VERY LARGE TELESCOPE

MACAO VLTI
Draft Maintenance Plan

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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 document presents a draft of the MACAO-VLTI Maintenance Plan. Without reaching the detail level required, it will allow Paranal staff to have a view at the range and nature of the various maintenance operations relevant to this instrument. Furthermore, we will also present a well elaborated maintenance scheme in the form of spare lists, identified LRU and SRU.

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	VLT maintenance concept	VLT-TRE-ESO-00000-0001 4 14.08.92
AD5	Environmental specification	VLT/SPE/ESO/10000/-0004 5 dated 27.05.93
AD6	General safety requirements for scientific instruments	VLT-SPE-ESO-10000-0017 2 16.09.92

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
RD5	MACAO-VLTI Observation Software – OS Design Description	VLT-SPE-ESO-15600-2439 v1.0

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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. MACAO-VLTI PRODUCT TREE

MACAO-VLTI Product Tree v1.0 (R. Arsenault 7.12.00)

- MACAO-VLTI 15600
  - 100000: X-Y Table
  - 110000: T-Mount
  - 120000: Mode Stage
  - 130000: Optics
  - 140000: Strap System
  - 150000: De-Rotator Prism
  - 160000: TCCD mechanical I/F
  - 200000: Electronics
    - 210000: IC Electronics
    - 230000: RTC Electronics
    - 240000: DM Electronics
    - 250000: APD Rack
  - 300000: Corrective Optics
    - 310000: TTM Assembly
      - 311000: TTM mechanical I/F
      - 312000: TTM Mount
      - 313000: TTM FE
      - 314000: TTM SU Rack
    - 320000: DM Assembly
  - 400000: Test Tools
    - 410000: IR Test Camera
    - 420000: IR Lab. Camera
    - 430000: Test Bench
    - 440000: Turbulence Generator

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4. MAINTENANCE REQUIREMENTS

4.1. MAINTENANCE CONCEPT

The MACAO-VLTI equipments will be designed in accordance with the general maintenance concept for VLT, as outlined in document RD4 and fully exposed hereafter.

A three level-maintenance policy will be implemented as described hereafter.

4.1.1. 1st level

It consists in maintenance performed on MACAO-VLTI. This maintenance implies the repair of MACAO-VLTI and the restoring of the VLT availability by easy exchange of modules, PCB boards, mechanical units. It can be performed by Paranal on-site maintenance staff of technicians.

- 1st level maintenance deals with Line Replaceable Units (LRUs) and is performed in the VLT environment.
- 1st level requires to the possible extent the use of standard Support Equipment (SE) and tools.
- On-line maintenance is thus intended to restore availability within the shortest time.

4.1.2. 2nd level

It consists in the maintenance that is performed in workshops, in general the closest possible from the operational site.

Maintenance performed at this level covers repairs of LRU removed at 1st level. It involves the repairing of the LRU by exchange of the faulty module/component it contains also called Shop Replaceable Unit (SRU).

2nd level does not require the use of specific SE and tools but relies on skilled technicians operating in good conditions of cleanliness and access. Number of technicians and specialities is not a limit. Maintenance time duration, thus return of repaired LRU on site, is not a critical parameter as long as spares stocks on site permit to sustain a failure of the same nature.

4.1.3. 3rd level

It consists in the industrial support for LRU or SRU whose repair requires industry SE and specialised staff (MACAO-VLTI designers, optical laboratories, suppliers).

A preventive maintenance program can be implemented to enable the following actions, if required :

- inspections ;
- consumable exchange (filters, calibration lamps) ;

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- functional checks ;
- cleaning of optical surfaces ;
- checking of MACAO-VLTI performance.

The following specifications have been our guideline for defining the following approach:

- Simple actions, weekly: 1 man-hour
- Monthly, thorough inspection: 8 man-hours
- Two-years interval: 40 man-hours

And other requirements found in ESO general maintenance policy:

- Overhaul: 4 days (3 observing nights) every 10 yrs
- MTBF: 9 months (1200 hrs)

Preventive maintenance inspections shall not require, as a goal, more than 2 hours per month.

Other preventive actions can be accomplished by 2 technicians within a maximum of 6 hours.

The need for overhaul will be minimised as a general objective. Nevertheless, specific operations such as mirrors re-coating are authorised.

The maintenance corrective requirement is that the replacement of LRU shall not require special tools and extensive calibrations. The Maximum Corrective Time (MCT) shall be less than 4 hours.

There are no specific requirements as regards :

Turn Around Time for LRUs to be repaired at 2nd or 3rd levels of maintenance ;

MCT or Mean Time To Repair LRU or SRU at 2nd or 3rd levels of maintenance.

4.1.4. LRU and SRU breakdown

Section 7. attempts a breakdown of the various components of MACAO-VLTI into LRU's and SRU's. Approximate duration of the exchange, repair or maintenance operation is provided.

5. PROCEDURES

The following may already be part of standard procedures in Paranal, but these are the underlying assumption in the elaboration of our maintenance plan and have been assumed also in the elaboration of the Detailed Hazard Analysis.

5.1. HANDLING

Only trained operators are allowed to use cranes or lifting devices. When such operations are carried out, there should always be clear communication between the operator and an observer close to the load being manipulated.

Any work carried out on heavy equipment should be carried out by at least 2 persons.

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Visitors are not welcome during these operations (hinder communication and distraction to the task being carried out).

5.2. OPTICS

During the assembly usual precautions should be taken for the handling of optical elements; use of gloves, covers on sensitive optics. Covers should be on also during chemical cleaning, and to avoid damage from chemical product spilling or vapors or finger prints.

Chemical products used during various operations on the instrument should be checked (expiration date).

5.3. INSTRUMENT INTERVENTION

Basic rules of intervention on an instrument shall include:

- Ensure that nobody is already working close or on the instrument
- Ensure that the instrument status will not change (remote operation)
- Work perform with knowledge of the last configuration of the instrument
- Wrist wrap to prevent electrical discharge
- Check cables are all well connected before power on
- Never leave tools or accessories in area where they can fall down
- First, protect optical components close to where work is being performed
- !!! in some cases helmet might jeopardize optics !!!

6. REGULAR MAINTENANCE OPERATIONS

6.1. INTERACTION MATRICE MEASUREMENT

6.1.1. Frequency

This operation needs to be performed on a regular basis. More information will be gathered during prototyping and integration, but present experiences on similar systems suggest an interval of one month maximum frequency (from AO curvature systems regularly mounted and dismounted from a telescope).

6.1.2. Nature

This operation consists in measuring the WFS signals for a given voltage applied to every single electrodes of the DM. Assuming a luminous calibration source, <1 sec. per measurement, 10 measurements and 60 electrodes ~10 membrane strokes give a total duration of the order of 6000 sec. or <2 hours.

6.1.3. Required facility

- Pupil mask on DM (M8)

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- Nasmyth calibration sources
- 1-2 hours technical staff, (unattended activity single soft. command)

The pupil mask needs to be installed manually on the TTM assembly. There is easy access into the M8 and the operation, although being delicate, should not require more than 5-10 min (access through the 2nd M7 tube; **!!! REQUIRES PROTECTION ON M7 !!!)**

6.2. DEFORMABLE MIRROR FLATTENING VOLTAGES

This operation is much simpler and shorter than the interaction matrix measurement but of the same type.

6.2.1. Frequency

Similar to Interaction Matrix (done at the same time) but shorter.

6.2.2. Nature

This operation consists in measuring the closing the loop (requires a calculated command matrice) and keeping record of the voltages to the DM. A typical duration of 10-15 min. is sufficient

6.2.3. Required facility

- Nasmyth calibration sources
- 10-15 min. technical staff, (unattended activity single soft. command)

6.3. MEMBRANE EXAMINATION

6.3.1. Membrane use

The membrane mirror is contained in a complex unit including resonant cavity, loudspeaker, motorized gimball mount. The membrane is made of nitrocellulose and coated with Aluminum to a high reflectivity (>95%). Maximum displacement when set in vibration is ~25 µm at the center of the membrane. The signal applied to the loudspeaker is a sinusoidal 2.1 kHz.

6.3.2. Coating & Surface

Regular examination of the membrane (months) should be done to insure that the coating reflectivity is not degraded, and that vibration has not produced cracking or defects in the coating.

6.3.3. Precautions

The membrane ***should never be cleaned with solvent ;*** only with a gentle jet of clean air (these are similar to membrane beamsplitter only coated with Al). The solvent vapor can attack the nitrocellulose.

Also the 2.1 kHz vibration can be annoying to staff working in close proximity. Therefore, we suggest the use of hear protection during intervention. This is only when the instrument is in operation; in opened loop, off-line, no signal is sent to the membrane.

6.4. HYDRAULIC

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Normal procedures and safety measures should be taken to avoid possible damage by wrong connections of cooling fluid pipes.

The following air pressure system should undergo normal maintenance:

- Air brake are used on the XY tables.
- An Air valve has been implemented on cooling of the WFS box units triggered by a fluid detector.

6.5. DM COATINGS

A bi-yearly examination of the DM coatings is in order to try predict any long term degradation. Cleaning can probably be avoided since it is a down-looking piece of optics.

6.6. WFS BOX OPTICS CLEANING

We believe cleaning of the optics is not required since the whole opto-mechanical assembly is contained in a housing (external cover) closed by a shutter when off-line, and protected by other optics (M9 and telecentricity lens) when in operation (shutter opened).

6.7. MICRO-LENS FIBER BUNDLE

The Optical fiber bundle including the 2 micro-lens array up to the FC connector is a sensitive component of the system. Careful routing and holding should minimize possible damage in operation. However, manipulations during maintenance and integration are probably the highest risk phases for this piece of equipment. Spares will be provided. A simple visual test can be performed to identify broken fibers by looking at the FC connectors while the micro-lens is illuminated. This test is suggested only as a debugging aid, if this component is suspected of damage. We do not recommend doing it on a regular basis since manipulation could increase the risk of damage.

7. SPARE PART LIST

The following components are purchased in several copies for MACAO-VLTI, SINFONI and CRIRES. Similarities in the designs allow this strategy by decreasing the unit cost.

- 1 Beam-Expander Unit*
- 1 De-rotator prism and mount
- Density filters (for MACAO)
- 1 DM
- 1 membrane mirror unit (membrane, loudspeaker, resonant cavity, gimball)
- 4 Micro-Lens arrays*
- 2 Optical Fiber Bundles (60 fibers) with 60 aperture plate mechanical I/F*
- Beam Switching device 45 deg. Mirrors & Beamsplitters
- XY-Table spares:

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  - 1 INLAND motor QT-3103,
  - 1 tachometer INLAND TG-1318,
  - 4 ball bearings SKF type 6201-2RS1,
  - 2 ball bearings SKF type 61901-2RS1,
  - 2 linear actuators SKF type TN2 16x5R,
  - 2 brake actuators FESTO type ADVU 50-10A,
  - 2 Heidenhain LS-106 encoders,
- 60 spare APD modules*
- 1 high voltage driver rack for the DM*
- 1 PowerPC board with 256 MB*
- 2 APD counter boards*
- Standard motor control/amplifier boards
- 1 TTM front end (sensor) box
- 1 spare of all TTM servo-electronic PCB + cables*

*These components are spares for the SINFONI and CRIRES instruments also.

8. LRU, SRU AND MAINTENANCE STRATEGY

8.1. XY-TABLES

These stages are very robust and reliable. We do not expect particular failure modes of these. Should it occur spare parts will be available. The operation will then be involved required a few man-days. Drive mechanisms are identical to the one used under the Coudé rotating platform.

8.2. OPTO-MECHANICS

8.2.1. Optics

8.2.1.1. WFS optics

No particular failure mode is planned for the main optics the so-called beam expander. However, long term evolution of the coating is not well known. This is why a spare system is provided. In case of an incident that would lead to a repair, the unit can be changed with a minimum of alignment procedures since the whole self-contained module is mounted onto the T-Mount with locating pins. The Beam-Expander can be considered a LRU given its modular design but the exchange operation could last up to one man-day.

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8.2.1.2. TTM

The TTM electronics is a highly reliable unit that has been in use (such design) for several years. The technology applied is the same as for the CFHT PUEO tip-tilt mirror, COME-ON two axis mirror. These have been in service since 1992 without major failure. Similar system are in use on NAOS, GEMINI Altair, CFHT Megacam (electronics only).

The critical components: power supplies, power amplifier, flexible pivots and actuators are chosen with large security margins.

A change of the whole TTM+DM assembly would be much more involved and would imply a longer downtime and more man-hour of repair work. However, this failure mode did not appear in the hazard analysis and seems therefore highly improbable.

8.2.1.3. DM

A re-coating of the DM if needed, requires careful planning. It can only be done at the manufacturer premises in France (CILAS). Down time would be minimized by using the spare DM. Change of the DM requires disconnecting from the azimuth platform the DM and TTM cables. Actual change of the DM must be carried out from the M8 well. The whole operation should require 3-4 man-hour. No re-alignment would be needed since the TTM remains in place for the whole operation.

8.2.2. Micro-Lens & Fibers

This unit is particularly vulnerable and fragile. This is why 2 spares will be provided. Several micro-lens spares are ordered and are SRU. The LRU unit will be the combination Micro-Lenses and mount already coupled with the optical fiber bundle. The Micro-lens end of the bundle is mounted on a rigid mount with locating pins, and can be “reconnected” onto the T-mount without alignment. The other end is composed of 60 FC connectors. Change of this LRU necessitates 1-2 man-hour (time to disconnect/reconnect 60 FC connectors).

A defective unit will need to be shipped to Garching for repair. The SRU are then the 2 Micro-lens on one hand, and the optical fiber bundle on the other hand. The second micro-lens would be destroyed in the process (glue and micro-lens material are the same, and both are destroyed by the ungluing solvent).

8.2.3. Membrane Unit

Membranes are relatively fragile and a number of units will be ordered. They are mounted on a ring with 2 threaded mounting holes. Membranes are SRU. A whole membrane unit can be exchanged as a LRU. The replacement of a membrane unit can be done at Paranal, it is a simple operation. The LRU exchange should require 1-2 man-hours, while a LRU repair by replacement of the membrane could take a similar amount of effort.

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8.3. ELECTRONICS

8.3.1. High Voltage Drivers

One complete unit of HV driver is provided as spare. Replacement is simple and requires only cables disconnection, removal of rack from cabinet, re-insertion of the spare rack, reconnection. The whole operation would require 3-4 man-hour maximum. The defective HV driver could be tested and a spare board ordered. (16 channels PCB are the SRU, the HV driver is the LRU).

8.3.2. TTM electronics

Spare components are provided for all custom made boards: X servo, Y servo, X amp., Y amp., Test board, Interface board.

Detail debugging procedure will be provided (similar to previous designed systems).

A Test box is provided with this procedure that allows a complete diagnostic of the system.

8.3.3. APD Cabinet

The APD cabinet is located in close proximity to the WFS Box. It contains the conditioning electronics and power supplies for the APD. These are mounted by set of 16 on 4 liquid cooled plates. In case of an APD module(s) failures one of these plate would be changed (LRU). This would involve the disconnection/reconnection of 16 APD modules. The defective APD can then be dismounted in the shop (SRU). A typical 2-3 man-hours would be required for LRU exchange.

8.3.4. LCU's

All LCU's are standard ESO piece of equipment using standard CPU, Motor controller and amplifier, communication and network boards. It is assumed that Paranal staff is familiar with this type of equipment for debugging, reparing and typical maintenance operations.

9. CONCLUSION

MACAO-VLTI has been designed keeping in mind the various maintenance, availability and reliability requirements typical for ESO instruments.

Spares are provided, LRU's and SRU's breakdown as well. Regular maintenance operations are suggested with approximate manpower requirement.