E U R O P E A N   S O U T H E R N   O B S E R V A T O R Y

Organisation Européenne pour des Recherches Astronomiques dans l'Hémisphère Austral
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VERY LARGE TELESCOPE

MACAO -VLTI
Interface Control Document

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CHANGE RECORD

Issue	Date	Section/Page affected	Reason/ Initiation/Remarks
1.0/prep1	09 Mar 2000	All	First prep
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2.0	5 Feb 2001	All	Revision for FDR

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1 Purpose

The purpose of this document is to define the evolving interfaces between the VLT Interferometer (VLTI) and the MACAO system.

1.1 Scope

The document deals with the following interfacing issues:

- Mechanical Interfaces
- Optical Interfaces
- Software Interfaces
- Electronic Interfaces
- Environmental Interfaces

This document covers only those interfaces between MACAO and the VLTI, interfaces between MACAO and the VLT are covered in the following documents:

Mechanical Interfaces , RD2
Electrical Interfaces, RD3-3c

1.2 Applicable Documents

The following documents are applicable:

AD1	*VLT Specification: Basic Telescope Definitions*	VLT-SPE-ESO-10000-0016	2
AD2	*List of Service Connection Points*	VLT-LIS-ESO-10000-0551	3.2
AD3	*Requirements and environment for the Coude train and Coude room*	VLT-SPE-ESO-11500-2322	In prep
AD4	*Technical Specification for the Image Alignment Unit of the VLTI, Part I: Unit Telescopes*	VLT-SPE-ESO-15442-2380	1.0
AD5-a	*VLT UT Coude Relay Optics M9, M10 & M11 Optical Design Report*	VLT-SPE-ESO-11535-1937	3
AD5-b	*MACAO-VLTI Telecentricity Lenses, Technical Specification*	VLT-SPE-ESO-15600-2213	2.0
AD6	*VLT UT Coude Relay Optics M9, M10 & M11 Technical Specifications*	VLT-SPE-ESO-11535-1656	2.0
AD7	*Technical CCD Systems, Operation Manual*	VLT-MAN-ESO-11700-1775	2.1
AD8	*APD Tilt Loop Interfaces Control Document (STRAP)*	VLT-ICD-ESO-11670-1288	3.0
AD9	Optical design of the VLT Coudé optics	VLT-SPE-ESO-11500-1641	4

1.3 Applicable Drawings

The following drawings applicable:

ADW1	*M8 Train Coude Assembly*	VLT-DWG-REO-11518-0010	00
ADW2	*M9-M10 Tower; Base Plate*	VLT-DWG-ESO-11535-2072	00
ADW3	*M9-M10 Tower; Topr part*	VLT-DWG-ESO-11535-xxxx	In prep.
ADW4	*MACAO-VLTI Allowable Volume*	VLT-DWG-ESO-15600-000000-0000	Issue 0 12.03.01

1.4 Reference documents

The following documents contain useful information for reference:

RD0	*Top Level Requirements for MACAO-VLTI*	VLT-SPE-ESO-15600-2082	1.2
RD 1	*MACAO-VLTI Conceptual System Design Analysis*	VLT-TRE-ESO-15600-2067	1.1
RD 2	*MACAO-VLTI Preliminary Mechanical Design and analysis report of the coude AO facilities*	VLT-TRE-ESO-15600-2274	1.0
RD 3	*MACAO-VLTI Electronics – Overview*	VLT-TRE-ESO-15600-2268	1.0
RD3a	*MACAO-VLTI Electronics – APD*	VLT-TRE-ESO-15600-2269	1.0
RD3b	*MACAO-VLTI Electronics – LCU*	VLT-TRE-ESO-15600-2270	1.0
RD3c	*MACAO-VLTI Electronics – DM Control*	VLT-TRE-ESO-15600-2271	1.0
RD 4	*MACAO-VLTI Software Design OS*	VLT-SPE-ESO-15600-2439	1.0
RD 4B	*MACAO-VLTI Software Functional Specifications RTC*	VLT-SPE-ESO-15600-2062	1.1
RD5	*Telescope Control System User Manual*	VLT-MAN-ESO-17230-0942	1.5
RD6	*Alignment of the Coude train M4-M8*	VLT-PRO-REO-11500-0026	2.0
RD7	*MACAO-VLTI Technical Specifications*	VLT-SPE-ESO-15600-2245	1.1

1.5 Acronyms

RD	Reference Document
AIT	Assembly, Integration and Tests
AO	Adaptive Optics
APD	Avalanche Photo Diode
ASM	Atmospherical Site Monitor
BOB	Broker of Observation Blocks
CCS	Central Control Software
CDT	Command Definition Tabler
CWFS	Curvature Wavefront Sensor
DM	Deformable Mirror
ESO	European Southern Observatory
FITS	Flexible Image Transport System
FOV	Field of View

HO	High Order
HW	Hardware
ICS	Instrument Control Software
ICD	Interface Control Document
IR	Infrared
ISS	VLTI Interferometer Supervisor Software
LCU	Local Control Unit
LOS	Line of Sight, the seeing in the direction that the scope is looking
MACAO	Multiple Applications Curvature Adaptive Optics
Mas	Milli arcsec on the sky
ND	Neutral Density filter
NGS	Natural Guide Star
OB	Observation Block
OLDB	Online Database
OS	Observing Software
PSF	Point Spread Function
STRAP	System for Tip-tilt Removal with Avalanche Photodiodes
SW	Software
TBC	To Be Confirmed
TBD	To be determined
TRS	Time Reference System
UT	Unit Telescope (8.2-m diameter)
VLT	Very Large Telescope
VLTI	VLT Interferometer
WFS	WaveFront Sensor
WRT	with respect to
WS	Workstation

2 Overview

The MACAO-VLTI system is a 60 element curvature AO system operating at the Coudé focus of one of the VLT UTs delivering a corrected wavefront to the VLTI delay lines after reflection off the dichroic M9. The corrective optics consists of a deformable mirror with 60 actuators mounted on a tip/tilt stage situated at M8 in the Coudé train. The Curvature Wavefront Sensor is based on a 60 element lenslet array feeding 60 APD modules, the CWFS is hosted in a WFS box mounted on an X-Y table standing on the Coudé floor below M9. MACAO-VLTI is designed to operate only with natural guide stars.

MACAO consists of the following subsystems:

- Corrective Optics subsystem
  Which includes the deformable mirror mounted in a tip/tilt stage, and the corrective optics electronics. The DM is located at M8 in the Coudé train (part of the rotating telescope structure), the corrective optics electronics is mounted on the azimuth platform.

- CWFS subsystem
  Which includes the WFS box, mounted on the X-Y Tables and the APD rack located <3m away. This subsystem is mounted on the Coudé platform and is located below the dichroic M9 and the telecentricity lens.

- Control electronics rack
  Hosting the instrument control and real time LCUs, VLTI LCU for control of STRAP, TCCD, and M10 translation and tip-tilt,, APD counters and associated electronics. This subsystem is mounted on the Coudé platform.

- MACAO Instrument Workstation
  Located in the computer room adjacent to the VLTI control room. Each MACAO system requires an X-Terminal in the control room for MACAO status monitoring.

- Calibration source subsystem (VLTI responsibility)
  Located at the bent Nasmyth focus/M4.

- Test IR camera for use only during system AIT and commissioning
  Located at the folded Coudé focus (reflected off M9)

Figure 1 gives an overview of the MACAO system components and their locations in the M8 area and the Coudé lab.

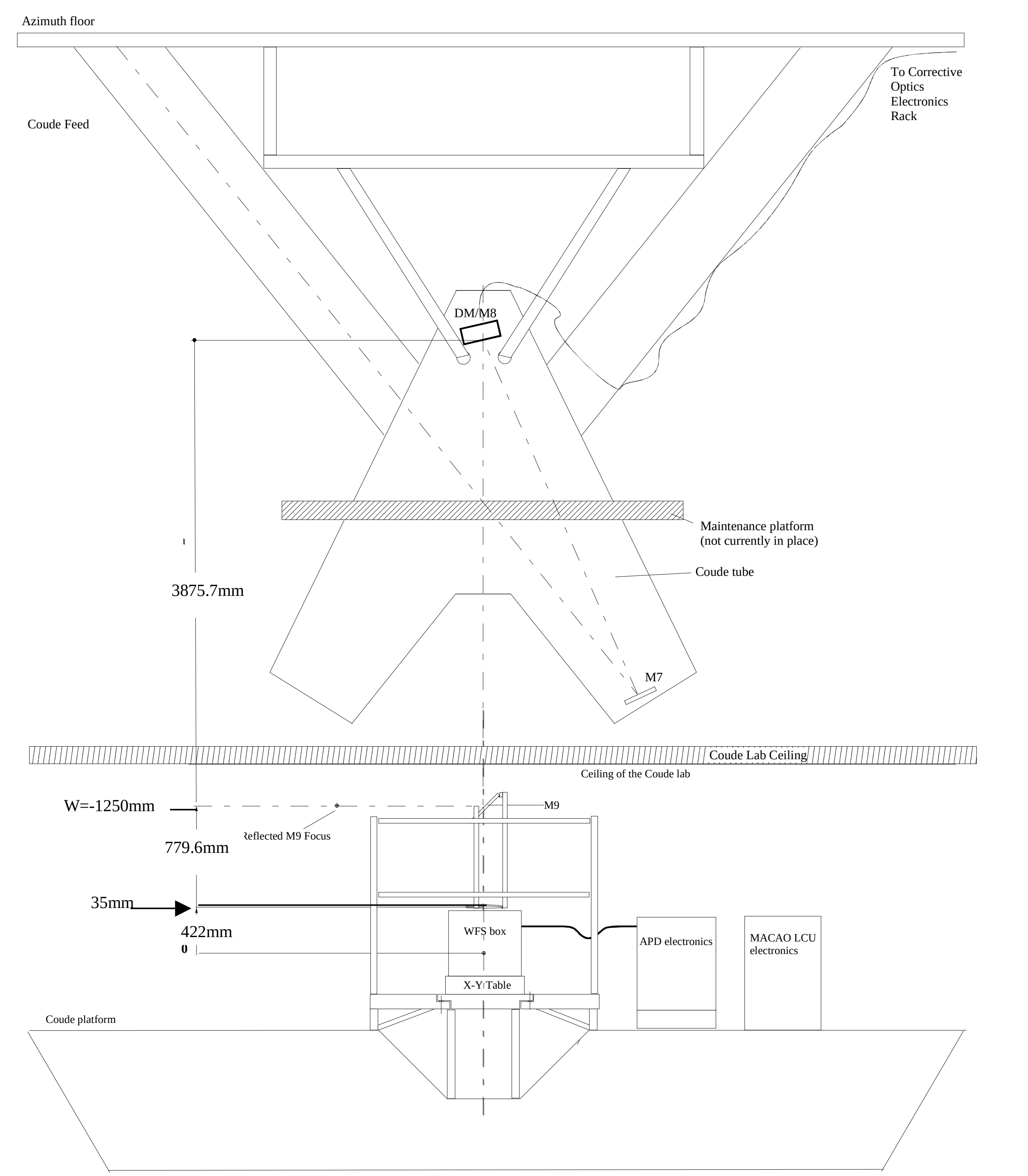


Figure 1 Schematic of macao component locations

3 Interface Definition

The following interface have been identified:

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
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
I/F23 MEC M9 TOWER ↔ MACAO IR CAM
I/F24 OPT Folded Coudé Focus ↔ MACAO IR CAM

I/F1 is defined as a specification in RD7. The complete design relative to this spec. can be found in RD4.

I/F2, I/F5, I/F6, I/F7, I/F10 to I/F16 are well known standard by the electronic group (or defined by them).

I/F3, I/F4, I/F8 are covered in RD7

I/F17 to I/F22 are described in AD7 and AD8, furthermore they are covered in RD7.

I/F8, I/F9, I/F23 and I/F24 are described in more details in the present document since they are still subject to possible evolutions.

4 Allowable Volumes

4.1 Coudé Platform

The allowable volume for MACAO-VLTI in the Coude Environment is described in ADW4.

The 3 main components of MACAO-VLTI in this volume are the APD cabinet, the Electronics Cabinets (VLTI/RTC and IC) and the WFS assembly under the M9 tower; the volume required by these is indicated below.

- APD Cabinet

The APD cabinet is located on the Coudé rotating platform less than 3 m from the WFS. The volume occupied by this cabinet is:

- Width: 600 mm
- Depth: 1040 mm
- Height: 850 mm
- Weight: ~50 kg

This rack will require cooling fluids and electrical power from the Coudé platform SCP#21-N (see AD2).

- Electronics Cabinets

The VLTI/RTC/IC cabinets are located on the Coudé rotating platform less than. The volume occupied by this cabinet is:

- Width: 2x800 mm
- Depth: 1040 mm
- Height: 1450 mm
- Weight: ~2x100 kg

This rack will require cooling fluids from the Coudé platform SCP#21-N (see AD2), power and network connection as well.

- CWFS assembly

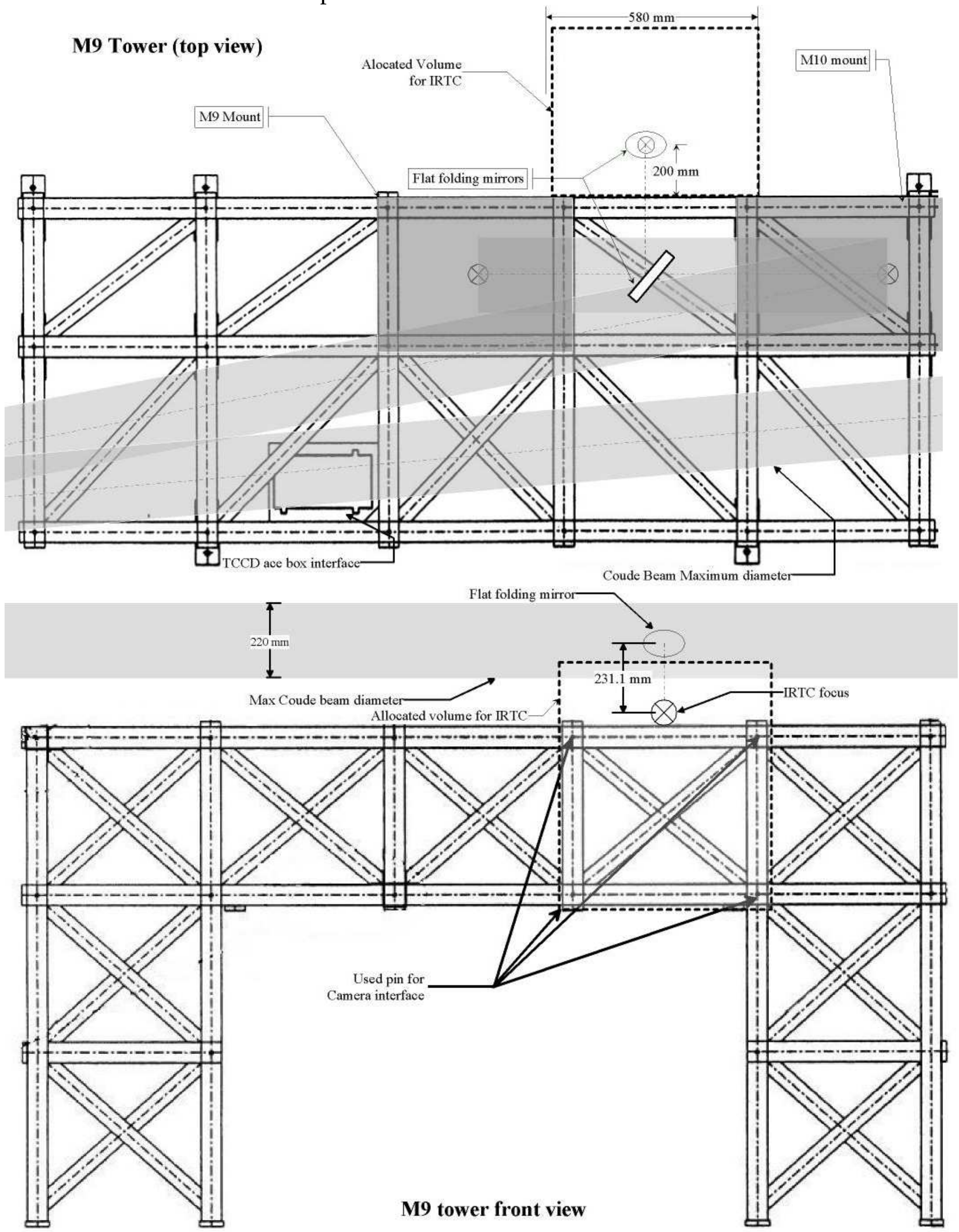
The I/F for the WFS assembly is described in more detail in section 5.
The Volume occupied by the CWFS assembly is given below. The “width” is the dimension along the “Y” axis of the table (6° with respect to the “V” axis of the VLTI) and the “depth” is along the “X” axis (also 6° with respect to the VLTI “U” axis).

- Width: 830mm (+250 mm)
- Depth: 812mm (+250 mm)
- Height: 879mm
- Weight:~150kg

Bear in mind that the values of 830mm and 812mm describe the sizes that contain the CWFS (plus XY table); however, one needs to add to these the actual displacement of the XY table system which means an increment of 250mm in X and Y direction (-125mm and +125mm).
Also, an additional “soft” 25mm must be added along the “width” to take into account the cables. The depth

- Infrared test camera and M9 tower interface.

We define here the location where the infrared test camera will be placed in Paranal with respect to the M9 tower. Since this camera is not yet fully designed we just define which interface we need to mount it on the M9 tower. The following figures show a top and a front view of the M9 tower with the camera location in dashed line. We basically foresee to put the camera on one side of the tower in a vertical position and use four pins to mount it as indicated in the front view. The Coude beam is folded by two flat mirrors at 45 degrees. In this situation, only the first mirror is in the Coude beam path, and will be manually removed for VLTI operations. This mirror mount will be clamped on the tube of the framework structure located below it, whereas the second mirror will be mounted on the camera holding structure. No optics or mechanical part will stand permanently either in the Coude beam or in the PRIMA beam path.



4.2 Azimuth Platform

All electronics for the TTM and DM subsystem is located on the Azimuth platform. This cabinet is cooled down using fluid from the Azimuth platform SCP#9-N (or 8-N –TBC-) as defined in AD2. Power and network are also provided by the same SCP. A length of 12m is planned for cables going from the electronics cabinet to the M8 tower; these are the HV cables (2) and the TTM cables (2). This cabinet has the following caracteristics:

- Width: 800 mm
- Depth: 1040 mm
- Height: 1450 mm
- Weight: ~100 kg

5 CWFS subsystem-Coude focus interface

5.1 List of components

Located at the Coudé platform are the CWFS box, the APD electronics rack and the MACAO LCU racks. The WFS box is mounted on its X-Y table such that the CWFS membrane is at the transmitted focus. The APD electronics rack is mounted such that the maximum fiber length from APD module to CWFS lenslet is < 3m. The CWFS box and X-Y stage are mounted on the platform hosting the M9, Telecentricity lens and AO IR test camera (during commisioning).

5.2 Coudé Optical interface

The optical interfaces at the coudé focus (after the Telecentricity Lens) are defined in AD5-a (see also AD5-b, AD6 and AD9 for more details).

5.3 Environmental Interface

The environmental conditions are described in AD3.

5.4 CWFS Mechanical interfaces

The MACAO-VLTI WFS will be bolted onto the M9-M10 Tower Base Plate that cover the Coudé “pit” and support the M9 tower. This base plate with the hole patterns for bolting the WFS is defined in ADW2.

The drawing ADW3 describes the M9-M10 Tower. The space available for the MACAO-VLTI WFS under the M9 tower is defined in ADW4

The mass of the WFS (including X-Y Table) shall not exceed: <150kg

The WFS will incorporate the TCCD according to interfaces defined in AD7 and the STRAP according to the interfaces defined in AD8.

The WFS assembly will require cooling fluids from the Coudé platform SCP#21-N for the STRAP and TCCD cooling.

6 Alignment Issues

6.1 Azimuthal target

As part of the alignment procedure for the WFS box the AO group will require the use of the removable "secondary azimuthal target" provided and used by REOSC during Coudé relay installation, installed at its nomical location.

6.2 Calibration source- Nasmyth focus/M4 interface

The following two alignment sources will be provided (by VLTI) for MACAO-VLTI operation and installation. Detailed characteristics of these alignment sources and related interface requirements can be found in AD4.

- **White Light Source for MACAO calibration**. This source is required for interaction matrix acquisition and should be available at all times and be remotely controlable by the MACAO software
- **Alignment Source**. This source is required for visual alignment of the MACAO optical components during AIT. Control of this source is not required from the MACAO software.

7 Computer & Control room Interface

Up to 4 MACAO systems will be supported by a single HP J-5000 workstation located in the VLTI computer room. In addition each MACAO system operating requires a single X-Terminal located in the VLTI control room for control of MACAO and display status information.

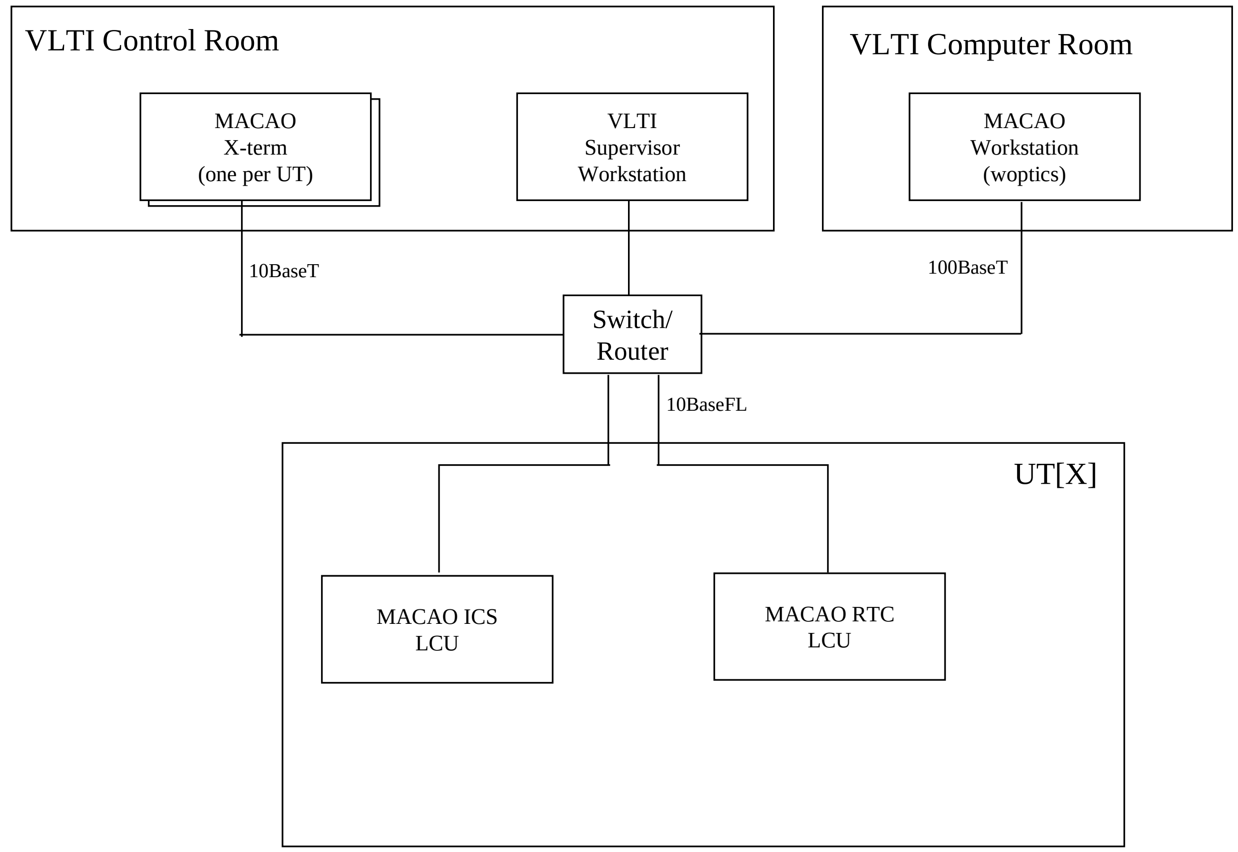


Figure 2 Hardware Components inr VLTI Computer & Control Rooms

The VLTI group shall provide all computers located in the VLTI computer and control rooms, the AO group shall supply all MACAO LCUs located at each UT.

7.1 STRAP & TCCD Control

7.1.1 Operating Modes

The normal mode of operation of MACAO-VLTI is with all light sent to the WFS assembly. On top of that, an opto-mechanical system shall allow the following operating modes for STRAP and the TCCD:

- 50/50 % Split between TCCD and WFS assembly with 3.1"x4.2" FOV on TCCD
- 50/50% Split between TCCD and STRAP with 3.1"x4.2" FOV on TCCD
- 100% to TCCD with ~10" FOV on TCCD
- 100% to STRAP

Switching between these operating modes is performed by the MACAO-VLTI ICS.

7.1.2 Electronics

Detailed interfaces are defined in AD7 (TCCD) and AD8 (STRAP).

One of the LCU cooled electronics cabinets located at the Coudé floor close to the WFS box will have space allocated for the electronics and LCU required by the VLTI for control of the TCCD and STRAP unit. This space will be 6HE in a standard 19" rack (See RD3b). All electronics and LCU to be supplied by the VLTI.

7.1.3 Software

Detailed interfaces are defined in AD7 (TCCD) and AD8 (STRAP).

All software to be implemented for the control of the TCCD, STRAP and the STRAP motorised functions (diaphragm and ND wheel) is the responsibility of the VLTI group.

8 MACAO-VLTI control software interface

The following figure shows how the MACAO software operates within the overall structure of the VLTI.

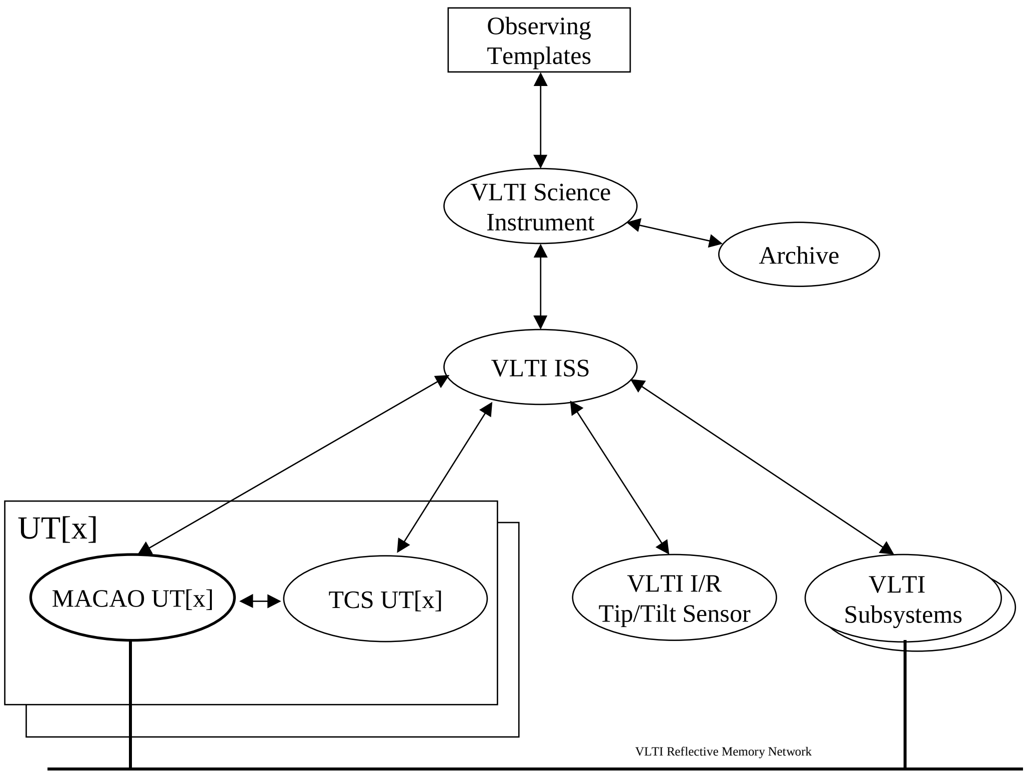


Figure 3 MACAO Software in the VLTI Context

The VLTI ISS coordinates the activity of MACAO and the TCS for each UT with the other VLTI sub-systems providing a single interface to the VLTI science instrument. Other VLTI subsystems attached to the VLTI reflective memory network can access real-time diagnostics generated by MACAO.

The interface to each MACAO system is implemented by an instance of the MACAO OS operating on the MACAO instrument workstation (woptics) each within the same CCS environment. The MACAO instrument workstation is connected to the VLTI LAN by a 100BaseT network connection.

The interface to MACAO is defined by the following:

- CCS Commands issued by the VLTI ISS to the MACAO OS
  For normal AO operations, and Tip/Tilt and Focus offsetting
- CCS Commands issued by the MACAO OS to the TCS
  For Tip/Tilt and Focus offloading
- Commands implemented by the **tif** interface for control of the calibration sources

For interaction matrix generation and calibration

- Public database class scanned from the woptics on-line DB
  Reflecting current values of AO diagnostic values
- FITS file generated at the end of an exposure
  Containing date acquired during an exposure with time tagged values sampling the atmospheric conditions and AO performance at a user definable sampling period
- Data Passed across the VLTI Reflective Memory network
  At the end of each AO cycle estimating the current atmospheric conditions

8.1 Commands Issued by the VLTI ISS to MACAO OS

These commands cover the normal control of the MACAO AO system and are split into the following categories.

- VLT Standard Commands
  For standard state switching
- Preset/Offset Commands
  For presetting the X/Y table to the GS position and initiating the GS tracking and for subsequent offsetting of the X/Y table trajectory
- Guide Star acquisition commands
  Acquiring the guide star and closing the AO loop
- Observation handling commands
  To indicate the start and end of science observations
- Chopping/ Nodding commands
  To inform the MACAO system of chopping frequency or of start/end of nodding cycles
- Miscellaneous commands
  Measurement and setting of AO parameters

The CDT for the MACAO OS process is included in **Error! Reference source not found.**.

VLT Standard Commands

Command	Parameters	Description
OFF	None	Bring the OS to LOADED State
STANDBY	None	Bring the OS to STANDBY state
ONLINE	None	Bring the OS to ONLINE state
STOP	None	Stop current action e.g. acquisition, preset

Preset / Offset commands

Command	Parameters	Description
PRSCOOR		Moves the X/Y table to the NGS location and initiates the X/Y table and Lenslet rotation tracking loops
OFFSET	offsetAlpha, offSetDelta	Apply an offset in: ❑ X/Y table trajectory in RA/DEC

	offsetX, offsetY XYHome OffsetFocus offsetZernike	❑ X/Y table trajectory in X/Y ❑ X/Y table to home (center) position ❑ Focus in mm ❑ Higher order Zernike in nm

The preset command relies on the following setup keywords:

- TEL.TARG.*
  Defining the telescope target RA/DEC and observing wavelength
- COU.*
  Defining the Coudé guide star RA/DEC, magnitude, FWHM and guiding wavelength

The current RA/DEC of the X/Y table is updated (by reverse calculation on the MACAO WS) and is available as part of the public OLDB.

NOTE: That the VLTI ISS will normally initiate a the preset by a SETUP of the function TEL.TARG.TYPE = COORDINATE.

Guide Star Acquisition commands

Command	Parameters	Description
ACQUIRE	 OffsetSkyAlpha, offsetSkyDelta MinStarFlux MinStrehl Safe	Acquire a guide star, optimize AO loop parameters and close the AO loop returning an estimate of the expected Strehl. ❑ Offset in RA/DEC where sky should be measured ❑ Expected GS flux ❑ Miniumum strehl required ❑ “Safe” mode (See RD 4-4B)

Observation Commands

Command	Parameters	Description
START	Exposure Id	Start acquiring AO calibration data
PAUSE	None	Pause acquisition of AO calibration data
CONT	None	Continue AO calibration data acquisition
END	None	End of observation, complete FITS file

Chopping /Nodding Commands

Command	Parameters	Description
STRTCHP	Absolute Start time	Start AO chopping mode at specified time
STOPCHP	Absolute Stop Time	Stop AO chopping mode at specified time

SUSPEND	None	Suspend the AO loop at beginning of nod to sky cycle
RESUME	None	Re close the AO loop at nod to object cycle

The STARTCHP command also relies on the following setup keywords

- TEL.CHOP.*
  Defining the telescope chopping frequency, amplitude and duty cycle

Miscellaneous Commands

Command	Parameters	Description
SETUP	AOS.OCS.WFFLAT.ST	Set the DM to its last calibrated “flat” vector
	AOS.INS.MODE	Move the linear stage selecting the beam path within the WFS box to one of the five named positions. ❑ CWFS ❑ CWFS+TCCD ❑ TCCD (wide FOV) ❑ STRAP ❑ STRAP+TCCD
	AOS.OCS.FITS.NAME	Name of the FITS file to produce at end of observation
	AOS.OCS.OFFLD.TIPTILT.ST	Enable/Disable offload of Tip/Tilt
	AOS.OCS.OFFLD.FOCUS.ST	Enable/Disable offload of Focus
OPENLP	None	Open the AO loop
PARK	None	Bring MACAO to safe parked state

8.2 CCS Commands Issued by the MACAO OS to VLTI ISS

Currently the only commands defined to be sent by the MACAO OS to the VLTI ISS are for the offloading of low frequency Tip/Tilt or optionally Focus to the TCS.

Offloading of focus is only expected to be performed infrequently (and not during VLTI observations) caused by temperature drifts.

Tip/Tilt and Focus offloading

Command	Parameters	Description
OFFSGP	Tip/Tilt offset in arcseconds	Request ISS to pass the offset command to the TCS for offloading of specified parameter
OFFSFAD	Focus Offset in mm	

8.3 Commands for control of calibration sources

The reference source used by MACAO for generation of interaction matrixes and "flat" vector calibration is under the control of a TCS LCU located near M4. Control of this source is via public **tif** commands, these commands will support the following functionality:

- Move MACAO calibration source into beam path
- Select MACAO calibration source intensity
- Set MACAO calibration source on/off
- Move MACAO calibration source in "Z" for focus adjustment

The command to be utilised is TBD by the TCS group. (reference ?)

8.4 OLDB Public Database Points

MACAO provides a set of OLDB classes which represents its public database interface (similar to the mechanisim implemented by ***tif***).

The class **macOLDB_PUBLIC** can be instantiated into any OLDB providing a local copy of the MACAO public database items in an environment different to that in which the MACAO S/W is running. The scan system is used to retrieve the values from the MACAO environment. MACAO will supply public script configuring the scan links from the MACAO environment to the local OLDB.

8.4.1 The macOLDDB_PUBLIC structure

```
#ifndef macPUBLIC_CLASS
#define macPUBLIC_CLASS
//************************************************************************
//* E.S.O. - VLT project
//*
//* "@(#) $Id: macPUBLIC_CLASS
//*
//* who       when       what
//* --------  --------   ----------------------------------------------
//* rdonalds  27-07-2000 Created for PDR
//* rdonalds  12-02-2001 Updated after prototype tests for FDR

//**************************************************************************
//*   NAME
//*   macPUBLIC.class - Public MACAO database class
//*
//*   SYNOPSIS
//*   #include "macPUBLIC.class" in a branch configuration file
//*
//*   PARENT CLASS
//*
//*   DESCRIPTION
//*   This file contains the definition of the database class which
//*   defines the public MACAO database structure.
//*   It defines a set of attributes that MACAO defines as publicly accessible.
//*   A user wishing to access some of these attributes must:
//*       - put an instance of this class in its own environment
```

```
//*       - create the proper set of scan link using the macScanSetup tool
//*       - activate the scan links for the attributes he needs
//*
//*   EXAMPLES
//*
//*   SEE ALSO
//*
//*   BUGS
//*
//*------------------------------------------------------------------------*/


//
// Public database points representing overall state of MACAO
//
CLASS BASE_CLASS macPUB_STATUS
BEGIN
    ATTRIBUTE INT32   macState    0     // MACAO main state STANDBY/ONLINE/...
    ATTRIBUTE INT32   macSubstate 0     // MACAO main sub-state
    ATTRIBUTE LOGICAL gpInpos     0     // guide probe in position
    ATTRIBUTE LOGICAL tracking    0     // tracking state
    ATTRIBUTE LOGICAL locked      0     // AO correction active ?
END

//
// Public database points representing the AO Loop
//

//
// required classes
//

CLASS BASE_CLASS macRTC_Atmosphere
BEGIN

 // Updated each 15 seconds
 ATTRIBUTE DOUBLE r0 // Fried parameter
 ATTRIBUTE DOUBLE L0 // Outer scale
 ATTRIBUTE DOUBLE t0 // correlation time

END

CLASS BASE_CLASS macRTC_Statistics
BEGIN

 // Updated each cycle
 ATTRIBUTE DOUBLE flux      // flux
 ATTRIBUTE DOUBLE magnitude // flux converted in magnitude
 ATTRIBUTE DOUBLE wfe       // wavefront error
 ATTRIBUTE DOUBLE strehl    // Strehl Ratio

 // Updated each second
 ATTRIBUTE DOUBLE fwhm      // Full Width at Half Maximum
 ATTRIBUTE DOUBLE enc       // encircled energy

END
```

```
CLASS BASE_CLASS macRTC_AOLoop
BEGIN

 ATTRIBUTE LOGICAL             locked
 ATTRIBUTE macaoRTC_Atmosphere atmosphere
 ATTRIBUTE macaoRTC_Statistics target

END

CLASS BASE_CLASS macRTC_Observation
BEGIN

  // The following value are averaged over the
  // entire observation time

 ATTRIBUTE macaoRTC_Atmosphere       atmosphere
 ATTRIBUTE macaoRTC_Statistics       target

END

CLASS BASE_CLASS macPUB_RTC
BEGIN

 macRTC_AOLoop      aoLoop
 macRTC_Observation  observation

 ATTRIBUTE INT32      aoLoopUnstable 0 // Event: loss of loop stability
                               // Reasons: APDs overcount
                               //          Mirror overvoltage
                               //          Flux variation
END

//
// Public database points representing tracking
//
CLASS BASE_CLASS macPUB_TRACK
BEGIN
    ATTRIBUTE DOUBLE  ra           0    // Guide star RA J2000
    ATTRIBUTE DOUBLE  dec          0    // Guide star DEC J2000

    ATTRIBUTE DOUBLE  probeX       0    // Guide probe X coordinate
    ATTRIBUTE DOUBLE  probeY       0    // Guide probe Y coordinate

    ATTRIBUTE DOUBLE  probeRa      0    // Guide probe RA J2000 coordinate (HMS)
    ATTRIBUTE DOUBLE  probeDec     0    // Guide probe DEC J2000 coordinate (HMS)

    ATTRIBUTE DOUBLE  remtime      0    // remaining tracking time in seconds

    ATTRIBUTE INT32   trackingLost  0  // Event: Unexpected loss of tracking
    ATTRIBUTE INT32   remTimeLow   0   // Event: remaining tracking time below
limit
END

//
// Public database points representing ICS
```

```
//
CLASS BASE_CLASS macPUB_ICS
BEGIN
    ATTRIBUTE INT32   icsState    0     // ICS state

    ATTRIBUTE BYTES20 beamPosition  // CWFS
                              // CWFS+TCCD
                              // STRAP
                              // STRAP+TCCD
                              // TCCD
END

CLASS BASE_CLASS macPUBLIC
BEGIN
    ATTRIBUTE maxPUB_STATUS     macStatus
    ATTRIBUTE macPUB_TRACK    trackStatus
    ATTRIBUTE macPUB_RTC        rtcStatus
    ATTRIBUTE macPUB_ICS        icsStatus
END


#endif /*!macPUBLIC_CLASS*/

// *___oOo___*
```

8.5 FITS File

At the end of each exposure a FITS file will be produced on the MACAO workstation containing a FITS binary table with the following columns:

- Time stamp of sample (relative to the start time of the exposure)
- Measured tip
- Measured tilt
- Measured defocus
- Measured total wavefront error (WFE)

The sampling period of this binary table is defined by a SETUP parameter and may take values with a lower limit of 10ms. The sampling period will be modified by MACAO to match the AO loop cycle time i.e. the sample period will be a multiple of the AO loop feedback cycle period.

8.6 Reflective Memory Interface

At the end of each AO feedback cycle a value is sent by the RTC over the reflective memory interface which is an estimate of the last measured wavefront error (WFE) calculated by projecting the last measured 60 curvature values into Zernike space via a projection matrix

Appendix A: MACAO OS CDT

```
//******************************************************************************
// E.S.O. - VLT project
//
// "@(#) $Id: mvoControl.cdt,v 1.34 2000/06/09 09:50:42 vltsccm Exp $"
//
// who        when      what
// ---------- --------  ----------------------------------------------
// rdonalds   15/11/2000  created for MACAO-VLTI
//
//

//*************************************************************************
//  NAME
//    mvoControl.cdt - command definition table
//
//  DESCRIPTION
//    This file describes the specific public commands which can been sent to
//    the  MACAO OS control process
//
//
//
//-------------------------------------------------------------------------
//
//*************************************************************************
PUBLIC_COMMANDS:

//-------------------------------------------------------------------------
//  BOSS commands
//*********************************************************************

#include "osbControl.cdt"


//-------------------------------------------------------------------------

//  MACAO OS Server specific commands

//*********************************************************************
//
COMMAND=  PRSCOOR
FORMAT= A

PARAMETERS=
    // Target Alpha
    PAR_NAME=    alpha
    PAR_UNIT=    HHMMSS.TTT
    PAR_TYPE=    REAL
    PAR_RANGE=   INTERVAL MIN=0;MAX=240000.0

    // Target Delta
```

```
PAR_NAME=    delta
PAR_UNIT=    [+-]DDMMSS.TTT
PAR_TYPE=    REAL
PAR_RANGE=   INTERVAL MIN=-900000.0;MAX=900000.0

PAR_NAME=    epochSystem
PAR_UNIT=    YEARS
PAR_TYPE=    STRING
PAR_RANGE=   ENUM "J","B"
PAR_DEF_VAL= "J"

PAR_NAME=    epoch
PAR_UNIT=
PAR_TYPE=    REAL
PAR_RANGE=   INTERVAL MIN=-2000.0;MAX=3000.0
PAR_DEF_VAL= 2000

PAR_NAME=    equinox
PAR_UNIT=    YEARS
PAR_TYPE=    REAL
PAR_RANGE=   INTERVAL MIN=-2000.0;MAX=3000.0
PAR_DEF_VAL= 2000

PAR_NAME=    pma
PAR_UNIT=    ARCSECONDS/YEAR
PAR_TYPE=    REAL
PAR_RANGE=   INTERVAL MIN=-10.0;MAX=10.0
PAR_DEF_VAL= 0

PAR_NAME=    pmd
PAR_UNIT=    ARCSECONDS/YEAR
PAR_TYPE=    REAL
PAR_RANGE=   INTERVAL MIN=-10.0;MAX=10.0
PAR_DEF_VAL= 0

PAR_NAME=    radvel
PAR_UNIT=    km/sec
PAR_TYPE=    REAL
PAR_RANGE=   INTERVAL MIN=-200000.0;MAX=200000.0
PAR_DEF_VAL= 0

PAR_NAME=    parallax
PAR_UNIT=    ARCSECONDS
PAR_TYPE=    REAL
PAR_RANGE=   INTERVAL MIN=-10000.0;MAX=10000.0
PAR_DEF_VAL= 0

PAR_NAME=    coordinateType
PAR_TYPE=    STRING
PAR_RANGE=   ENUM "A","M"
PAR_DEF_VAL= "M"

// Observing wavelength
PAR_NAME=    wavelength
PAR_UNIT=    NANOMETER
PAR_TYPE=    REAL
```

```
    PAR_RANGE=   INTERVAL MIN=100.0 ; MAX=20000.0
    PAR_DEF_VAL= 650.0


REPLY_FORMAT = A
REPLY_PARAMETERS=
    PAR_NAME=    done
    PAR_TYPE=    STRING
    PAR_DEF_VAL= "OK"

HELP_TEXT=
Preset Macao X/Y table and start tracking
the tracking

NOTE: That a PRESET will also will also triggered by a SETUP including the
keyword TEL.TARG.TYPE = COORD (same functionality as TCS)

@
//**********************************************************************
//
COMMAND=                ACQUIRE
FORMAT=                 A

PARAMETERS=
    PAR_NAME=           offsetSkyAlpha
    PAR_UNIT=           arcsec
    PAR_TYPE=           REAL
    PAR_RANGE=          INTERVAL MIN=-3600.0;MAX=3600.0   // +-1 degree
    PAR_OPTIONAL=       NO

    PAR_NAME=           offsetSkyDelta
    PAR_UNIT=           arcsec
    PAR_TYPE=           REAL
    PAR_RANGE=          INTERVAL MIN=-3600.0;MAX=3600.0   // +-1 degree
    PAR_OPTIONAL=       NO

    PAR_NAME=           minStarMag
    PAR_UNIT=           magnitude
    PAR_TYPE=           REAL
    PAR_OPTIONAL=       NO
    PAR_RANGE=          INTERVAL MIN=-NNN.0;MAX=NNN.0

    PAR_NAME=           minStrehlRatio
    PAR_UNIT=           percent
    PAR_TYPE=           REAL
    PAR_OPTIONAL=       YES
    PAR_DEF_VAL=        25.0

    PAR_NAME=           safe
    PAR_TYPE=           LOGICAL
    PAR_OPTIONAL=       YES
    PAR_DEF_VAL=        FALSE

REPLY_FORMAT=           A
REPLY_PARAMETERS=
    PAR_NAME=           reply
```

```
    PAR_TYPE=           STRING

HELP_TEXT=
Consists of MACAO performing an optimization procedure for the AO loop.
At the end of acquisistion, the AO loop has been closed

    offsetSkyAlpha <offset> is the amount of arcsec to move in alpha on the sky
                            for measurement of the sky emission and thermic
                            background,
    offsetSkyDelta <offset> is the amount of arcsec to move in delta on the sky
                            for measurement of the sky emission and thermic
                            background,
    minStarMag <value>      is the minimal star magnitude expected during the
                            photometric check of reference source,
    minStrehlRatio <value>  is the minimal Strehl Ratio used  during the
                            performance check of the adaptive correction
                            efficiency,
    safe                    specify that the acquisition has to be performed
                      "safely" by starting with a the maximum ND in
                      front of the APDs and slowly reducing
@

//**********************************************************************
//
COMMAND=                OFFSET
FORMAT=                 A

PARAMETERS=
    PAR_NAME=           offsetAlpha
    PAR_UNIT=           arcsec
    PAR_TYPE=           REAL
    PAR_RANGE=          INTERVAL MIN=-1.0;MAX=1.0   // +-1 arcsec
    PAR_DEF_VAL=        0.0

    PAR_NAME=           offsetDelta
    PAR_UNIT=           arcsec
    PAR_TYPE=           REAL
    PAR_RANGE=          INTERVAL MIN=-3600.0;MAX=3600.0   // +-1 arcsec
    PAR_DEF_VAL=        0.0

    PAR_NAME=           offsetFocus
    PAR_UNIT=           mm
    PAR_TYPE=           REAL
    PAR_DEF_VAL=        0.0

//  Need some agreement on the format of this offset
    PAR_NAME=           offsetZernike
    PAR_TYPE=           INTEGER
    PAR_OPTIONAL=       YES

    PAR_NAME=           home
    PAR_TYPE=           LOGICAL
    PAR_DEF_VAL=        FALSE

REPLY_FORMAT=           A
REPLY_PARAMETERS=
```

```
    PAR_NAME=           reply
    PAR_TYPE=           STRING

HELP_TEXT=
Performs various offset types i.e. alpha/delta (in arcsec), X/Y stage (in mm),
or focus (in mm) on MACAO output image.

    offsetAlpha <offset>    is the amount of arcsec to move in alpha on the sky,
    offsetDelta <offset>    is the amount of arcsec to move in delta on the sky,
    offsetFocus <offset>    is the amount of mm to move the focus of output
    offsetZernike <Zernike> <value>
                      offset the identified zernike mode by value nm
    home                    specify that the X/Y table returns to the position
                      where the WFS detector is centered on the optical
                      axis

Note:
The offset types are for obvious reasons only possible for only one type at the
time.
@

//*******************************************************************
//
COMMAND=                PARK
FORMAT=                 A

PARAMETERS=
    PAR_NAME=           subSystem
    PAR_TYPE=           STRING
    PAR_OPTIONAL=       YES

REPLY_FORMAT=           A       // One reply only at end of execution
REPLY_PARAMETERS=
    PAR_NAME=           done
    PAR_TYPE=           STRING
    PAR_DEF_VAL=        "OK"

HELP_TEXT=
Bring MACAO or only the specified sub-system into a safe setup.
    subSystem <subSystem>   specify the name of the sub-system to switch to a
                            safe position. Sub system can be one of RTC, ICS
@

//*******************************************************************
//

COMMAND=  SUSPEND
FORMAT= A

PARAMETERS=

REPLY_FORMAT=           A
REPLY_PARAMETERS=
    PAR_NAME=           reply
    PAR_TYPE=           STRING
```

```
HELP_TEXT=
Suspend the AO loop before a nod to sky cycle
@

//*********************************************************************
//

COMMAND=  RESUME
FORMAT= A

PARAMETERS=

REPLY_FORMAT=           A
REPLY_PARAMETERS=
    PAR_NAME=           reply
    PAR_TYPE=           STRING

HELP_TEXT=
Resume the AO loop after the telescope has nodded back to object
@

//*********************************************************************
//
COMMAND=  OPENLP
FORMAT= A

PARAMETERS=

REPLY_FORMAT=           A
REPLY_PARAMETERS=
    PAR_NAME=           reply
    PAR_TYPE=           STRING

HELP_TEXT=
Stop AO correction
@

//*********************************************************************
//
COMMAND=                SAVESUP
FORMAT=                 A

PARAMETERS=
    PAR_NAME=           file
    PAR_TYPE=           STRING

    PAR_NAME=           mergeFiles
    PAR_TYPE=           STRING
    PAR_OPTIONAL=       YES
    PAR_MAX_REPETITION= 999

    PAR_NAME=           function
    PAR_TYPE=           STRING
    PAR_OPTIONAL=       YES
    PAR_MAX_REPETITION= 999
```

```
    PAR_NAME=           addFunction
    PAR_TYPE=           STRING
    PAR_OPTIONAL=       YES
    PAR_MAX_REPETITION= 999

REPLY_FORMAT=           A
REPLY_PARAMETERS=
    PAR_NAME=           reply
    PAR_TYPE=           STRING

HELP_TEXT=
Saves a set of parameters (Short FITS keywords with associated value), which
can be retrieved at a later stage with the RESTSUP command. This functionality
is intended to support calibration observations by saving the AO systems
state whilst on a science target and restoring it on the calibrator.

The following options are supported:
    file <filename>         specify the name of the file in which the
                            parameters (short-FITS keywords) will be saved. It
                            is used to retrieve parameters, and must allow to
                            identify saved data without ambiguity. If the
                            given file name is already used, and error reply
                            will be returned.
    mergeFiles <file1> [<file2> ... ]
                            specify one or more parameter files (PAF) to read to
                            merge the corresponding keywords into the file
                            <filename>.
    function <param1> [<param2> ...]
                            specifies the name of keywords to save. They are
                            stored with their current values.
    addFunction <param1> <value1> [<param2> <value2> ...]
                            specifies the name and value of keywords to save.
@


//**********************************************************************
//
COMMAND=                RESTSUP
FORMAT=                 A

PARAMETERS=
    PAR_NAME=           file
    PAR_TYPE=           STRING

    PAR_NAME=           function
    PAR_TYPE=           STRING
    PAR_OPTIONAL=       YES
    PAR_MAX_REPETITION= 999

    PAR_NAME=           path
    PAR_TYPE=           LOGICAL
    PAR_OPTIONAL=       YES
    PAR_DEF_VAL=        FALSE

REPLY_FORMAT= A
REPLY_PARAMETERS=
```

```
    PAR_NAME=           reply
    PAR_TYPE=           STRING

HELP_TEXT=
Retrieves a set of parameters previously saved with the SAVESUP command. The
following options are supported:
    file <filename>         specify the name of the file in which the
                            parameters (short-FITS keywords) have been saved.
    function <param1> [<param2> ...]
                            specify one or more parameters to be retrieved. By
                            default, all saved parameters are restored.
    path                    setting this option, the command returns the
                            complete path of the file where are stored
                            parameters. In this case, 'function' option is
                            ignored.


@
//**********************************************************************
//
COMMAND=                MEASURE
FORMAT=                 A
PARAMETERS=
    PAR_NAME=           function
    PAR_TYPE=           STRING
    PAR_OPTIONAL=       YES
    PAR_MAX_REPETITION= 999



REPLY_FORMAT=           A       // One reply only at end of execution
REPLY_PARAMETERS=
    PAR_NAME=           status
    PAR_TYPE=           STRING
    PAR_DEF_VAL=        "OK"

HELP_TEXT=
Measure the identified function of the AO system where function is one of:

      "Flat"      : Measure the "flat" vector
      "Imat"  : Measure a new interaction matrix
@
```

___oOo___