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VERY LARGE TELESCOPE

Top-Level Requirements
For MACAO-VLTI

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CHANGE RECORD

Issue	Date	Section/Page affected	Reason/ Initiation/Remarks
1.0	March 3, 2000	All	first issue
1.1	April 10, 2000	see revision marks (additions are in Italic font)	Update following CDR
1.2	September 1, 2000		**Answer and comments to VLT-CRE-ESO-11640-0001 as contained in:** - **VLT-INS-00/0058** - **VIF-00/082** **Clarification on Namyth Beacons** - **VIF-00/088**
		Cover Page	Product Number *11640* updated to *15600*
		§2.1.10..	*TBC* removed, *residual* replaced by *measured*
		§ 2.2.1, 2.2.3, 2.2.5	mv=*8* instead of *9*
		§ 3.2..	*TBC* removed
		§ 3.3..	*residual WFE* replaced by *measured WFE*
		§ 3.1.1	*V-band* replaced by *0.45µm to 1µm*
		§ 3.1.7...	§ added (optical req TCCD objective)
		§ 3.2.1...	§ numbering added
		§ 3.2.2...	§ added (provision for TCCD filter)
		§ 4...	Reference to VIF-00/088 added
1.3	March 08, 2001	Applicable Documents	AD 4 (MACAO-VLTI ICD) added
		Section 3..	All interface requirements removed and reference made to AD4
		Section 4..	Old section removed (I/F with calibration tools are now covered in AD4) and replaced by new section 'miscelaneous' to keep functional & performance requirements previously embedded in the I/F section 3.
	March 15,2001	Sections 3 and 4	Interface requirements shortly summarised with reference to AD4 and AD5 (MACAO-VLTI Technical Specifications)

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

AD	Applicable Document
AO	Adaptive Optics
DM	Deformable Mirror
FOV	Field of View
LGS	Laser Guide Star
NGS	Natural Guide Start
STRAP	ESO-developped System for Tip-tilt Removal with APD
TBC	To Be Confirmed
TBD	To Be Defined
UT	Unit Telescope
TCCD	ESO standard Technical CCD
WFS	Wave Front Sensor
VLT	Very Large Telescope
VLTI	Very Large Telescope Interferometer

APPLICABLE DOCUMENTS

	Title	Number	Issue	Issue date
AD1	VLT Optics: Design of telescope optics	VLT-TRE-ESO-10000-0526	1.2	February 24, 1995
AD2	Optical design of the VLT Coudé optics	VLT-SPE-ESO-11500-1641	4	July 08, 1999
AD3	VLT Specification: Basic telescope definitions	VLT-SPE-ESO-10000-0016	2	07.10.92
AD4	MACAO-VLTI Interface Control Document	VLT-ICD-ESO-15600-2057	2	15.03.01
AD5	MACAO-VLTI Technical Specifications	VLT-SPE-ESO-15600-2245	1.1	15.03.01

1. SCOPE

This document defines the top-level requirements applicable for MACAO-VLTI.
MACAO-VLTI is a complete system (including optics, opto-mechanics, detectors and control Hardware and Software) delivering a corrected wavefront after M9 of the UT.

2. FUNCTIONAL AND PERFORMANCE REQUIREMENTS

This section describes the main functions to be provided by MACAO-VLTI and the high-level performance requirements.

2.1. GENERAL

2.1.1. MACAO-VLTI shall deliver to VLTI a corrected wavefront after reflection on the dichroïc M9 for use by the VLTI instrument observing at wavelengths between 1.5 and 25 µm.
2.1.2. MACAO-VLTI will operate the WFS at the UT Coudé focus behind M9 but provisions should be kept in the architecture of the system for a possible future implementation of the WFS inside the Interferometric Laboratory.
2.1.3. MACAO-VLTI will operate the DM located at M8 in the Coudé train.
2.1.4. MACAO-VLTI shall be able to work on Natural Guide Star (NGS) "on-axis" (i.e. using the same object as that used by the VLTI Instrument) as well as "off-axis" (i.e. using a reference star). The requirements for the acquisition mode are given in section 2.3.
2.1.5. MACAO-VLTI is not required to operate with a Laser Guide Star (LGS).
2.1.6. While the M2 is chopping, MACAO-VLTI shall be able to work in closed-loop (as a minimum on the "star" position with mv≤16). The achievable chopping frequency shall be 1Hz (goal 5Hz). The duty cycle shall be >50% (goal 80%).
2.1.7. The set-up time on an object (AO related operations) shall not take longer than 3 minutes.
2.1.8. MACAO-VLTI shall be able to accept from VLTI and perform in closed-loop offsets in tip-tilt, defocus. See characteristics given below (section 2.4).
2.1.9. MACAO-VLTI shall deliver diagnostics during closed-loop operation including average seeing, coherence time, flux, estimated Strehl (or wavefront spatial rms) and FWHM of the compensated image. Sampling rate of diagnostics down to 1 sec shall be possible.
2.1.10. MACAO-VLTI shall deliver calibration data during closed-loop operation. These data shall include: a time stamp associated with the average and standard deviation over short exposure time τ (down to 10 msec and set by VLTI) of the Zernike coefficients for: estimated MACAO removed piston, measured tip, measured tilt, measured defocus and measured WFE for the other higher orders. These data shall be collected over the time period defined by the START and STOP commands received for VLTISS. They shall be made available at the end of that period in less than 10 sec.
2.1.11. MACAO-VLTI is allowed to use M2 for downloading low-frequency/large-amplitude tip-tilt errors from the Deformable Mirror including during VLTI-Instrument observation.
2.1.12. MACAO-VLTI shall be designed <u>not</u> to use M2 for downloading low-frequency/large-amplitude focus errors from the Deformable Mirror during VLTI-Instrument observation (lasting < 10 min.). If at a particular instance during observation, downloading appears absolutely compulsory, VLTI shall be informed and its "agreement" received before performing the M2 motion (via an autoguider offset). This is necessary to stop Instrument integration and compensate the induced OPD offset with the Delay Line.

2.1.13. Power dissipated during observation in the Coudé Train environment by M8 shall be limited to +10W/-10W and surface temperature difference with respect to ambient shall be limited to +2/-1°C
2.1.14. Power dissipated during observation in the Coudé Room by MACAO should be limited +10W/-20W and surface temperature difference with respect to ambient shall be limited to +1/-5°C.
2.1.15. M8 shall be coated with protected silver. The differential phase retardation of the polarization states between different M8 shall be less than 2° for λ> 1.5 µm.
2.1.16. It shall also be possible to have M8 flat and stable for at least 5min with the following accuracy: 120 nm RMS wavefront errors.
2.1.17. It shall be possible for one trained telescope operator to operate MACAO-VLTI.

2.2. Optical performance of the Wave front after M9

The following performances apply for a guide star located anywhere in the FOV but exclude the contribution of atmospheric anisoplanatic effects.

2.2.1. MACAO-VLTI shall deliver a beam after M9 providing compensated images with Strehl ratio larger than 50% at 2.2µm under median Paranal seeing conditions (seeing=0.65", v=10 m/s, at 0.5µm) on a point source NGS m_V = 0 to 8 during an exposure of 10 minutes.
2.2.2. In the same conditions as above but for a NGS of m_V =15.5 the Strehl shall be > 25%.
2.2.3. MACAO-VLTI shall be able to work (i.e. close the loop) up to a seeing of 1 arcsec (at 0.5 µm) with a Strehl of >30% with a NGS m_V = 8.
2.2.4. MACAO-VLTI shall be able to work with an extended source of FWHM up to 2.5 arcsec (including seeing). The associated Strehl performance is on a best-effort basis.
2.2.5. The tilt error[1] (whose contribution is included in the above Strehl values) shall not be more than 0.010 arcsec RMS on the sky over a period of typically 1min under median Paranal seeing conditions (seeing=0.65", v=10 m/s, at 0.5µm) on a NGS m_V = 8.
2.2.6. The wavefront piston jitter introduced by MACAO-VLTI shall not be more than:
- 25nm RMS over time window of 48msec,
- 125 nm RMS over time window of 290 msec
- 2 µm PTV over time window of 10 minutes

This includes the piston generated by the deformable mirror and by possible vibrations of the Relay Optics (M9,M10,M11) generated by any MACAO_VLTI subsystems.
This also applies when the DM is set to flat.

2.3. Acquisition capabilities

2.3.1. Field of view for guide star at Coudé: ≥±1 arcmin (sky)
2.3.2. Zenith Distance: 0.5° to 60°

The following characteristics apply on the tip-tilt of the reflected science beam during acquisition:

2.3.3.	Resolution:	< 0.002 arcsec/sky
2.3.4.	Repeatability on the 2" central FOV:	< 0.003 arcsec/sky RMS (over a night)
2.3.5.	Repeatability on the whole FOV:	< 0.010 arcsec/sky RMS (over 2h)
2.3.6.	Absolute accuracy:	< ±0.100 arcsec/sky

[1] defined as the residual tip-tilt error after AO correction

It assumes that the following parameters are passed to MACAO and are perfectly known:
a) the science beam effective wavelength
b) the spectral type of the guide star
c) the science and guide star coordinates
d) the relevant atmospheric data (Temperature, Pressure, Humidity).

2.4. OFFSETS CAPABILITIES

2.4.1. MACAO-VLTI shall be able to perform offsets (fixed in U-V-W site coordinates) sent on request from VLTI (maximum every 1 sec) with the following characteristics:

	Tip & Tilt	**Focus (WFE PTVRMS)**
Range	> ±1 arcsec/sky	> ±100nm.
Resolution[2]	< 0.002 arcsec/sky	< 5 nm.
Repeatability	< 0.003 arcsec/sky RMS	< ± 10 nm
Absolute accuracy[3]	< ±0.010 arcsec/sky	< ± 10 nm
Time response[4] time/ step	< 1 sec / 0.100 arcsec/sky	< 1 sec / 20 nm
Cross-coupling	when commanding an offset, the error induced on the other parameters shall remain less than the respective absolute accuracy.	

2.4.2. The MACAO-VLTI shall be able to perform offsets of the "high-order modes" on the science beam (fixed in U-V-W site coordinates) with the characteristics given below. These offsets will be performed typically once a night. If these offsets are non-zero, the performance requirements on Strehl do not apply (i.e. best-effort basis). The "higher orders" on which offsets can be applied shall include: decentering coma, 3rd order spherical aberration and 3rd order astigmatism.

	Higher order mode (WFE PTV)
Range	> ±50nm.
Resolution[5]	< 5 nm
Absolute accuracy[6]	< ± 10 nm
Time response[7] time/ step	< 1 min / 20 nm
Cross-coupling	when commanding an offset, the error induced on the other parameters shall remain less than the respective absolute accuracy.

2 minimum achievable step .
3 over the whole range, including repeatability errors.
4 time required to perform the step with a final error (PTV) less than 2 times the resolution.
5 minimum achievable step .
6 over the whole range, including repeatability errors.
7 time required to perform the step with a final error (PTV) less than 2 times the resolution.

3. MAIN INTERFACES

The MACAO-VLTI interface requirements are defined in AD4 and AD5. Here, we just summarise the interfaces MACAO-VLTI has to be compatible with.

3.1. OPTICAL INTERFACES

3.1.1. The MACAO-VLTI Deformable Mirror shall replace the (pupil) mirror M8 of the Coude train.

3.1.2. The MACAO-VLTI Wave-Front Sensor shall be placed at the transmitted Coude focus, after the M9 dichroic and the telecentricity lens.

The optical characteristics of the corresponding beams are described in AD5.

3.2. MECHANICAL INTERFACES

3.2.1. The MACAO-VLTI Deformable Mirror and Tip-tilt mount shall be installed on the same mechanical mount as the Coude train flat M8. It is desctibed in AD5.

3.2.2. The MACAO-VLTI Wave-Front Sensor shall be installed on the Coude rotating platform and on the M9-M10 tower base plate. Still under definition, this interface is described in the ICD (AD4).

3.2.3. The electronic cabinets shall be placed on the Nasmyth platform and on the Coude rotating platform.

3.3. HARDWARE INTERFACES

3.3.1. The HW interfaces between VLTI and MACAO-VLTI shall be according to the standard VLT Control architecture.

3.3.2. A fast communication between VLTI and MACAO-VLTI shall be implemented by placing a standard VMIVME-5576 Reflective Memory Board inside a MACAO-VLTI LCU. The spatial variance of the measured WFE shall be written in the reflective memory at every AO loop sampling time. This will be used by the VLTI OPD Controller.

3.4. SOFTWARE INTERFACES

3.4.1. The software interfaces is located between the "VLT Interferometer Supervisor Software" (ISS) and the MACAO-VLTI SW. Commands from the VLTI Instruments will be routed through the ISS.

3.4.2. The AO facility being similar in its function to the telescope Autoguiding or Field Stabilisation, the Software interface should be as similar as possible to that of these existing control modes.

The software interface is described in AD4 in more details.

4. MISCELANEOUS

4.1.1. The optical quality of the objective in front of the TCCD shall be: ≤80% polychromatic encircled energy within ϕ0.2 arcsec (sky) in the band 450-900nm.

4.1.2. The design of the WFS shall fit with the need to install the VLTI Field Acquisition Sensor (using a TCCD) with a field of view of 10 to 20 arcsec, a STRAP unit, and a Coudé Beam switching device allowing to direct the light to: WFS, TCCD, STRAP, WFS+TCCD, STRAP+TCCD. Provision shall be kept to install (manually) a filter (similar to that of Nasmyth Guide Probe) in front of the TCCD. Detailed requirements are defined in AD4.

4.1.3. The Nasmyth Beacons provided at Nasmyth for calibration and alignment purposes are defined in VLT-VIF-00/088, dated 19/7/00. The characteristics of the Nasmyth sources required by MACAO-VLTI are given in the ICD (AD4).