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VERY LARGE TELESCOPE

MACAO VLTI

Technical Specifications

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Prepared: R. Arsenault . . . .

Name Date Signature

Approved: N. Hubin . . . .

Name Date Signature

Released: G. Monnet . . . .

Name Date Signature

VLT PROGRAMME * TELEPHONE: (089) 3 20 06-0 * FAX: (089) 320 2362

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CHANGE RECORD

Issue	Date	Section/Page Affected	Reason/ Remarks
1.0	12.12.00	All	First issue
1.1	9.03.01	All updated	Internal review after first draft

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List of Acronyms

ADn	Applicable Document No. n
AIV	Assembly, Integration and Verification
AO	Adaptive Optics
AoC	Award of Contract
ARE	Acceptance Review Europe
ARC	Acceptance Review Chile
DM	Deformable Mirror
ESO	European Southern Observatory
FDR	Final Design Review
FOV	Field of View
HD	Hardware Deliveries
I/F	Interface
ISS	Interferometer Software Superviser
LAN	Local Area Network
LB	Laser Bench
LCU	Local Control Unit
MLE	Maximum Likely Earthquake
OPD	Optical Path Difference
PAC	Provisional Acceptance Chile
PDR	Preliminary Design Review
RDn	Reference Document No. n
SCP	Service Connection Point
SOW	Statement of Work
SW	Software
TBC	To Be Confirmed
TBD	To Be Defined
TLR	Top Level Requirements
TTM	Tip Tilt Mount
UPS	Uninterruptible Power Supply
UT	Unit Telescope
VLT	Very Large Telescope
VLTI	Very Large Telescope Interferometer
VLTISS	Very Large Telescope Interferometer Supervisory Software
WFS	Wave Front Sensor
WS	WorkStation

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1. SCOPE

This technical specification document aims at identifying and listing all relevant specifications for the MACAO VLTI AO modules; performance, optical, software, mechanical, maintainability and safety.

2. APPLICABLE & REFERENCE DOCUMENTS

2.1. APPLICABLE DOCUMENTS

Number	Document Title	Document Number
AD1	Requirements for the Environment of the Coudé Train and the Coudé Room	VLT-SPE-ESO-11500-2322, in prep.
AD2	Top Level Requirements for MACAO VLTI	VLT-SPE-ESO-15600-2082, issue 1.2
AD3	Requirements for the UT Nasmyth Beacons	VLT-VIF-00/088, 19/07/00
AD4	Service Connection Point Technical Specification	VLT-SPE-ESO-10000-0013
AD5	VLT Astronomical Site Monitro seeing and coherence monitor	VLT-SPE-ESO-17410-1174
AD6	VLT Optics: design of telescope optics	VLT-TRE-ESO-10000-0526
AD7	Technical Specifications for the Image Alignment Unit of the VLTI, Part 1: Unit Telescopes	VLT-SPE-ESO-15442-2380
AD8	VLT UT Coude Relay Optics M9, M10, & M11 Optical Design Report	VLT-SPE-ESO-11535-1937
AD9	MACAO-VLTI Telecentricity Lenses, Technical Specification	VLT-SPE-ESO-15600-2213
AD10	VLT UT Coude Relay Optics M9, M10, & M11 Technical Specifications	VLT-SPE-ESO-11535-1656
AD11	Technical CCD Systems, Operation Manual	VLT-MAN-ESO-11700-1775
AD12	APD Tilt Loop Interfaces Control Document (STRAP)	VLT-ICD-ESO-11670-1288

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AD13	Optical Design of the VLT Coude Optics	VLT-SPE-ESO-11500-1641
AD14	VLT Environmental Conditions	VLT-SPE-ESO-10000-0004
AD15	Instruction to Perform Earthquake Analysis for VLT Instrument and Similar Equipment	VLT-SPE-ESO-10000-1853
AD16	Image motion due to telescope excitation by wind	VLT-TRE-ESO-11000-0854
AD17	VLT Electronic Design Specification	VLT-SPE-ESO-10000-0015
AD18	VLT Maintenance Concept	VLT-TRE-ESO-00000-0001
AD19	VLT Programme Test Plan	VLT-PLA-ESO-00000-0007
AD20	VLT-Time Reference System, time interface module, technical manual	VLT-MAN-ESO-17300-0473
AD21	General Safety Requirements for Scientific Instruments	VLT-SPE-ESO-10000-0017
AD22	VLT Software Programming Standard	VLT-PRO-ESO-10000-0228
AD23	VLT Software Management Plan	VLT-PLA-ESO-00000-0006
AD24	Final lay-out of VLT Control LANs	VLT-SPE-ESO-17200-0642
AD25	Electromagnetic Compatibility and Power Quality Specification Part 1	VLT-SPE-ESO-10000-0002
AD26	Electromagnetic Compatibility and Power Quality Specification Part 2	VLT-SPE-ESO-10000-0003

2.2. REFERENCE DOCUMENTS

Number	Document Title	Document Number
RD1	MACAO-VLTI System Overview	VLT-TRE-ESO-15600-2251 v1.2
RD2	MACAO-VLTI System Design Analysis	VLT-TRE-ESO 15600-2067 v2.1
RD3	MACAO-VLTI WFS Optics	VLT-TRE-ESO-15600-2273 v2
RD4	MACAO-VLTI Electronics Overview	VLT-SPE-ESO-15600-2268 v2.0

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RD5	MACAO-VLTI Observation Software – OS Design Description	VLT-SPE-ESO-15600-2439 v1.0
RD6	MACAO-VLTI Instrument Control Software – ICS Design Description	VLT-SPE-ESO-15600-2440 v1.0
RD7	MACAO-VLTI Interface Control Document	VLT-ICD-ESO-15600-2057 v2.1
RD8	MACAO-VLTI Project Management Plan	VLT-PLA-ESO-15600-1742 v1.2

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3. INTRODUCTION

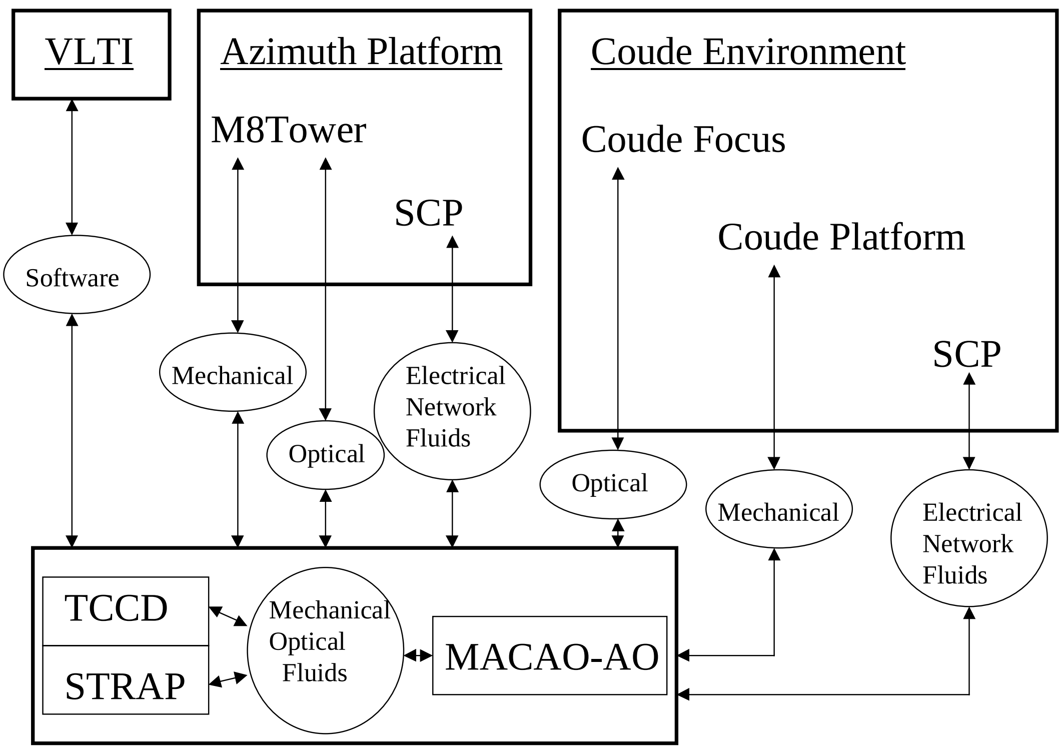
The MACAO VLTI consists in four (4) AO modules installed at the Coudé focus of each UT. It shall correct the wavefront coming from the telescopes from atmospheric turbulence, before recombination of the beams in the interferometric laboratory of the VLTI.

There are a two main sources that drive these specifications:

1. VLT Coudé environment requirements,
2. VLTI Top-Level Requirements for MACAO-VLTI,

4. MAIN INTERFACES DEFINITION

The environment of MACAO-VLTI is well defined and I/F are defined from these systems. They will in turn specify MACAO-VLTI own I/F's.



I/F1 SOF VLTI ISS ←→ MACAO OS

I/F2 MEC Azimuth platform ←→ MACAO Electronic Cabinet

I/F3 MEC M8 Tower ←→ MACAO TTM

I/F4 OPT M8 Tower ←→ MACAO TTM pupil

I/F5 ELE Azimuth platform-SCP ←→ MACAO Electronic Cabinet

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I/F6 NET Azimuth platform-SCP ←→ MACAO Electronic Cabinet

I/F7 FLU Azimuth platform-SCP ←→ MACAO Electronic Cabinet

I/F8 OPT Coudé Focus ←→ MACAO focal plane

I/F9 MEC Coudé Platform ←→ MACAO WFS mech. I/F

I/F10 ELE Coudé Platform-SCP ←→ MACAO Electronic Cabinets

I/F11 NET Coudé Platform-SCP ←→ MACAO Electronic Cabinets

I/F12 FLU Coudé Platform-SCP ←→ MACAO Electronic Cabinets

I/F13 MEC Coudé Platform ←→ MACAO Electronic Cabinets

I/F14 MEC Coudé Platform ←→ MACAO APD Cabinet

I/F15 ELE Coudé Platform-SCP ←→ MACAO APD Cabinet

I/F16 FLU Coudé Platform-SCP ←→ MACAO APD Cabinet

I/F17 MEC TCCD ←→ MACAO WFS

I/F18 OPT TCCD ←→ MACAO WFS

I/F19 FLU TCCD ←→ MACAO WFS

I/F20 MEC STRAP ←→ MACAO WFS

I/F21 OPT STRAP ←→ MACAO WFS

I/F22 FLU STRAP ←→ MACAO WFS

The following interfaces must be defined in the RD7 since they are likely to evolve:

- I/F8, I/F9

All other interfaces are already designed and fabricated systems or well documented VLT systems. Note also that the RD5 contains all pertinent information relevant to software communication and interface with the VLTI-ISS.

5. AO MODULE PERFORMANCE

5.1. ATMOSPHERIC CONDITIONS

The specifications shall be fulfilled under the following general observing conditions.

The atmosphere model contains three main layers, matching what is agreed to be the standard average atmosphere in Paranal. The three layers are chosen to match a median seeing condition of 0.65” at 500 nm, τ_o~4ms, wind speed ~11 m/s and r_o~16 cm, and they are characterised by the following parameters:

LAYER	Wind Speed	Direction	Weight
Upper Layer (10000m)	33 m/s	Horizontal	0.2
Medium Layer (1000m)	5.7 m/s	Vertical	0.6

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Low Layer (10m)	5.7 m/s	Horizontal	0.2

For a seeing of 1” at 500 nm τ_o~3ms and r_o~10 cm shall be assumed.

Other conditions will have an impact on the AO performance of MACAO and need to be well known. They are the following:

- The science beam effective wavelength,
- The spectral type of the reference source,
- The science and reference object coordinates,
- The relevant atmospheric data (temperature, pressure, humidity).

5.2. NGS PERFORMANCE

Note that MACAO-VLTI will be used only on NGS. The possibility to use a LGS is not insured by the actual design.

The MACAO basic specifications are listed in the following table. Please note that these are defined for an on-axis performance (on-axis being defined as the center of the Coudé FOV). Anisoplanetism will obviously degrade these as the distance between the reference source and the science target increases.

WF quality	λ	Atmosphere @ 0.5 µm	NGS magnitude	Duration
Strehl >50%	2.2µm	0.65”, v=10m/s	0 < V < 8	10 min.
Strehl >25%	2.2µm	0.65”, v=10m/s	V=15.5	10 min.
Strehl >30%	2.2µm	1.0”, v=10m/s	V=8	10 min.
Strehl Best effort	2.2µm	Reference source *plus* seeing = FWHM 2.5”		________
Tilt error < 10 mas RMS (sky)	_____	0.65”, v=10m/s	V=8	1 min.
Piston < 25 nm RMS	_____	Irrelevant	irrelevant	48 ms
Piston < 125 nm RMS				290 ms
Piston < 2 µm PTV				10 min

Simulations carried out by the AO department provide the following expectations for the MACAO-VLTI performances. They are in agreement with the basic VLTI requirements. MACAO-VLTI shall provide a corrected Coudé beam with the following Strehl ratio (Strehl at 2.2 µm for 0.65” at 500 nm, τ_o~4ms, sky background V=20.5 mag/ ”). Crosses indicate the above specifications:

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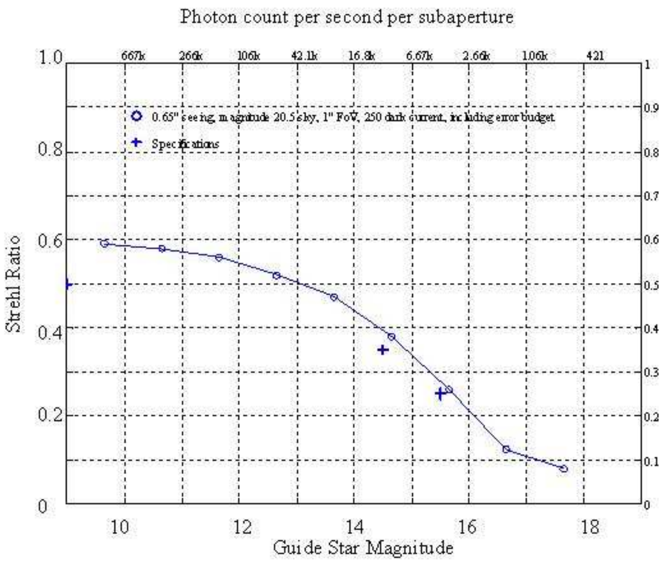

6. SYSTEM REQUIREMENTS

6.1. INTRODUCTION

The “SYSn” type of requirements are high level requirements having implications on the mode of operation of MACAO-VLTI. The TLR’s might have repercussions in terms of optical or mechanical or other type of specifications. The main statements are out of the AD2 and the following sub-statements are specifications, made quantitative when possible, or functional implied by the TLR’s.

6.2. LIST OF REQUIREMENTS

SYS1 MACAO-VLTI 4 AO systems can be operated individually from each UT Coudé room (*integration stand-alone)* and or from the interferometric laboratory

MACAO-VLTI OS can function without calls to VLTISS and TCS, which implies it shall have its own Graphical User Interface to launch commands to the LCU’s
WS can be installed and connected in various environments as need be (integration or operation through network connection)

SYS2 MACAO-VLTI 4 AO systems shall allow coordinated operation simultaneously from a single WS through VLTISS

One mode of the VLTISS will send commands to the 2 to 4 MACAO-VLTI OS's and monitor their response

SYS3 MACAO-VLTI can acquire & close the loop on-axis on science target or on an off-axis reference object as well.

An optical setup or mechanism shall allow the MACAO-VLTI WFS to pick up an object in the FOV of the Coudé focus (Coudé focus specifications are listed in OPT2)
MACAO-VLTI OS shall allow a complete, coordinated science target acquisition procedure with a potential different reference source, from acquisition until closing of the loop on the science target or onto a different reference source.

SYS4 MACAO-VLTI can be used while the telescope is in chopping mode; it shall be able to close loop on target, on object magnitude V<16, with a chopping frequency of 1 Hz (goal 5 Hz) with a duty cycle >50% (goal 80%).

MACAO-VLTI OS shall allow within a single observation to open or pause the loop				
MACAO-VLTI OS shall provide a "fast" object recovery and re-closing of the AO loop when M2 returns on-axis	**Period on target (chop freq.)**	**Duty cycle**	**Time available to close loop**	**Number of loop cycle (@350 Hz)**
	500 ms (1 Hz)	50%	<250 ms	89
		80% (goal)	<100 ms	35
	100 ms (5 Hz) (goal)	50%	<50 ms	17
		80% (goal)	<20 ms	6

SYS5 Set-up time on an object should not take longer than 3 min

MACAO-VLTI OS shall provide a Science target, and reference source when necessary, "fast" and complete acquisition scheme with the WFS
Once on target (science or science/reference), the loop must be closed in a relatively "fast" time. A budget of 2min. is allocated to reference source acquisition by the WFS and 1min. to close the loop.

SYS6 MACAO-VLTI shall be able to accept and perform in close-loop from VLTI tip-tilt and defocus offsets

MACAO-VLTI shall use the FOV acquisition capability to carry out a WFS equivalent displacement in the focal plane, during close-loop operation (in response the Tip-Tilt mount will change orientation). Accuracy required are listed in SYS7
MACAO-VLTI WFS shall be able to perform an opto-mechanical displacement that produces a focus change for the WFS (in response, the focus term on the DM will change)
MACAO-VLTI shall develop a control of the WFS positioning device in UVW coordinates

SYS7 MACAO-VLTI shall be able to perform offsets (+ or -), in UVW site coordinates on request from the VLTISS, at a frequency ≤ 1 Hz with the following characteristics:

	Tip-Tilt (sky angle)	**In Coudé Focal Plane**	**Focus (WFE PTV)**	**In Coudé Focal Plane**
Range	> 1 arcsec	>1.84 mm	> 100 nm	>1.8 mm
Resolution	< 2 mas	<3.7 μm	< 5 nm	< 90 μm
Repeatability	< 3 mas	<5.5 μm	< 10 nm	< 180 μm
Absolute accuracy	< 10 mas	<18.4 μm	< 10 nm	< 180 μm
Time response Time/step	< 1sec / 100 mas	< 1sec / 184 μm	< 1 sec /20 nm	<1sec/ 0.36 mm
Cross-coupling	When commanding an offset, the error induced on the other parameters shall remain less than the respective absolute accuracy			

SYS8 MACAO-VLTI shall provide diagnostics during close-loop operation at a maximum rate of 1 Hz: average seeing, coherence time, flux, estimated Strehl (or wavefront spatial rms) and FWHM of the compensated image.

MACAO-VLTI RTC must provide reserve CPU for calculation of the diagnostic parameters. Conversely, the calculation of these parameters must not hinder the close-loop performance of MACAO-VLTI and resulting Strehl ratio performance
MACAO-VLTI RTC must provide to the reserve CPU all data necessary for calculation of the diagnosis parameters at a frequency higher than 1 Hz, without degradation of the close-loop performance
Basic parameters that MACAO-VLTI shall provide for such calculations are: command vector, curvature measurements vector, integration time, gain, APD count rate vector.

SYS9 MACAO-VLTI shall provide calibration data during close loop: average and standard deviation of the Zernike coefficients of removed piston, measured tip, measured tilt, measured defocus and measured sum of the WFE for all the higher orders. These data should have a corresponding time stamp (down to 10 ms and set by VLTI). The commands

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START and STOP received from VLTISS will determine the duration for which these calibration data must be measured and they should be made available in less than 10 sec.

MACAO-VLTI shall provide running average and standard deviation of the removed piston
MACAO-VLTI shall provide running average and standard deviation of the 3 first coefficients (tip, tilt and focus) of command vector on request from VLTISS
MACAO-VLTI shall provide running average and standard deviation of the quadratic sum of all coefficients of command vector starting with coefficient number 4 (higher than focus)
MACAO-VLTI will assign a time stamp to each data corresponding to [time(START)+time(STOP)]/2 with an accuracy of 0.01 sec
MACAO-VLTI should calculate the above parameters and send result to VLTISS within 10 sec of the STOP command

SYS10 It shall be possible for one trained telescope operator to operate MACAO-VLTI

Each MACAO-VLTI AO system can be controlled with one single WS by one operator (Note: this particular specification has more implications on the VLTISS than on the MACAO-VLTI OS's)
The MACAO-VLTI system shall require a minimum number of parameters to be properly setup and a basic training for the user (similar to other instrument). The specification SYS14 will insure that a minimum number of parameters need to be set by the operator.

SYS11 MACAO-VLTI shall be able to perform offsets of high order modes on the science beam in UVW coordinates with the characteristics given below. They should be applied once a night. If non-zero, the strehl ratio performance is on a best effort basis. The highest order on which offset can be applied are decentering coma, 3rd order spherical, and 3rd order astigmatism:

	Higher order mode (WFE PTV)
Range	> 50 nm
Resolution	< 5 nm
Absolute accuracy	< 10 nm
Time response Time/step	 < 1 min/20 nm
Cross-coupling	When commanding an offset, the error induced on the other parameter shall remain less than the respective absolute accuracy.

MACAO-VLTI shall be able to apply a constant (not evolving with time) command vector to the DM which implies that this vector must be subtracted from each close-loop curvature measurements (at each cycle)

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MACAO-VLTI must provide control modes that are *approaching (might not be identical to the following Zernike polynomial*) coma { Z7√8(3r^3-2r)sinθ, Z8√8(3r^3-2r)cosθ } , 3rd order spherical { Z11√5(6r^4-6r^2+1) } and 3rd order astigmatism { Z5√6r^{2}sin2θ, Z6√6r^{2}cos2θ }
MACAO-VLTI must command at least 11 modes

SYS12 MACAO-VLTI shall have a "TEST" and "MAINTENANCE"

MACAO-VLTI OS can run in stand-alone without communications with the VLTISS and/or the TCS

SYS13 Compatible with VLTI beacon

No components of MACAO-VLTI shall hinder or prevent the use of the VLTI beacon
MACAO-VLTI must provide protection to its own components from retro-reflected beacon (APDs)

SYS14 MACAO-VLTI will have its own internal automatic close loop optimization scheme

MACAO-VLTI RTC shall have enough reserve CPU power in order to perform during close-loop operation the required calculations (not yet defined) to optimize the close-loop performance
MACAO-VLTI RTC shall have the possibility to change the close-loop parameters during close-loop operation and without opening of the loop.

7. OPTICAL SPECIFICATIONS

OPT1 Wavelength range: MACAO provides a corrected beam in the range 1.5 to 25 μm (reflectivity level under the responsibility of VLTI (except for M8), but wavefront correction under the responsibility of MACAO)

OPT2 Optical beam: MACAO-VLTI located behind M9 which implies:

Focal plane position	U=Utel+1mm(±2mm) V=Vtel+10mm (±2mm) W=-2453mm (+25/-50mm)
Beam Focal ratio	f/47.60
Beam FOV	120 arcsec no field curvature
Beam incidence angle	5'3" (±0.5') rotation around U
Non-telecentricity	±18 arcsec (equivalent to 0.1mm lenslet shift)

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WFE of telecentricity lens	25nm RMS (goal 15nm) on any 25 mm footprint		
WFE of M9	≤ 35nm RMS on any 25mm footprint		
Beam throughput after telecentricity lens	26% (0.4-0.7μm), 22% (0.7-0.8μm), 26% (0.8-0.9μm),		
Static aberration at the Coudé focus due to manufacturing and alignement	**Telescope**	LF (Active Optics Residuals)	200nm RMS
		HF (above mode 16th)	55nm RMS
	Coudé train	LF (below Zernike mode 40)	500nm PTV
		HF (above Zernike mode 40)	70nm RMS

OPT3 M8 must be coated with protected silver

OPT4 Differential phase retardation by shall be less than 2° at λ>1.5 μm between different M8

OPT5 M8 shall stay flat, WFE < 120 nm RMS and stable for duration > 5 min

MACAO-VLTI shall provide a mean of measuring offset voltages required to flatten the DM and in open loop apply this set of command voltage to the DM
Creeping effect on the DM shall be stay at a level where the WFE<120 nm RMS at least 5 min.

OPT6 Accuracy on the reflected (post M9) beam tip-tilt characteristics (angles on sky):

Characteristic	**On the sky**	**On the TTM**
Resolution	< 2 mas	< 160 mas
Repeatability on 2" central FOV	< 3 mas	< 240 mas
Repeatability on the whole FOV	< 10 mas	< 800 mas
Absolute accuracy	< 100 mas	< 8 arcsec
Telescope pointing accuracy Coudé	1.5 arcsec	(120 arcsec)
Telescope-related tilt error at Coudé	0.1 arcsec per 10 min and 5mas RMS over 10 ms	___________________

OPT7 Opto-mechanical interface shall allow re-direction of the optical beam in the WFS

Function	**Specification**
Close-loop adaptive correction	All light to WFS with mirror system
Acquisition/Field Search	All light to TCCD with mirror system; require re-imaging optics and manual filter
Tip-Tilt correction only	All light to STRAP with mirror system

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Close-loop adaptive correction diagnosis	Split light between WFS and TCCD with beam splitter 50/50* and manual filter in front of TCCD
Tip-Tilt correction diagnosis	Split light between STRAP and TCCD with beam splitter 50/50* and manual filter in front of TCCD

*(the factor “50/50” means a similar repartition of light intensity in the 2 paths, but does not include loss. The actual values reflected and transmitted will be inferior to 50%)

OPT8 Optical quality of objective in front of TCCD:

Image Quality	80% encircled energy within 0.2arcsec diameter
Wavelength range	450 to 900 nm

OPT9 Possibility to install (manually) a filter in front of TCCD

8. MECHANICAL SPECIFICATIONS

MEC1 DM should replace M8

Size	DM should be larger than pupil which is 98.4±0.5 mm in diameter (allowing for outer electrode pattern)
Beam incidence angle	Beam has an incidence angle of 13.26°±0.1° at M8
Position	DM should be centered to better than 0.5mm Pupil position is determined: X/Y location: ±0.3mm w/r azimuth axis Z location: ±5mm w/r M8 nominal
Orientation	Electrode pattern on the DM should correspond to WFS sub-aperture geometry to better than 10% of a sub-aperture
Mechanical I/F drawing and/or environment	VLT-IDW- (definition of I/F3)
Access	Required for installation; pupil mask insertion/removal

MEC2 Flexible, modular WFS assembly can be operated inside the interferometric laboratory; self-contained design

MEC3 WFS assembly should fit on the existing Coudé rotating platform

9. ELECTRONICS SPECIFICATIONS

ELE1 Power dissipated by M8 shall be limited to +10/-10W and surface temperature difference with respect to ambient shall be limited to +2/-1C

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ELE2 Power dissipated by MACAO in the Coudé Room should be limited to +10/-20W and surface temperature difference with respect to ambient shall be limited to +1/-5C

10. SOFTWARE SPECIFICATIONS

SOF1 Commands between MACAO-VLTI and VLTI will go through the VLTI Backbone Network and processed by the VLTISS.

SOF2 Commands between MACAO-VLTI and TCS will be processed by the VLTISS

SOF3 Reflective memory VMIVME-5576 board will be used for fast communication between MACAO-VLTI and VLTI

SOF4 MACAO-VLTI shall write WFE in reflective memory at every sampling

SOF5 Commands to VLTI instruments are routed through the VLTISS

SOF6 Commands set to be as close as possible to the following:

Command	Action
INIT AO	initialize AO system
START AO	loop closed on reference source using the parameters: science target coordinates, NGS coordinates, observing wavelength, centering type
STOP AO	open the AO loop; the M8 is set to flat and to reference tip-tilt position
OFFSET	in close-loop apply the required offset (M9 reflected wavefront affected by this offset)
SET M8 TO FLAT	DM is commanded to a flat surface and the TTM to a reference position
SET TIP-TILT REFERENCE OF FLAT_M8	TTM set to reference position
OFFSET IMAGE BEACON	AO system ensures that the beam that the beam forom the Nasmyth Image Beacon is adjusted (after reflection of M9) in tilt and focus with the required offset (alignment procedure)
CENTER ON IMAGE BEACON	WFS centered on the image of the Nasmyth Image Beacon and the X-Y position of the WFS recorded

11. AIT

AIT1 MACAO-VLTI shall function in daytime on the Nasmyth artificial source

AIT2 MACAO-VLTI will have tools for alignment check of the pupil and focus

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12. GENERAL DESIGN REQUIREMENTS

12.1. ENVIRONMENTAL SPECIFICATIONS

Environmental conditions for nominal operation and transportation are defined in AD1 and AD14.

AD15 provides instructions for the design of instrument in order to take into account the effect of Earthquake.

12.2. SOFTWARE REQUIREMENTS

The general programming standards which shall be used are defined in AD22 and AD23.

A description of the LAN as built can be found in AD24.

12.3. ELECTRICAL REQUIREMENTS

For the design of electronic equipment guidelines are provided in AD17.

12.4. EMI & EMC REQUIREMENTS

AD25 and AD26 provides requirements that shall be applied with respect to EMC, EMI

12.5. RELIABILITY

The minimum operational life expectancy of the AO Module shall be 10 years. The working time per year is estimated as follows:

- Approximately 1200 hours/year
- The rest of the time the AO Module will be in Stand-by mode.

The Mean Time Between Failure (MTBF) under the operational conditions described above shall not be less than 1 year.

12.6. MAINTENANCE

AD18 describes the guidelines and maintenance policy for ESO instruments.

12.7. SAFETY

General safety requirements for ESO instruments are described in AD21.

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