghosting assessment.	3.4
REQ 046	INS shall provide functionality for linearity measurements.	
REQ 047	INS shall provide capabilities for engineering operations beyond the typical functionality covered by OBs.	3.4
REQ 048	OSS shall combine P2PP and MICADO-specific functionality.	3.5
REQ 049	A BOB-like tool (OB executing application) shall be part of INS.	3.5
REQ 050	An RTD-like tool (real-time image display) shall be provided.	3.5
REQ 051	A logging system shall be part of INS.	3.5
REQ 052	An event handling system shall be part of INS.	3.5
REQ 053	A software alarm system shall be part of INS.	3.5
REQ 054	MICADO INS states: OFF, LOADED, STANDBY, ONLINE.	3.6
REQ 055	For degraded operations it shall be possible to simulate individual hardware components by software.	3.7
REQ 056	For training and test purposes it shall be possible to simulate the complete instrument by software.	3.7

REQ 057	During normal operations the OB executing application, the real-time display, an OS control panel and the alarm display shall be available on the instrument workstation screen.	4.1.1
REQ 058	The real-time display application shall be part of OS.	4.1.2
REQ 059	Every acquired image shall be displayed.	4.1.2
REQ 060	Positions and intensities shall be measurable at cursor position.	4.1.2
REQ 061	Maximum delay between end of image acquisition and image display shall not exceed 5 sec.	4.1.2
REQ 062	OSS GUI shall combine P2PP and MICADO-specific GUI features.	4.1.3
REQ 063	OSS GUI shall provide overview of all fields for user input.	4.1.3
REQ 064	OSS GUI shall contain FITS viewer.	4.1.3
REQ 065	OSS GUI shall enable connections to catalogue and image server and to ESO database.	4.1.3
REQ 066	OS GUI shall provide overview of the states of MICADO and external actors (AO System, TCS, DCS).	4.1.4
REQ 067	ICS GUI shall provide overview of the states of all relevant hardware devices.	4.1.5
REQ 068	Active alarms and warnings shall be displayed in a dedicated GUI.	4.1.6
REQ 069	Logging information shall be displayed in a dedicated GUI.	4.1.7
REQ 070	OBs created by OSS shall be stored in ESO repository.	4.2
REQ 071	Communication with TCS will be accomplished through E-ELT Common SW.	4.5
REQ 072	INS will request telescope preset, offset, guiding and FITS header information via TCS interface.	4.5
REQ 073	Communication with AO System will be accomplished through E-ELT Common SW.	4.6
REQ 074	INS will request FITS header information via AO System interface.	4.6
REQ 075	INS shall control different sizes of detector mosaic via DCS interface	4.7
REQ 076	INS shall determine target position of SGS via DCS interface.	4.7
REQ 077	All OB parameters shall be specified during observation preparation by means of OSS.	5.1
REQ 078	The instrument setup parameters form a part of the observation parameters.	5.1.1
REQ 079	The telescope setup parameters form a part of the observation parameters.	5.1.2
REQ 080	The AO System setup parameters form a part of the observation parameters.	5.1.3
REQ 081	The detector setup parameters form a part of the observation parameters.	5.1.4
REQ 082	The details of the observing sequence form a part of the observation parameters.	5.1.5
REQ 083	The SW overhead for image acquirement shall not exceed 2 sec.	5.2
REQ 084	Calibration and observation data shall be stored in FITS files.	5.3
REQ 085	FITS header contains a detector, telescope AO System and instrument part.	5.3
REQ 086	FITS header shall contain sensor values.	5.3
REQ 087	The typical amount of data produced and to be stored during an	5.3

	observation night is in the order of 1 TB.	
REQ 088	The maximum amount of data produced and to be stored during an observation night is in the order of 7 GB.	5.3
REQ 089	All stored FITS files shall be archived.	5.4
REQ 090	The archiving process shall run in the background.	5.4
REQ 091	Target position determination on Instrument WS shall be possible by means of online data reduction.	5.5
REQ 092	Half width of star determination on Instrument WS shall be possible by means of online data reduction.	5.5
REQ 093	Sky intensity determination on Instrument WS shall be possible by means of online data reduction.	5.5
REQ 094	All essential information shall be logged.	5.6
REQ 095	MICADO Instrument SW shall be developed under configuration control.	6.1
REQ 096	All possibly changing parameters shall preferably be stored at a central location instead of being hardcoded.	6.1
REQ 097	It must be possible at any time to save and retrieve the current Instrument Configuration.	6.1
REQ 098	Only authorized users can modify the Instrument Configuration.	6.1
REQ 099	Appropriate documentation shall be delivered along with the MICADO Instrument SW.	6.2
REQ 100	Test software has to be part of the delivered packages.	6.3
REQ 101	Software alarms shall warn users that environmental conditions are approaching hardware limits.	6.4.1
REQ 102	Warnings shall be part of operational logs.	6.4.2
REQ 103	Warnings shall be treated as low priority alarms.	6.4.2
REQ 104	Alarms shall be clearly shown to the user/operator.	6.4.3
REQ 105	Alarms GUI shall be permanently running on the User Station.	6.4.3
REQ 106	All alarms shall be implemented.	6.4.3
REQ 107	All Alarms shall be logged as operational logs.	6.4.3
REQ 108	Alarm monitoring shall be active also in STANDBY.	6.4.3

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