S.A. AMOS
ADVANCED MECHANICAL AND OPTICAL SYSTEMS

MULTI APPLICATION SOLAR TELESCOPE (MAST)

TECHNICAL PROPOSAL

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1.0	19/01/06	41		Initial issue
2.0	19/05/06	55	all	Reworked version with the proposal of a new design

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1. SCOPE

This document presents the AMOS technical proposal for the design, manufacturing and on site installation of the 50 cm Multi Application Solar Telescope (MAST) for the Udaipur Solar Observatory (USO), Physical Research Laboratory (PRL, India).

With respect to the first answer to the global tender notice, provided in issue 1.0 of this document, AMOS was invited to propose an option, which was not strictly required to follow the nominal lay-out proposed by the PRL, but was aimed at giving the best answer to the science requirements attached to the future PRL solar telescope.

2. APPLICABLE DOCUMENT

AD1: Global tender notice no : PRL/04/05-06 dated 22/12/05. Turn-key Supply of a 50 cm Aperture Solar Telescope including Design, Manufacturing and Installation at site.

3. TECHNICAL PROPOSAL

This section will deal with the technical presentation and discussion of the concept proposed by AMOS for the MAST.

It is important to point out that AMOS company has been developed with the strategy to be able to provide turn key projects in the field of opto-mechanical and electrical systems. Today AMOS has the in-house capability to design and manufacture the complete telescope (mechanics/optics and electronics).
This has to be considered as a big advantage for obvious reasons:

- high efficiency in the design/analysis iterative process since all experts are in house
- better management and system control of the overall project (design/manufacturing and AIV made in house and therefore directly under AMOS control)

To guarantee the final performance of the telescope, it is mandatory to implement within the project the system engineering producing the following tasks:

- Analyse and understand all the specifications
- Establish logical links between the specifications in order to enable to manage all the interactions between the different requirements

- Establish error budgets for all system requirements in order to identify all low level contributors
- Control of all the interfaces

To assess the telescope system performance, integrated modelling is used to provide a means of investigating the behaviour of the system with respect to disturbances of various origins acting concurrently.

3.1 TELESCOPE OPTICAL DESIGN

In this issue, the proposed telescope optical design is inspired from some concepts used purposely for solar telescopes.
An all-reflective open-air telescope concept has been favoured in view of the success of this configuration already implemented on other telescopes; the important point is to control in a very careful way the local thermal environment created by the collection of the sun light.

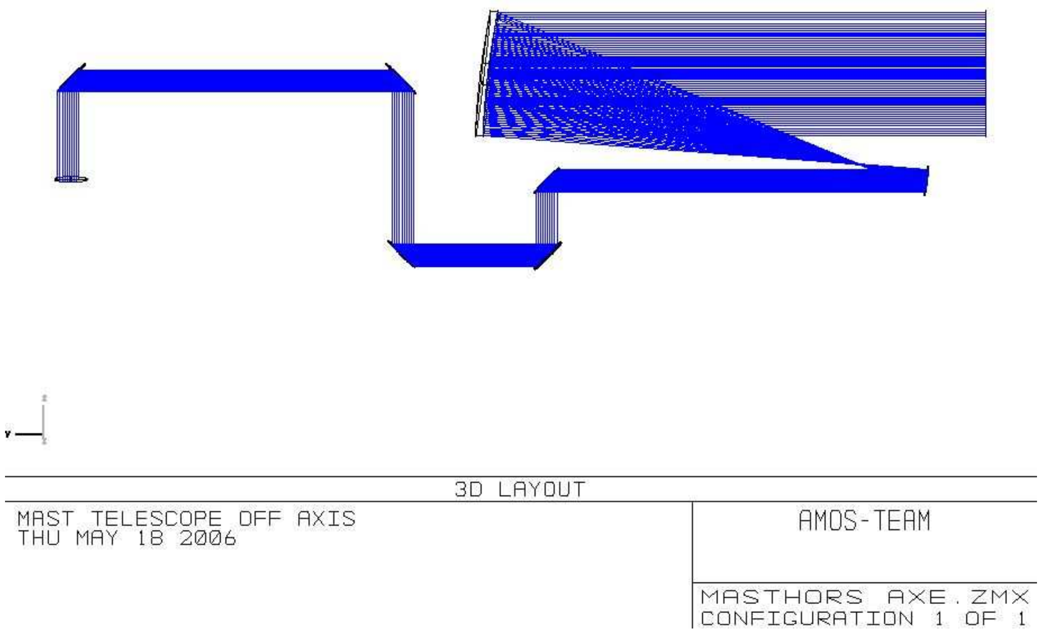
With respect to the first proposal which was based on the on-axis design suggested by the PRL, we present an alternative Gregorian off-axis design, which can show some assets related to a better straylight behaviour and an easier baffling scheme, an easier heat dissipation scheme, a better throughput and potential better polarization features despite the introduced asymmetry.
On the other hand, there are some issues linked to optical fabrication and alignment, which have to be adapted to the off-axis configuration. This is a matter already well mastered by AMOS through the design and manufacturing of off-axis components of the same size as the ones required by the PRL telescope.

The driver for the optical configuration (M1 focal length) is the design of the heat stop. We present here a preliminary optical lay-out, based on a confocal off-axis parabolas configuration that can be optimised within the FOV by acting on the shape of the secondary mirror; the heat stop is located at the primary focus. Then, a coudé train allows to fold and send the beam to the coudé platform as requested by the PRL.

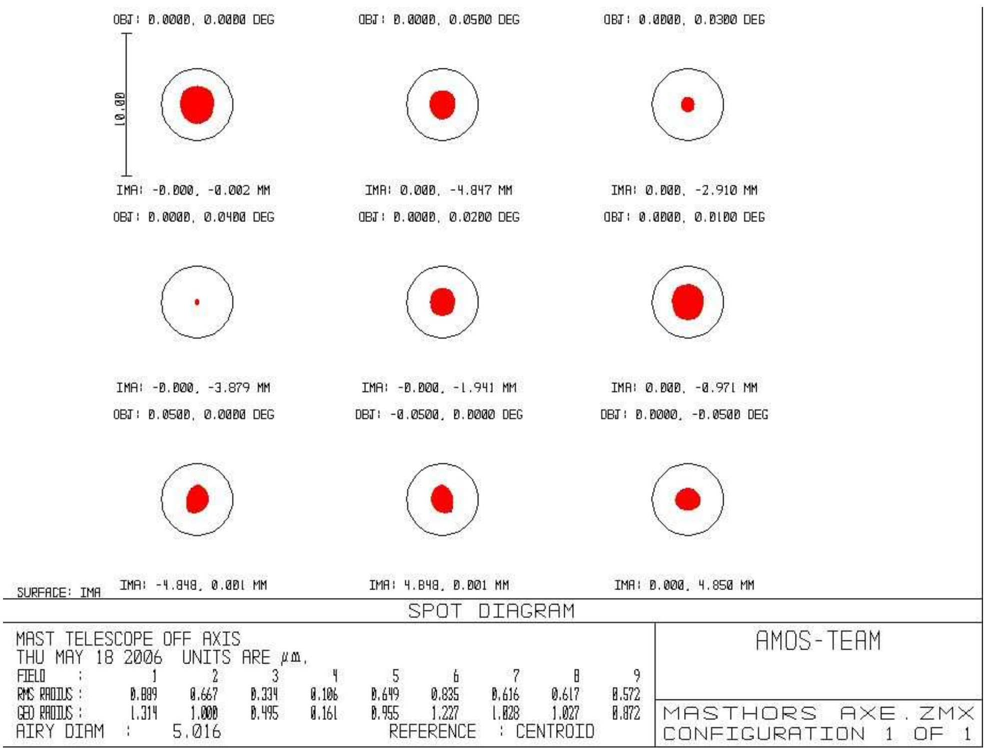
The main optical parameters of this afocal telescope are:

- Primary mirror clear aperture = 0,5 m
- FOV = 6 arcmin (diameter); limited by the heat stop
- Output wavefront error : $\lambda/12$ RMS on-axis, $\lambda/10$ RMS over FOV
- Output beam diameter > 100 mm

An optical lay-out of the configuration is given hereafter. The optical design will be optimised during the design phase.



Optical lay-out of the MAST off-axis configuration



MAST off-axis spot diagram

The mirror definition for this baseline (still to be optimised) is the following:

Mirror	Type	Radius	Conic	Diameter (clear aperture)	Off axis
Primary	Off axis concave parabola	3000	-1	500 mm	365 mm
Secondary	Off axis concave parabola	540	-1	120 mm	66 mm
Folding 1	Flat	-	0	Elliptical: 160*120 mm	92.5 mm
Folding 2	Flat	-	0	Elliptical: 170*120 mm	95 mm
Folding 3	Flat	-	0	Elliptical: 180*120 mm	95 mm
Folding 4	Flat	-	0	Elliptical: 180*120 mm	95 mm
Folding 5	Flat	-	0	Elliptical: 200*150 mm	95 mm

3.2 TELESCOPE MOUNTING

The mount of the telescope will be an alt-azimuth configuration. This mount concept is well mastered and known for its stiffness and its good gravity handling. It will have a better mechanical behaviour than the equatorial mount.

On the other hand, the alt-azimuth mount presents a near-zenith blind spot, but this should not be a problem for this solar telescope, due to the latitude of the site.
There is also a need for image derotation at the level of instruments.

3.3 OPTICAL MANUFACTURING

For AMOS, there is no critical issue from the mirrors manufacturing point of view.
(see section 10 for AMOS relevant experience in optical manufacturing). A tolerance/sensitivity analysis will be performed during the design phase; however we do not expect any critical manufacturing parameter.

The primary mirror will be made of ULE or Zerodur material ; a low expansion material is needed to manage the heavy thermal load seen by this mirror. Thermal gradients will appear between the front and the back face and the mirror distortion has to be kept minimal to guarantee the image quality. An air flow system with a dedicated geometry will be implemented to cool the mirror front surface; this point is further discussed in section 3.6.
We propose as a baseline and in order to achieve a good thermal control and a good image quality that all other mirrors will be made of SiC material. This material has an

outstanding specific stiffness which allows to limit the mirror weight and a large thermal conductivity which eases the thermal control.

Polishing and figuring of SiC mirrors is more difficult than glass mirrors but is not critical for AMOS. The roughness specification of 2 nm RMS can not be reached directly on SiC substrate and therefore a CVD layer has to be applied. This allows to reach a microroughness of the order of 1 nm RMS (see section 10). This is an important contributor to the straylight rejection factor and is needed to reach the required low level of straylight irradiance (0.2 %). **However, CVD process is quite expensive and could be avoided if roughness specification of about 3.5 nm RMS is allowed (TBD with customer) meaning that the required straylight level is not reached anymore.**

All the mirrors will be tested and qualified interferometrically at 633 nm.
The flat steering mirrors are tested by using a classical Fizeau test against a high reference flat quality surface.

The M1 and M2 mirrors will be tested interferometrically by autocollimation with a high quality flat mirror or by using a computer-generated hologram (CGH) in a null test configuration.

The mirrors will be mounted in specific cells, able to keep the mirror surface figure.
A finite-element analysis of the M1 cell will help to minimise the mirror surface deformation. Other cells are les critical and will be selected from our in-house standard designs. At the end, all the mirrors are qualified after integration within their mechanical interfaces (cells).

To guarantee the 95% reflectivity between 400 nm and 900 nm, all the mirrors will be coated with a dedicated protected silver.

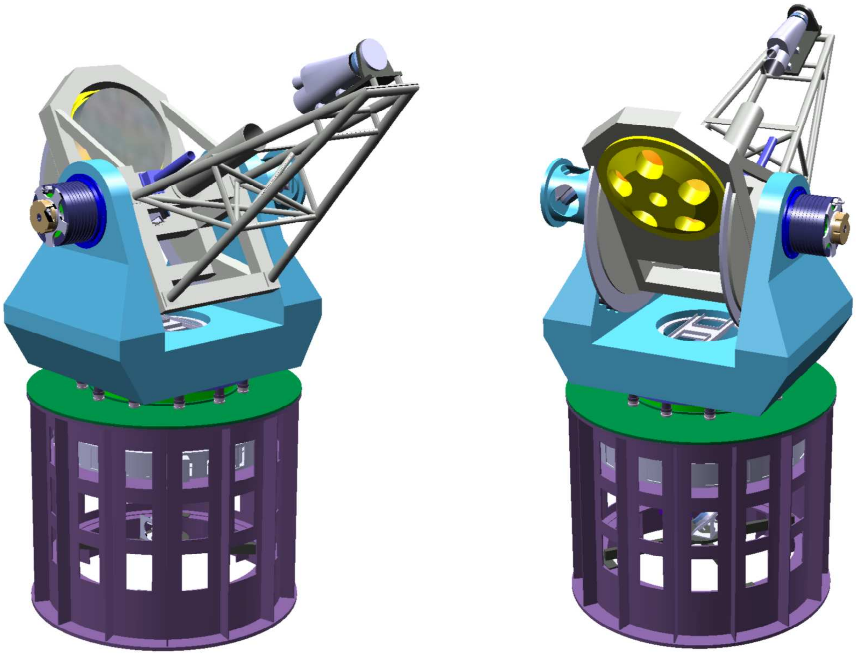
An overall WFE budget is presented hereafter for the MAST off-axis solution (root-square-summing all the contributors):

Contributors	FOV center (nm RMS WFE)	FOV edge (nm RMS WFE)
Design residuals	30	45
M1 Manufacturing	25	25
M2 manufacturing	15	15
M3 to M7 manufacturing	20	20
Alignment (with M2 mechanism)	3	8
Environment	20	20
TOTAL	**50.6**	**61.1**
specification	***52.7***	***62.4***

The total wavefront error is dominated by the design residuals inherent to the off-axis design; the total value given for the FOV edge is an average value; for some field points, this value could be higher and then we are marginally non-compliant for the WFE over the FOV.

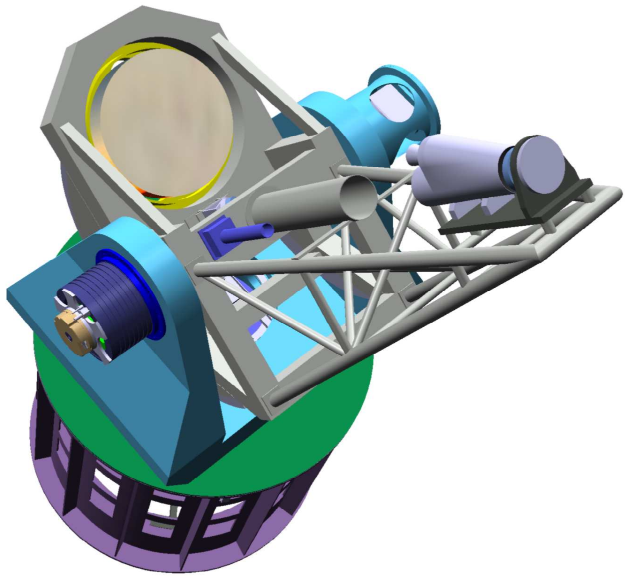
3.4 TELESCOPE ELECTRO-MECHANICAL DESIGN

The telescope mechanical structure consists of an open structure with a stiff truss tube and an Alt-Azimuth mounting. The tube design is especially adapted to an off-axis telescope and we will take care of the accurate balancing of the whole structure. A preliminary design is given in the ATT. 4.



MAST general views

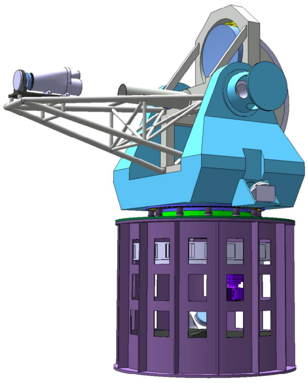
As usual, the mechanical structure and the mirror supports are optimised by using FEM models (static, dynamic and thermal) to guarantee the telescope performance during observation taking into account all the environmental conditions and especially the thermal constraint due to the sun observation. Assessment of the telescope pointing performance will be obtained from the FEM simulation results combined with optical models.



MAST view from top

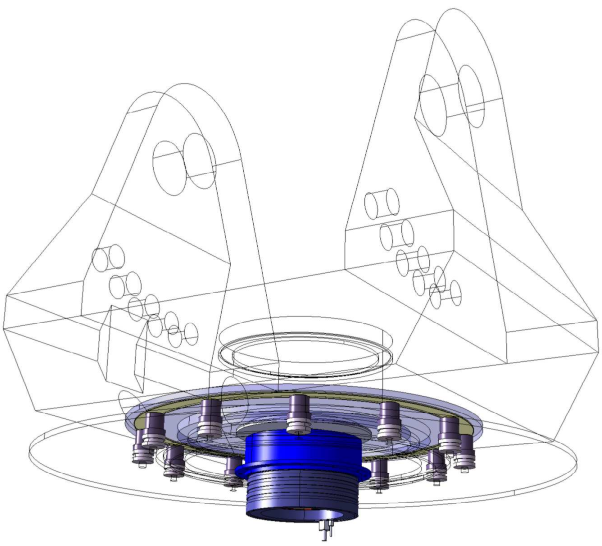
An appropriate baffling will prevent straight light to reach the instrument. A motorized protective cover for M1 will be integrated in the cell.

The Alt-Azimuth mount shows an image rotation as the telescope follows the sun.
A rotating system of three mirrors serves as an image de-rotator. The position of the de-rotator allows for rotation compensation. The de-rotator could be placed before or after the last mirror M7 within the collimated beam (TBD).

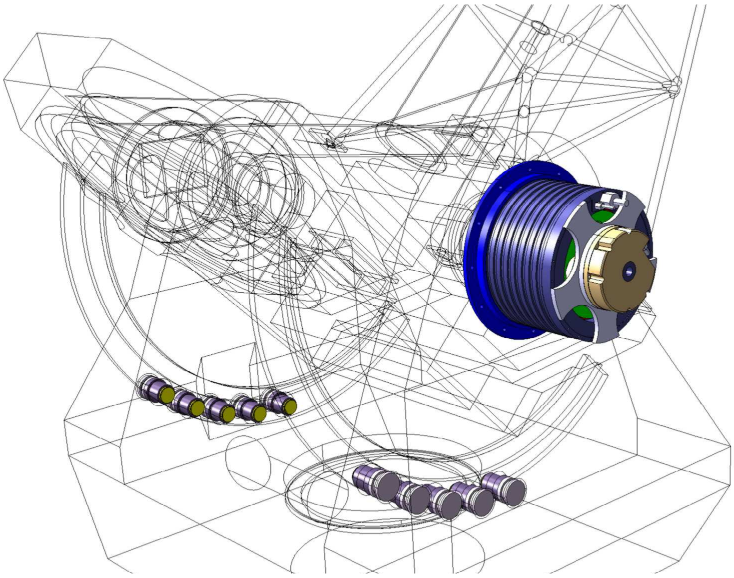


M2 Maintenance Position

Altitude and azimuth drives will of same type. The motors are direct drive type. They are mounted directly on the main axis. The encoders are mounted directly against the motor shaft. The Az motor and encoder shat is hollow to provide a clear aperture for the optical beam.



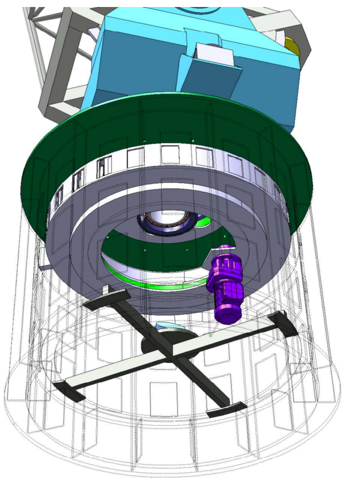
Azimuth drive and Brakes



Altitude drive and Brakes

Each motor will be equipped with a brake system. The power consumption, so heat dissipation, due to brake coil activation during movement is low (some watts). Another possible solution is to use a pneumatic actuator clamping a disc. To release the brake, pressure has to be applied to the actuator. When the pressure is removed, a spring pushes the actuator to the unclamped position and releases the brake. This solution is however more expensive than the electrical one.

A cable wrap (motorised or not) will be implemented if needed (TBC) but, up to now, it does not seem necessary.



View from bottom: Fold 5 and Motorized Cable Wrap

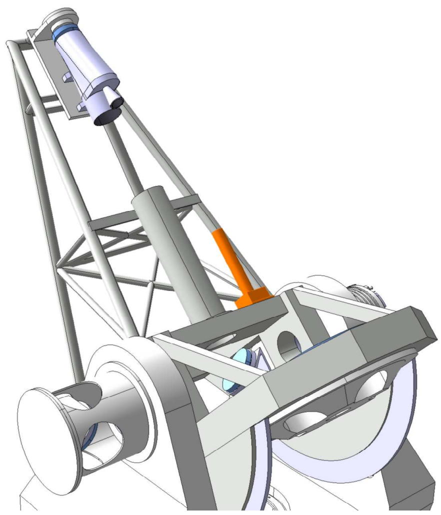
The M2 unit will be equipped with provisions for alignment (decentering X and Y, tip-tilt and focus) wrt the M1 mirror optical axis. The M2 mechanism will be motorised to also maintain the telescope optical performance under operational conditions (e.g. tube gravity deflection, thermal expansion of the mechanical structure, induced vibrations by main telescope driving system, etc).The specifications of this mechanism (e.g. hexapod) and associated sensors will be defined during the design phase. We have foreseen a tip-tilt mechanism with a range > ± 1 mrad (or ± 3,5 arcmin) and a frequency of about 1 Hz. Focus amplitude > 1 mm. Decentering ranges of few millimetres.

A wave front sensor will be installed (location TBD) to provide the corrections to the M2 mechanism in closed loop. Some information will be available through a serial RS232 interface or Ethernet port to the control room.

3.5 THE GUIDER TELESCOPE

A small guider telescope with a limb sensor in its focal plane will be attached and co-aligned with the main telescope. This auto-guider telescope will serve to control the main axis drives and to correct the small tracking error. The guiding will be performed using the solar limb image which offers the highest contrast.

The focal length and CCD pixel size for the guider will be selected for an image scale = 1 arcsec/pixel (corresponds to a 2,4 m focal length guider telescope equipped with a CCD pixel = 12 microns). A CCD size of 4kx4K is needed to cover twice the angular solar diameter (± 32 arcmin). A guiding accuracy of about 0,1 arcsec is expected (corresponds to centroiding accuracy = 1/10 pixel).



Guider Telescope

The error signal generated by the CCD guider will be sent to the telescope drive control system for correction. A correction rate of 1 Hz is more than sufficient.
Alignment of the guider telescope with the main telescope will be calibrated by generating pointing maps for a pointing model.

3.6 TELESCOPE THERMAL CONCEPT

The main mirrors of the telescope will be heated up by solar radiation. The transfer of heat to the ambient air results in degradation of image quality (mirror seeing). Specific thermal analyses are needed to implement an optimum system to be able to reduce the image disturbances.

Thermal models will be made and used to determine the temperature field under various operating conditions and the output serves as an input to the structural FEM to determine the thermally induced displacements of the telescope structure and optics.

It is expected from calculations that wind and radiation cooling effects will equalize temperature differences of structure elements to ambient temperature (we assume that the dome is completely retractable and the floor of the dome is thermally isolated and painted in white to minimize dome seeing).

From the thermal analyses, the concept for tube athermalisation, the paint formulation, the heat stop design, the baffling scheme, the air and water flow rates for equipment cooling will also be defined.

A preliminary thermal concept will be to have an open telescope structure made from steel material. The greatest part of the surface of the telescope structure will be covered with a special low emissivity paint to minimise the radiative exchange with the sky (this paint has been applied on the ATS telescope tube). Areas exposed directly to sun radiation will be covered by sun shields.

Mirror seeing is caused by the natural convection over the optical surface whenever that surface is warmer or colder than ambient air. Mirror seeing diminishes when the mirror is ventilated (seeing vary as function of air velocity above the mirror).

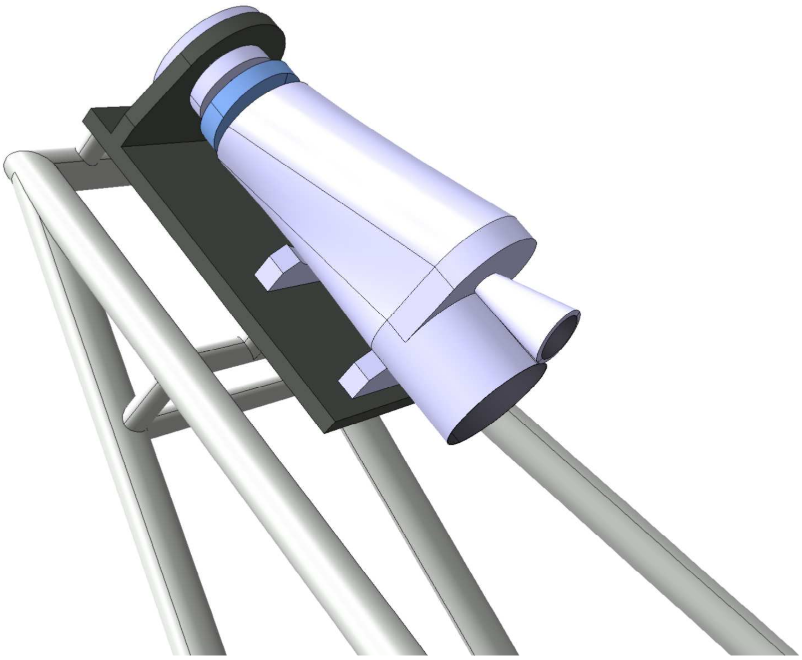
An estimated heat budget for each mirror is given hereafter, considering an incident sun irradiance of 1200 W/m2, a mirror coating absorption of 5 % and a heat stop reflectivity of 80 %:

Equipment	*Reflected flux (W)*	*Absorbed power (W)*
M1	224	12
heat stop	172 (in outside air)	43
M2	8.5	0.5
M3	8	0.42
M4	7.6	0.4
M5	7.2	0.38
M6	6.8	0.36
M7	6.5 (to instrument)	0.34

The M1 mirror will be made in ULE or Zerodur to cope with the thermal gradients thanks to the low coefficient of thermal expansion and so minimise the mirror distortion; in addition, this material has a low thermal conductivity and its control will be eased in case of a sudden variation of incident irradiance (cloudy sky).
It is foreseen to flush cooled air in a controlled way on its front surface. The best flushing scheme will be determined to minimise the seeing. To benefit from the flushing, the mirror should be as free as possible from surrounding structures. In particular, an optimal flushing speed has to be defined since this operation can increase spurious dynamic effects. It is also planned to have cooling from behind to remove the 12 W load and insure the 1°C maximum difference with ambient air.

For the other mirrors (made of SiC material), the supports will be designed to receive radiative cooling panels (equipped with system of coils) close to the back surfaces of the mirrors. The thermal load is lower and the SiC material has a very good thermal conductivity so that the cooling scheme is easier.

The heat stop (cold screen) is located at the primary focus; it will be reflective to reject the unwanted heat towards the sky (an advantage of the off-axis configuration) and it will be thermally controlled also with cooled liquid. A dedicated trade analysis will determine its optimal configuration (needed reflectivity, specific geometry to minimise seeing).



Heat Stop

AMOS has a great experience in designing and manufacturing cold screens and thermal control panels with regulation system.

To keep the mirrors at ± 0.5°C wrt the ambient temperature, we have foreseen to install two services modules: one to produce cooled air (chiller/exchanger/air dryer and thermal regulators) and the second one to produce cooled liquid (chiller/cooling liquid, i.e. glycol-water mixture/regulator/valves and pipes).
Thermal sensors are installed on the mirrors and at ambient air to close the loop by using an electronic regulator device.

The thermal control electronics will be integrated inside one of the main electronic rack of the telescope. A Siemens programmable logic controller (PLC) instead of the individual thermal regulators will be used. The PLC offers more flexibility and can be easily interfaced with other equipment.

The above solution which suggests to cool the SiC mirror is certainly a conservative one.

3.7 ELECTRICAL AND TELESCOPE CONTROL SYSTEM (TCS)

The TCS is the highest level of real-time controller. It will operate all the major telescope sub-systems, including mainly the M2 mechanism, image de-rotator and the Alt and Azimuth axes. It will also provide information as coordinated time, ephemeris calculation and prediction, coordinated motion, pointing and tracking.

The telescope control system allows to point accurately in the sky, and then track the sun over the observation period. To achieve the specifications, pointing and tracking use a "closed-loop" system (PID with friction and speed feedforward), in which deviations are detected with the guider telescope and set to the Alt and Azimuth control drivers of the telescope and then corrected.

A preliminary block diagram for the electrical and TCS is provided in ATT #2.

Three equipments compose the core of the system:

1) The PLC is mainly in charge with thermal regulation.
    a. It will control mirrors and chillers temperatures.
    b. It will also be connected to monitoring temperature sensors.
    c. As an option and to avoid condensation on mirrors due to too cold flushing air, we propose to install a dew point sensor. In this case, it would be connected to the same PLC.
2) The PMAC controller is in charge with telescope axes.
    a. It receives time
    b. It receives deviation coming from guider telescope CCD electronics
    c. It manages interlocks with outside. To do so, it checks the status of the "Disable Telescope Control" switch, interface signals with PRL and the status of the PLC.
    d. It controls Azimuth axis movement by reading axis encoder, limit switches and by sending torque command to amplifiers.
    e. It does the same for Altitude axis.
    f. It controls de-rotator axis
    g. It is linked to the M2 control Unit. This link is serial one. The M2 Control Unit controls Tip-Tilt /Focus actuators by using information coming from a wavefront sensor.

3) The local PC is connected via a serial link to the PLC and to the PMAC controller. At this level, the controller could also be a PCI card and be host inside the PC. The PC has Ethernet connection to the LAN to allow remote access. A VB program will be placed on it to produce the operator interface and manage the associated data base (including logs).

3.8 POLARIMETRY

In order to have a good measurement of solar polarisation, it is important to minimize the polarisation brought by the telescope itself.
The requirement on the Mueller matrix of M4 (here M3) is hardly reachable due to the high incidence on this mirror. We propose to discuss the specific point on polarimetry with the PRL at the beginning of the project, since with the off-axis design, a possibility exists to have the polarimetry package after M2.
It is also assumed that the polarisation effects due to the asymmetry of the off-axis design (crosstalk of Stokes parameters) can be calibrated; a similar approach should also be valid for minimising the pupil polarisation effects, due to the image rotation with respect to the pupil (time dependence of Mueller matrices).
The polarimeter package is assumed to be brought and installed by the PRL; we will only foresee its allocated volume.

3.9 TELESCOPE INTERFACES

3.9.1 Telescope mechanical interface

We assume that the telescope will be sited on the existing piers of the Udaipur Solar Observatory (USO). Data concerning piers geometry and stability will be provided at kick off meeting (KOF).
All the interfaces with the building (dome) and possible instruments have also to be provided at KOF.

3.9.2 Telescope electrical interfaces and interlocks (safety)

The electrical interface will be:

1) The main supply: UPS 200 ± 20 V, 50 ± 2 Hz.
2) The local PC has a RJ 45 port for connection to the LAN. The corresponding protocol will have to be discussed during design phase.
3) Some hardwire interface signals will be implemented between PRL and AMOS. At least one signal coming from PRL and giving the authorisation to operate the telescope (axis and thermal control) will have to be implemented. It will check that the environment outside of the present contact is in a situation compatible with the operation of the telescope.

4. TESTING IN EUROPE

An integration and verification program will be developed early, in conjunction with design, as it has strong implications on cost, risk and schedule, and often in design itself.
The overall telescope assembly will be performed at AMOS and several tests will be performed to verify all the sub-systems interfaces and the proper functioning of the overall telescope.
A verification matrix which defines the verification methods (i.e. by inspection, analysis and test) and the related test plan will be established.

5. PACKING/TRANSPORT/ON SITE INSTALLATION

After acceptance tests at AMOS, the telescope will be dismounted, and packed. In sealed plastic bags placed in fumigated wooden boxes transported in sea containers.
For the transport (out of scope of this contract, under PRL responsibility), we assume a transport by sea for the containers.
After delivery at USO, an AMOS team will perform the on-site installation, functional tests and the training.

6. COMPLIANCE MATRIX

C : Compliant
NC: Non-Compliant
PC: Partially Compliant
NA: Non-Applicable

SPEC TITLE	REQUIREMENT	COMPLIANCE	COMMENTS
SYSTEM SPECIFICATIONS			
Input beam size	50 cm Ø clear aperture	C	
Output beam size	10 to 12 cm corresponding to 6 arc-min FOV	C	

SPEC TITLE	REQUIREMENT	COMPLIANCE	COMMENTS
Output wave-front error @ 632,8 nm	λ/12 RMS on axis λ/10 RMS over FOV λ/4 ptv	C C NC	See section 3.3
Output beam Stray light irradiance	0,2% of solar flux	C	< 2.10-3 at telescope output level Mirror roughness < 1 nm RMS
Stationarity of FOV in output beam	Max movement less than 0,01 arc-sec per minute	C	Imposed by the image de-rotator
Vibration of output beam	Ø Less than 1 arc-sec RMS in 0-1 Hz bandwidth Ø Less than 0,5 arc-sec RMS in 1-10 Hz bandwidth Ø Less than 0,05 arc-sec RMS for frequency >10 Hz	PC	C for 0-1Hz bandwidth NC for other bandwidths: no active control in those bands; but if the site microvibrations are low, the telescope stiffness will be sufficient to prevent unwanted vibrations
System length	Less than 2 m	C	
System Height	Less than 2 m	C	
Total transmission	More than 50% in 400 nm – 900 nm	C	
SUBSYSTEM SPECIFICATIONS			
Size after M4 (M3 in off-axis design	≤ 5 cm	NC	
Mueller matrix of M3 with reference to plane of reflection	See section 3.2.1 b	NC	See section 3.8 for accommodation

SPEC TITLE	REQUIREMENT	COMPLIANCE	COMMENTS
Space to polarimeter package co-axial with elevation axis	15 cm length 10 cm Ø 10 arc-sec tilt 10 micron decentre	C	Place also available after M2
Mirror M1	ULE	C	or Zerodur
All other mirrors	SIC	C	With CVD layer
All mirror surface accuracy and microroughness	λ/50 RMS λ/4 ptv @ 632,8 nm < 2nm roughness	C	See section 3.3
Mirror coating reflectivity	$\geq$ 95% in 400-900 nm	C	Protected silver
Mirror coating absorptivity	<10% of incident solar flux	C	
M1 front surface	1°C from ambient	C	
M1 airflow	1 to 1,5 m/s	C	
All other mirrors	0,5°C from ambient	C	
Alt-Azimuth configuration		C	
Azimuth limits	85° - 275° from north to East	C	
Altitude limits	5° - 88,5° (3°avoidance zone at zenith)	C	
All mechanical members must be maintained within 1°c from ambient	1°C	PC	Excepted for some telescope parts
Pointing accuracy	<10 arc-sec RMS	C	

SPEC TITLE	REQUIREMENT	COMPLIANCE	COMMENTS
Differential pointing accuracy	<0,5 arc-sec RMMS	C	
Open loop tracking	<0,25 arc-sec RMS over 10min <0,05 arc-sec RMS over 1 sec	C	
Closed loop tracking	<0,1 arc-sec for 1 hour	C	
Tip-tilt secondary mechanism		C	
Telescope operation	10 – 50° 0-90% RH ≤ 30 km/hr wind speed	C	
	With UPS	C	
Telescope interface	Pier at USO island site	C	
Telescope operation	With vendor supplied TCS	C	

7. PLANNING PROPOSAL

The MAST planning is given in ATT3.
Note that critical items (long delivery, TBD) have to be ordered after the PDR (preliminary design phase).
The MAST will be completed, tested and packed at AMOS in less than 2 years.
We have assumed that the transport will be made by sea and therefore we have added into the planning a maximum of two months. Additional two months (maximum) are assumed for AMOS for on site activities (TBC).
It is important for the schedule that at the kick off meeting all the interfaces (mechanical and electrical) with the building/enclosure/piers and instruments have to be more or less defined.

8. DELIVERABLES

The deliverables by AMOS within this proposal are detailed hereafter.

8.1 HARDWARE

The following hardware is delivered:

- The complete telescope (mechanical structure, optics, electro-mechanical components, thermal system and TCS)
- Telescope interfaces (mechanical and electrical) with piers and enclosure

The following hardware is not delivered by AMOS (out of scope of this proposal):

- Instruments (polarimeter, etc.)
- Adaptive Optical system
- The enclosure
- The I/F (mechanical and electrical) for instruments and AOS (to be discussed with customer)

8.2 DOCUMENTS

The documents will be provided in printed format and in electronic PDF format (CD-ROM). You will find hereafter the list of the documents that AMOS has foreseen to provide within this proposal:

- Mechanical drawings (assembly drawings only and interface drawings)
- Electrical drawings
- I/F document (mechanical, electrical,…) for telescope installation
- Mechanical design & analysis report
- Optical design & analysis report
- Thermal design & analysis report
- Test plan and test procedures
- Acceptance Telescope test reports
- Packing list
- Operation and maintenance manuals (including maintenance schedule)
- Documents related to training

9. WARRANTY

The proposed warranty for the delivered goods is 12 months.

10. AMOS RELEVANT EXPERIENCE

10.1 AMOS RELEVANT EXPERIENCE IN ASTRONOMY

For the European Southern Observatory (ESO), AMOS has provided:

- 3 seeing monitors (portable telescope to measure the site seeing). Note that one unit with faster tracking has been provided to ONERA (France)
- the design of the 8 m VLT fork
- 12 adapter-rotators including AGU for Cassegrain and Nasmyth foci for the VLT
- the lifting and carriage unit to remove the M1 unit from the VLT 8 m telescope
- the washing unit to clean 8 m mirrors and to remove the coating
- 4 complete (turn key project) mobile telescopes of 2 m class for interferometry (Auxiliary Telescopes)

For the 1,8 m Korean Telescope (TELISSA), AMOS has provided:

- the rotating enclosure (home made)
- the adapter-rotator and acquisition and guiding units (AGU)

For the 8 m GEMINI telescope (USA), AMOS has provided:

- the Cassegrain cable wrap (structure of 8 m diameter with 1 ton of cable)
- the mechanical structure (ISS) to interface the instruments

For the 1 m ZIMLAT telescope (Switzerland), AMOS has provided:

- the telescope optical unit (M1/M2 and M3 units)
- the beam splitter unit

For 10 m GTC telescope (Spain), AMOS has provided:

- the M3 tower
- the M3 mirror unit
- the AGU

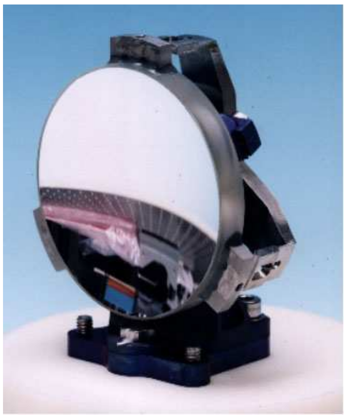
For VISTA 4 m telescope (UK), AMOS has provided:

- the preliminary design of the telescope with M1 cell;
- the telescope specifications and Statement of Work (SOW).

10.2 AMOS RELEVANT EXPERIENCE IN OPTICAL MANUFACTURING

10.2.1 NOZOMI Grating and its Holder

This very accurate opto-mechanical system was realized for ATAGO BUSSAN Co. LTD (final customers were Toshiba and the University of Tohoku). It is composed of a grating and its holder, which are parts of a spectrometer dedicated to the observation and analysis of Mars's atmosphere at a wavelength of 121,6 nm (Lyman α line). This is one of the eight instruments mounted on the "Nozomi Platform" launched in August 1998.



NOZOMI Grating

10.2.2 GERB Telescope

AMOS realized the design and AIV of the GERB experiment Telescope that flies on board MSG satellite beginning of next year.

1 kg 640 of Aluminium
180 X 135 X 150 mm
entrance aperture stop : size 20.6 mm x 20.6 mm (f-number : f/2)
mirror M1 (off-axis concave ellipsoidal) : 57 mm x 30 mm
mirror M2 (convex spherical) : 30 mm x 11 mm
mirror M3 (concave spherical) : 106 mm x 74 mm`
field-of-view : 18° x 0.28°

GERB Telescope

10.2.3 IMAGE NASA Mission

For IMAGE NASA Mission, AMOS has been involved in the manufacturing of the monochromator of the FUV instrument. The mirror collimator was a rectangular lightweighted conical mirror.

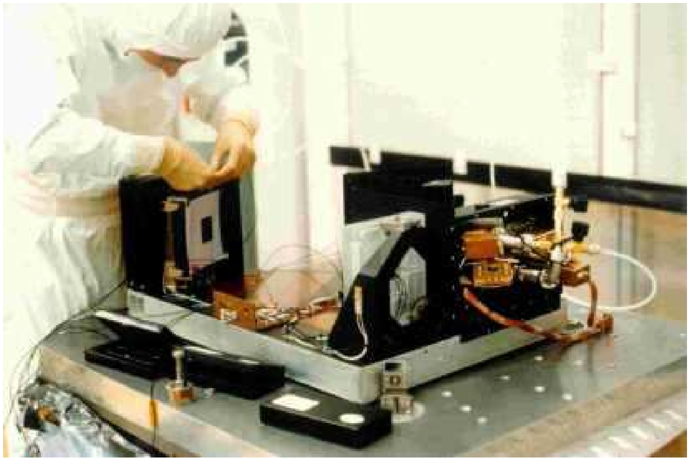
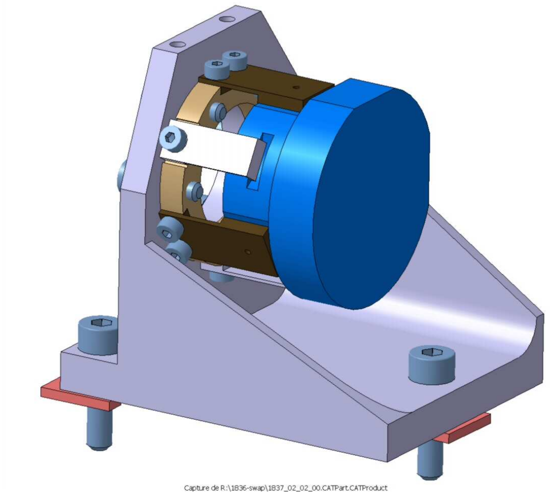


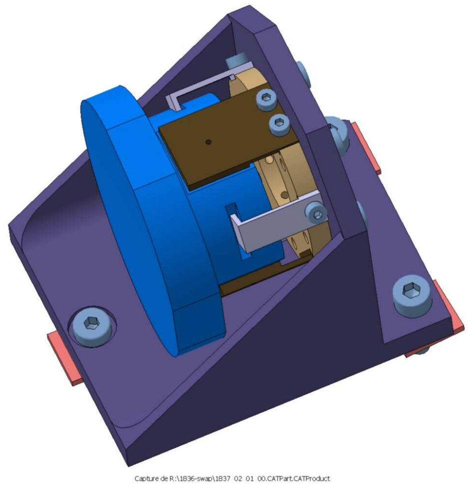
IMAGE Spectro Imager

10.2.4 SWAP Optics

The SWAP instrument is a sun observation optical payload in the extreme UV that will be embarked on-board PROBA-II satellite.

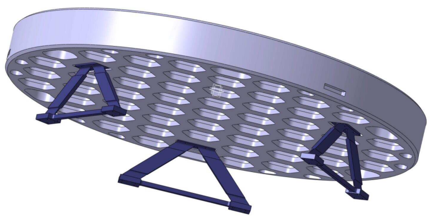
As a subcontractor of CSL, AMOS is responsible for the design, manufacturing and testing of the SWAP instrument base structure, including a door mechanism, and the fabrication and environment testing of the optics (supersmooth finish; Rq better than 5Å rms)

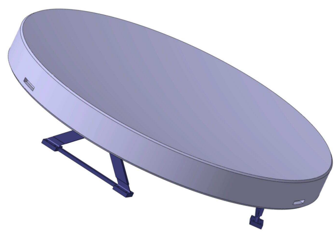


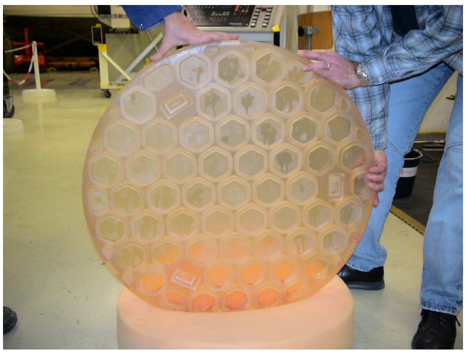


10.2.5 EUCLID

AMOS has manufactured a high optical quality (about 13 nm RMS WFE) 800 mm lightweighted mirror demonstrator for a military space application.







10.2.6 TMA

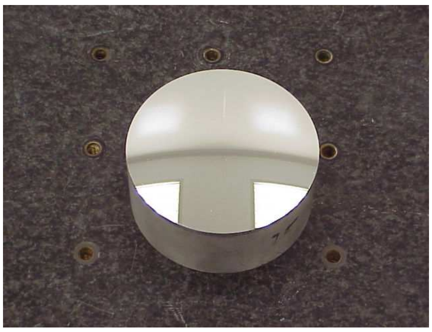
AMOS is currently developing for ESA Earth Observation directorate the concept of a four-mirror telescope with a wide field-of-view (26° * 4°) and an overall wavefront quality better than 100 nm rms over this field.

This development will lead to the fabrication and testing of a prototype totally representative of a flight model. It will include a SiC mirror. The characteristics of M1 and M2 mirrors from this telescope are depicted in the table hereafter.

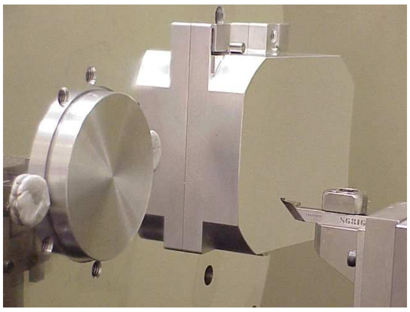
Mirror	Min. parent diameter (mm)	Parent f-number	Type	Aspherical departure* (µm)	Max. aspherical slope vs sphere (mrad)	Max. slope variation (mrad/mm)
M1	900 convex	1.67	off-axis	732	13	0.15
M2	680 concave	0.91	off-axis	378	9	0.15

10.2.7 MIRIM optics

As part of the MIRI instrument to be located in the focal plane of the James Webb space telescope, AMOS is responsible for manufacturing the MIRI imager mirrors for CSL and the CEA. The MIRI imager comprises 5 mirrors and among them , 3 are associated in a TMA configuration.
Those mirrors for the mid-infrared range will be manufactured in aluminium alloy using a single-point diamond turning technique on the new MOORE machine AMOS acquired last year.



mirror dia 75 radius 250: form: 11 nm RMS, Ra: < 2 nm



Demonstration Model (DM) - M1 mirror

10.2.8 Aluminium mirror

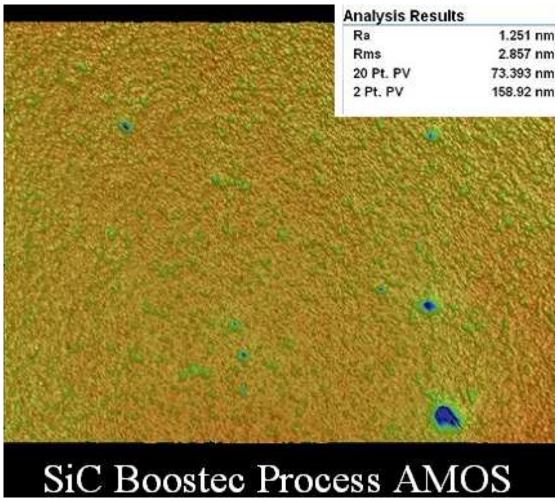
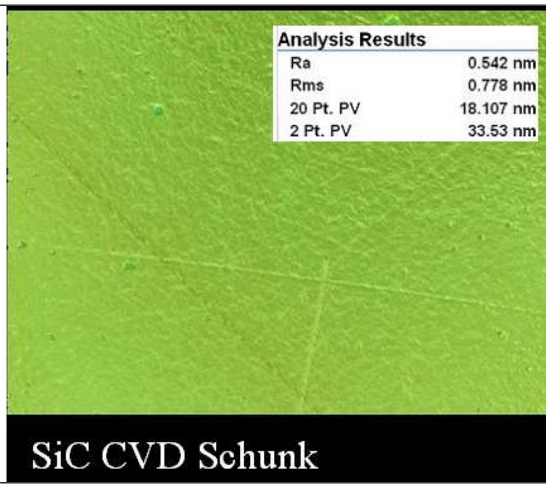
As part of the PLANCK Primary Reflector test bench, AMOS supplied to CSL a convex spherical mirror made of 5083 aluminium alloy.
(diameter 1520 mm; surface form error better than 1 µm rms)

10.2.9 SiC experience

Silicon carbide is a hard material with the best combination of mechanical and thermal properties and hence is a dedicated mirror substrate candidate.

Since more than two yeras, AMOS has developed an in-house know-how in silicon carbide polishing and figuring.

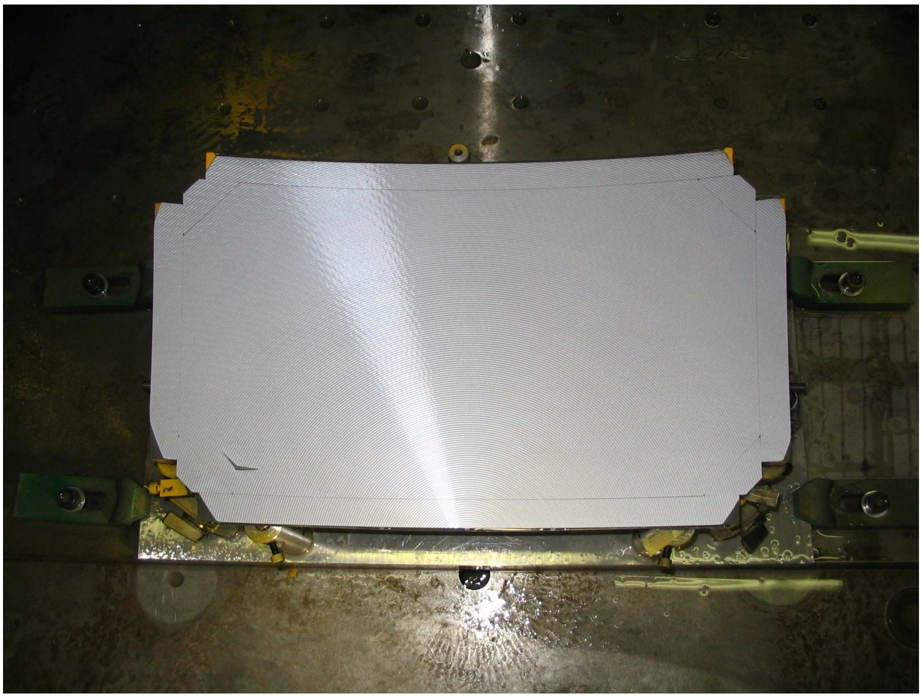
A test plan was established to evaluate the technologies on different silicon carbide samples by using a large set of polishing slurries and pads. The work resulted in the qualification of a process, which allows us to reach a roughness less than 7 Å RMS on compact substrates. In fact the roughness obtained is clearly related to the raw material and its porosities. The table hereafter provides the results after finishing for SiC-100 and CVD SiC silicon carbide technologies.

Material	Roughness
SiC 100 Supplier : Boostec Process : sintered	
SiC CVD. Supplier : Schunk Process : Chemical Vapor Deposit	

After the qualification of this process, AMOS has made some further developments in the field of optical surfaces manufacturing. Different polishing tools were created to be able to make SiC aspherical optics. Then classical polishing technology, Computer Controlled Polishing (CCP) and Ion Beam Figuring (IBF) technologies were used.
Since the beginning of the development stage, AMOS worked on several SiC mirrors for different customers.
First, an on-axis 360 mm lightweighted mirror (less than 35kg/m2) was polished and figured to the requirement of the customer (40 nm rms SFE).
The management of the CVD-layer thickness and of the quilting effect were the major difficulties encountered on this fabrication.

Then, the manufacturing of extremely accurate off-axis mirrors was started.
A CVD-SiC off-axis parabola of 135 mm diameter is currently under finishing (requirement of 12 nm rms WFE).
Another off-axis mirror (generalised aspherical shape) of 400 mm by 250 mm has been started for the European Space Agency (requirement 15 nm rms WFE).

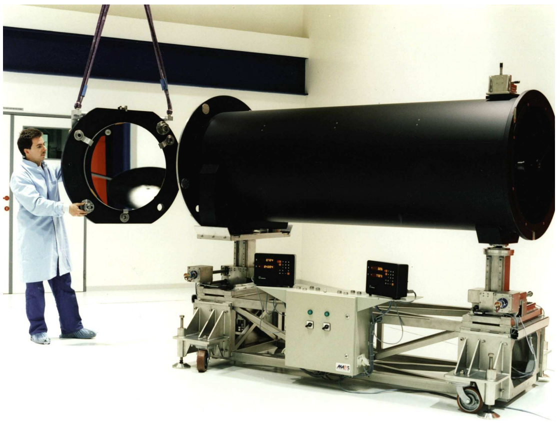
A picture of the mirror blank is given hereafter:



10.2.10 OGSE collimators

AMOS has realised several collimators as Optical Ground Support Equipment (OGSE) to qualify optical payload on ground:

10.2.10.1 ISO (700 mm primary mirror)



The ISO (**I**nfrared **S**pace **O**bservatory) collimator is based on a Newton system with a parabolic primary mirror of 700 mm diameter and f/4 aperture and a plane secondary which tilts the beam by 90 degrees. The wavefront error at 550 nm is smaller than λ/25 RMS. The light sources are situated on the side of the tube and positioned by 3 crossed linear translation stages.

The tube of the collimator is supported by linear translation stages which allow to tilt the collimator axis within a cone of 2 arcsec.

This device has been developed to qualify the optics of small size telescopes in the workshop.

10.2.10.2 SILEX (350 mm primary mirror)

AMOS was responsible for the study and the manufacturing of the SILEX (**S**emiconductor **I**ntersatellite **L**ink **EX**periment) telescope.

The main structure of the telescope consists of a cylinder made of stainless steel material. The support of the primary and secondary mirrors have been designed in order to obtain an athermal system. The alignment of the secondary mirror with the optical axis of the primary mirror is performed with the available motions on the spider and on the secondary mirror itself.
The inner wall of the cylinder as well as the mirror supports and baffles are black painted (vacuum compatible) to reduce the surfaces scattering.

The telescope has an optical quality better than λ/40 RMS WFE at 633 nm.

Weight:

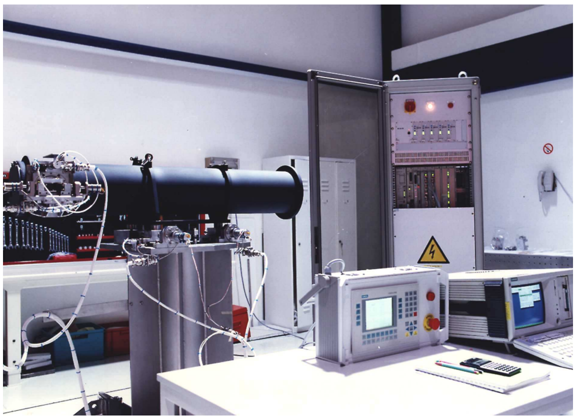
- Ø total value max. 150kg
- Ø primary mirror less than 9kg
- Ø secondary mirror weight negligible (Ø less than 40mm)
- Ø mechanical housing less than 70kg

10.2.10.3 UV XMM horizontal and verical collimators (400 mm and 800 mm primary mirrors)

Micro-roughness of the mirrors :	< 10 Å RMS
Optical quality of the primary mirror :	< 42 nm RMS Wave Front Error
Optical quality of the secondary mirror :	< 33 nm RMS Wave Front Error
Image quality :	< 63 nm RMS Wave Front Error

EUV Collimator (800 mm ∅)

10.2.10.4 MERIS (200 mm primary mirror)



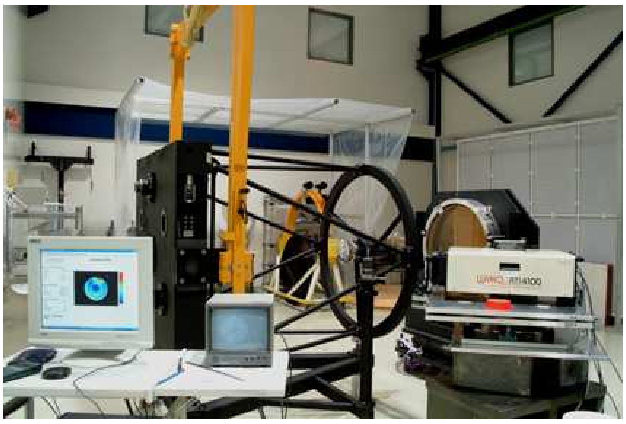
MERIS Collimator

The function of the collimator is to display in front of MERIS (**ME**dium **R**esolution **I**maging **S**pectrograph) a polychromatic reference line for the purpose of spectral registration and MTF measurement tests.

The instrument is used under vacuum (10^{-6} mbar) and it is designed around a Newton on-axis optical configuration with a primary mirror diameter equal to 250 mm.

10.2.10.5 ISRO (1 m primary mirror)

AMOS has designed, manufactured, assembled, and aligned an integrated collimator to be provided to ISRO/SAC in India. The collimator is a F/15 folded Cassegrain combination with a 1m diameter fast parabolic primary mirror, and a fast hyperbolic secondary mirror. Each mirror is specified to present lambda/60 rms surface accuracy, and the MTF specification for the integrated collimator is highly demanding in terms of alignment as well. Moreover, the mechanical structure and mirrors cells are designed to withstand gravity effects and a thermal variation of 10°C without loss of optical performance.

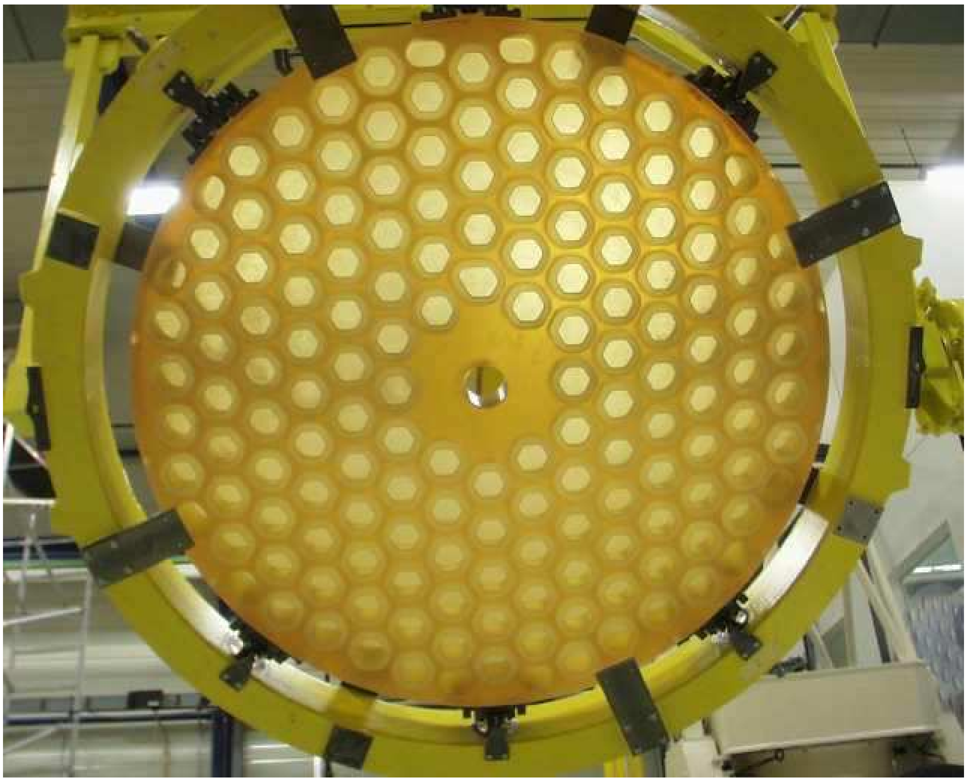


10.2.11 ATS OPTICS

AMOS has been awarded for the complete design and manufacture of the ATS (Auxiliary Telescope System) to be erected for ESO at Paranal Site in the framework of the VLTi. This includes the telescope optics, i.e. 11 mirors: Ritchey-Chrétien combination + Coudé train + Relay optics.

10.2.11.1 Primary mirror

The primary mirror is made of standard ZERODUR material. It is a lightweighted (60%) hyperbolic primary mirror of 1.87 m diameter, passively mounted (54 axial and 16 lateral supports). Intrinsic mirror optical quality is better than 15 nm RMS WFE.

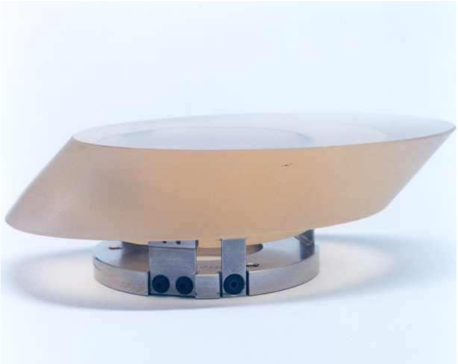


ATS – Primary Mirror lightweighted

10.2.11.2 *Secondary mirror*

ATS – Secondary Mirror (final optical quality = 15 nm RMS WFE)

10.2.11.3 *Tertiary mirror*



ATS – Tertiary Mirror (final optical quality = 15 nm RMS WFE)

10.2.12 Portable Seeing Monitor

Seeing Monitor

The Seeing Monitor developed by AMOS is a telescope system which measures the image motion and scintillation on an existing observatory site or on a candidate site for a future observatory. Such an objective imposes constraints on the optical quality of the telescope, which has to be diffraction limited, and on the accuracy of the tracking which must be better than 0.1 arcsec. In spite of this constraints and in order to avoid the defects of the telescope tracking, two pupils are defined on the primary mirror. The information on the wave front is obtained by comparing at the Cassegrain focus the relative motions of images produced by the two distinct sub-apertures. The two images are separated by a prism and are detected by an intensified CCD camera. The telescope is a lightweight 350 mm clear aperture Cassegrain on an alt-alt mount. Two pupils of 150 mm diameter are defined on the primary mirror.
The alt-alt telescope mount helps observations around the zenith. The mount is controlled by a lap computer which allows easy use of the telescope at any latitude. The seeing monitor is dismountable in parts lighter than 40 kg and able to resist transportation on rough roads.

Technical data:

field of view : +/- 10 arcmin
stable focusing between : 0° and 30°C
lightweighted primary mirror : 350 mm useful diameter
F ratio primary: 2
central hole : 55 mm
secondary mirror : 51 mm useful diameter
Cassegrain : F ratio : 15
black focus : 100 mm
total mass : 150 kg

CUSTOMER : ESO (European Southern Observatory) - GERMANY, - CHILE

10.2.13 Optical Components for the ZIMLAT Telescope

ZIMLAT Primary Mirror

AMOS was responsible of the study and the manufacturing of the opto-mechnanical components for the ZIMLAT telescope (M1/M2 and M3).

We have supplied the primary, the secondary and the third mirror as well as different plates. Each optical components includes the mirror and the cell.

Optical specifications of the telescope:

- optical configuration type Ritchey - Chretien
- pupil diameter: 1 m
- focal length: 10.5 m
- distance M1-M2: 1336.8 mm

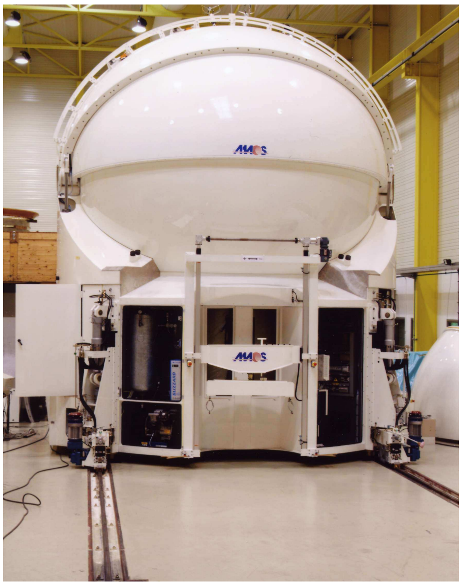
Primary mirror:

- total diameter : 1015 mm
- useful diameter : 1000 mm
- material: ZERODUR
- final optical surface quality in cell : λ / 20 RMS WFE (λ = 0.633 µm).

CUSTOMER : AEROSPATIALE France

10.2.14 ESO auxiliary telescopes

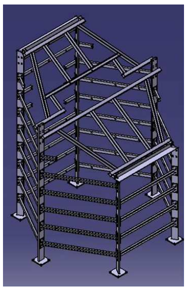
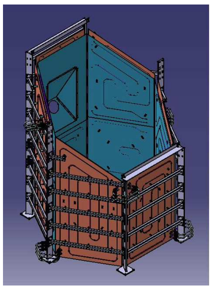
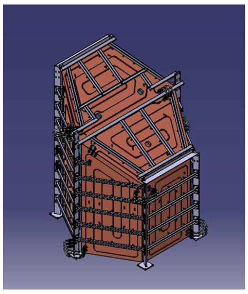
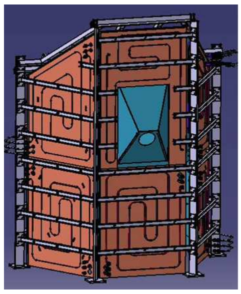
AMOS has been in charge to design, manufacture, assembly and tests four 2 m class movable telescopes to be installed at ESO Paranal site in Chili for interferometric application.
Figures hereafter show the telescopes AIV at AMOS assembly hall, the transporter during tests on rails, two telescopes on site with the UTs and one telescope with the enclosure opens.

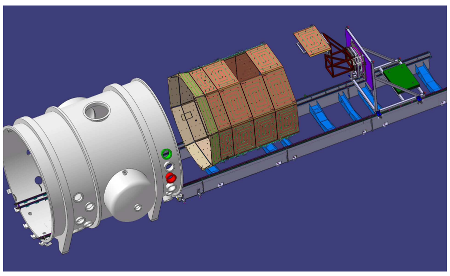
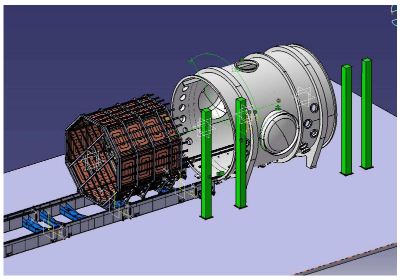


10.2.15 Thermal shrouds and cold scren

AMOS has a great experience in designing and manufacturing thermal regulated shrouds for space applications. These shrouds are used to simulate on ground the thermal environment of the satellite and then to measure the opto-thermal performance of the satellite when submitted to this thermal environment.
Usually these cryogenic shrouds are thermally regulated and work at nitrogen or helium liquid temperature.

A picture of a copper thermal tents manufactured by AMOS for the PLANCK satellite testing is provided herebelow.

11. FACILITIES

11.1 HARDWARE TOOLS

Computers:

- 8 stations DIGITAL PWS 433 MHz
- 25 MAC
- 40 PC's

Peripherals:

- 6 printers
- 1 HP colour plotter 1050 C

11.2 SOFTWARE TOOLS

CAD-CAM:

- 3D volumic & surfacic
- CATIA V5 R14, EUCLID 3 Version 2.2 Rev. B
- FEM meshing

Finite Elements

- SAMCEF version 10.1-4
- ASEF : linear static analysis
- DYNAM : linear dynamic analysis
- STABI : linear buckling analysis
- REPDYN : linear dynamic response analysis
- SAMNL : non linear astatic analysis
- THERNL : non linear thermic analysis
- BACON : Pre and Post-Processing
- POSTFAC : Post - Processing
- MECANO : kinematic analysis
- OPTI : optimisation

Optical Design:

- SYNOPSIS TM V8.1
- MAC SIGMA 2,71
- SODA 4,71
- Some specific home made opto-mechanical programs

Programming:

BASIC, PASCAL, FORTRAN, C++

11.3 CONTROL SUPPORT

At all steps of the manufacture, parts are tested in order to warrant quality and compliance with specifications. Our factory inspector's use :

11.3.1 Welding

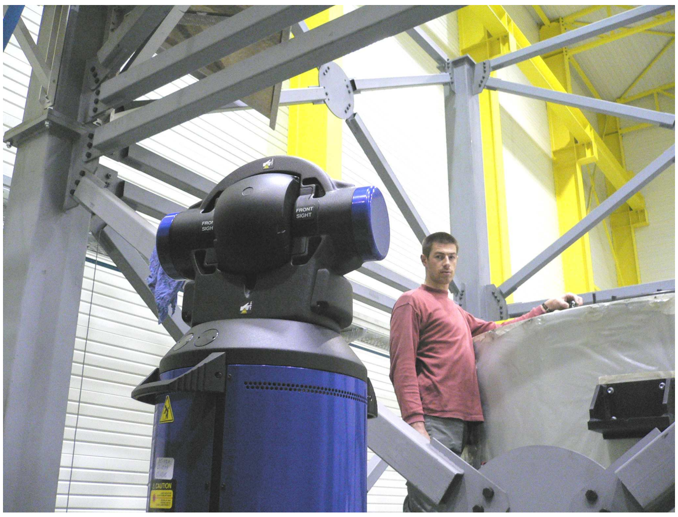
- Gauge testing bench
- Instruments for non destructive testing : X-Rays, ultrasonic (Krautkrammer), electromagnetic, fluorescent dye penetrant.

11.3.2 Metrology

- Profile Projector NIKON R14
- Electronic level TESA
- Level WILD N3
- Theodolite WILD T2
- Telescope TAYLOR-HOBSON
- Roughnessmeter DIALITE MT 10
- Optimeter KARL ZEISS
- INVAR rulers

11.3.3 Laser Tracker FARO

The laser tracker is a versatile measurement instrument making possible 3D dimensional control and alignment from 0 to 35 m with an accuracy up to 0.03 mm. The associated software allow to fit the measurements with any kind of geometrical entity and even directly with the CAD model. The geometrical tolerances and other dimensions can be calculated instantaneously and the test report issued directly.



Alignment of the Auxiliary Telescope azimuth bearing

In the following section, you will find some examples of such projects realised under very sharp schedule and perfectly working today all over the world with the requested behaviours.

11.3.4 3D measuring machine (Co-ordinate Measuring Machine) – WENZEL

type : LH64
Measuring Range : 650x1200x500 mm
accuracy : U1=2.5+(L/300) µm
U2=3.5+(L/200) µm
CNC operation.
Software : Metrosoft

The CMM can be used for dimensional AND figuring error control of mechanical parts.
Test reports can be edited using ISO1101 protocol.
Thanks to CNC operation allowing iterative measurements, CMM can be used for mechanical alignment purpose. This machine will be used during all the AIV operations of the three models of the Grating Drive Mechanism.

3D Co-ordinate Measuring Machine

11.3.5 Optical

- Laser interferometer ZYGO MARK II
  " " MOLLER V 100
  " " SMART
  " " SHACK
  " " ZEISS Direct 100
- IR laser CO_2 interferometer (10.6 microns)

- Mechanical spherometer - precision 1 µ
- Electronical spherometer - precision 0,2 µ
- Radius measurement test bench - precision 10 µ on 3 m length
- Granite optical test bench 6000 x 1500
- ZEISS theodolite with autocollimator
- RANK TAYLOR HOBSON autocollimator
- ZEISS differential interference contrast microscope (for roughness measurement)
- Access to WYKO RST Plus profiler interferometer also for roughness measurement

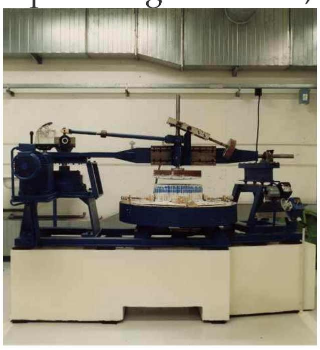
AMOS has an optical workshop for mirror fabrication up to 3 m diameter and the necessary metrology equipment for optics qualification.

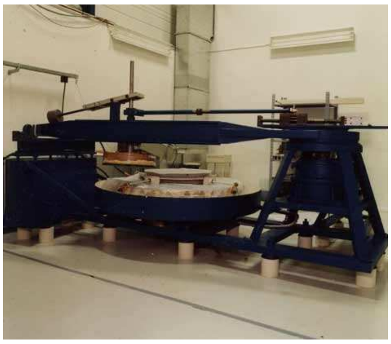
This workshop includes mainly:

Ø a lightweighting machine;

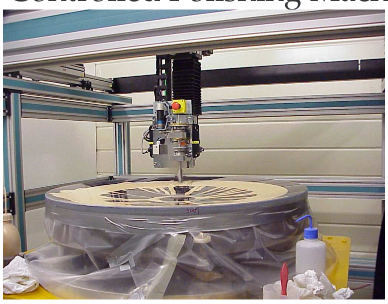
3-axis CNC Milling Machine

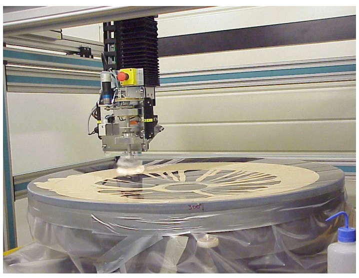
Ø grinding and polishing machines;





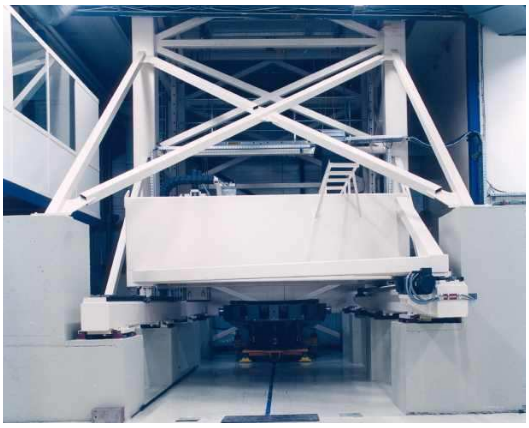
Ø Computer Controlled Polishing Machines;





- an interferometry test tower (12 m height) with a movable platform equipped with a ZEISS interferometer DIRECT 100 and an holography test bench

This facility is set up on a sismic block of 200 tons



AMOS Large Optical polishing facility with CCP process and interferometry test bench

11.4 WELDING SHOP EQUIPMENT

Welding equipment
- Micro-plasma
- TIG pulsed
- MIG - MAG 600 A
- Submerged arc welding complete with column and boom
- Welder certificates approved following ASME IX or NAF 88110

11.5 CLEANING EQUIPMENT

- Ultrasonic tank: 28 l Elma D7700 Single HTW Type T890/H
- Clean room class 10000
- Class 100 tents for cleaning and integration.

11.6 MECHANICAL MANUFACTURING

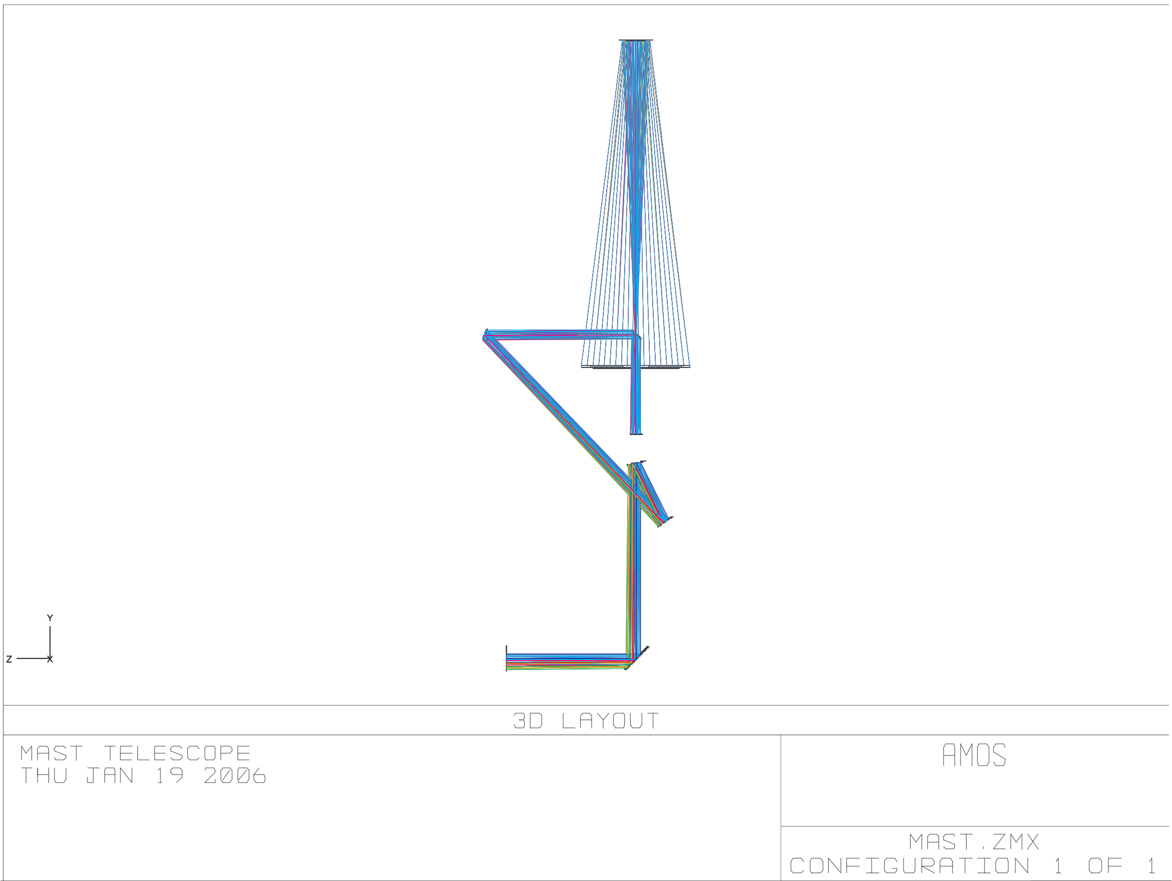
We have a number of vertical lathes, boring and drilling machines, machining centres, plane rectifying machines,

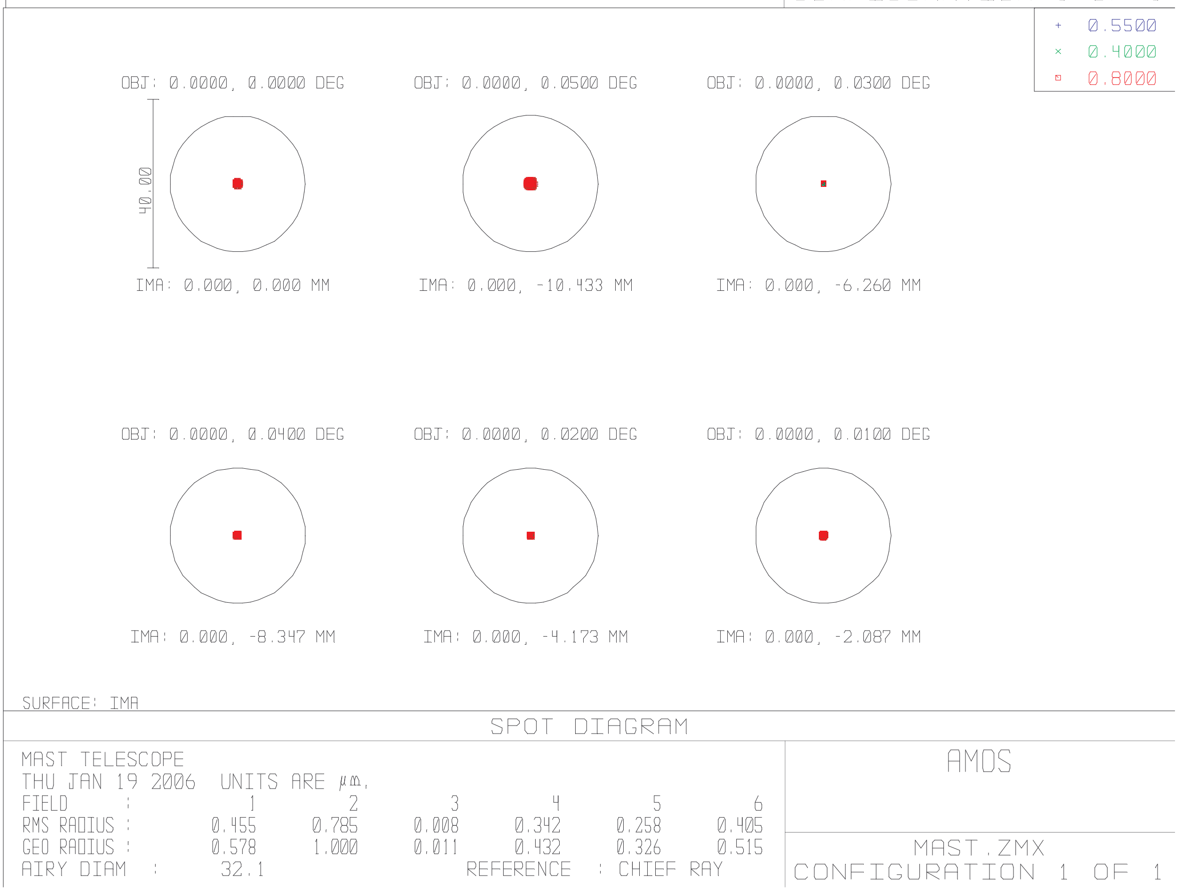
ATT1 : TELESCOPE OPTICAL DESIGN

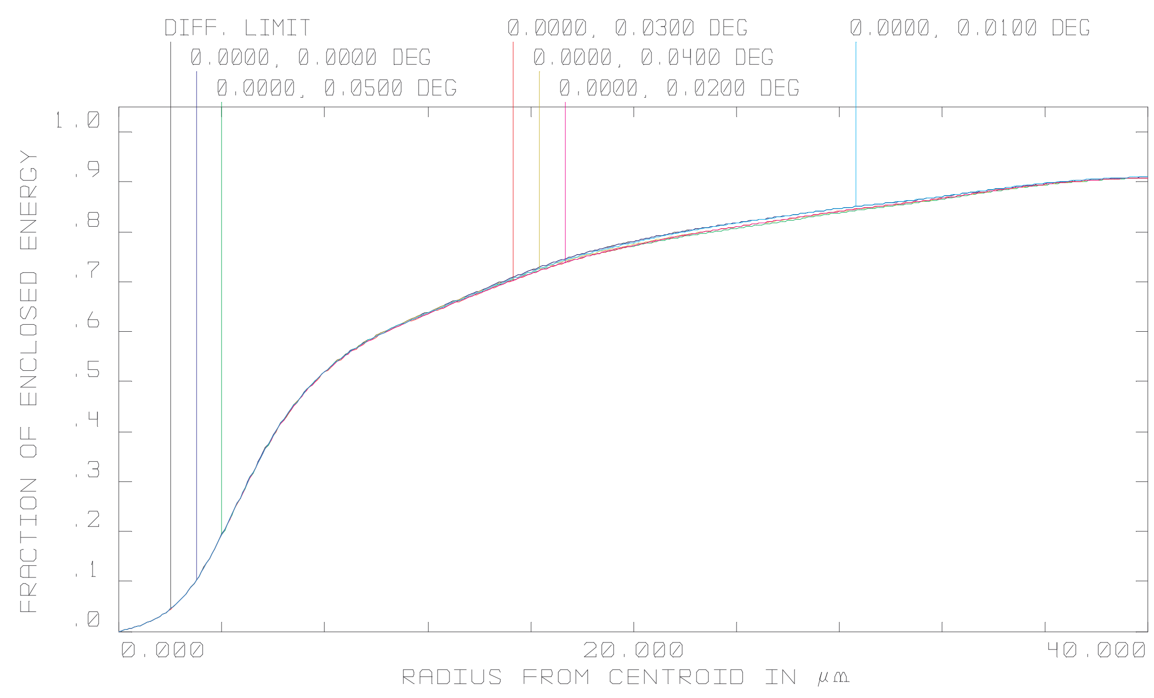
The telescope optical design has been settled on the basis of the specification data. The table herebelow details the nominal mirror configuration data.

Mirror	Diameter (mm)	Radius of curvature at vertex (mm)	Conic constant	Distance to next optics (mm)	Material	Surface irregularity (nm rms)
M1	500 concave	4000	-1	1506.66	ULE	15
M2	152 convex	1550.5	-4.591864	1816.68	SiC	12.5
M3	53.8 concave	920	-1	460	SiC	10
M4	63.2 flat	•	-	700 (Nasmyth mirror)	SiC	10
M5	59 flat	•	-	1200 (beam steering at 23°)	SiC	10
M6	81 flat	•	-	300 (beam steering at 9°)	SiC	10
M7	87 flat	•	-	900 (beam steering at 13°)	SiC	10
M8	150 flat	•	-	600 (beam steering at 45°)	SiC	10

The MAST optical design has been introduced in ZEMAX and subjected to a preliminary analysis. The focus spot diagram and encircled energy are provided herebelow for several field points and wavelengths.


3D LAYOUT
MAST TELESCOPE
THU JAN 19 2006
AMOS
MAST.ZMX
CONFIGURATION 1 OF 1


0.5500
0.4000
0.8000
OBJ: 0.0000, 0.0000 DEG
OBJ: 0.0000, 0.0500 DEG
OBJ: 0.0000, 0.0300 DEG
40.00
IMA: 0.000, 0.000 MM
IMA: 0.000, -10.433 MM
IMA: 0.000, -6.260 MM
OBJ: 0.0000, 0.0400 DEG
OBJ: 0.0000, 0.0200 DEG
OBJ: 0.0000, 0.0100 DEG
IMA: 0.000, -8.347 MM
IMA: 0.000, -4.173 MM
IMA: 0.000, -2.087 MM
SURFACE: IMA
SPOT DIAGRAM
MAST TELESCOPE
THU JAN 19 2006 UNITS ARE µm.
FIELD : 1 2 3 4 5 6
RMS RADIUS : 0.455 0.785 0.008 0.342 0.258 0.405
GEO RADIUS : 0.578 1.000 0.011 0.432 0.326 0.515
AIRY DIAM : 32.1 REFERENCE : CHIEF RAY
AMOS
MAST.ZMX
CONFIGURATION 1 OF 1



FFT DIFFRACTION ENCIRCLED ENERGY

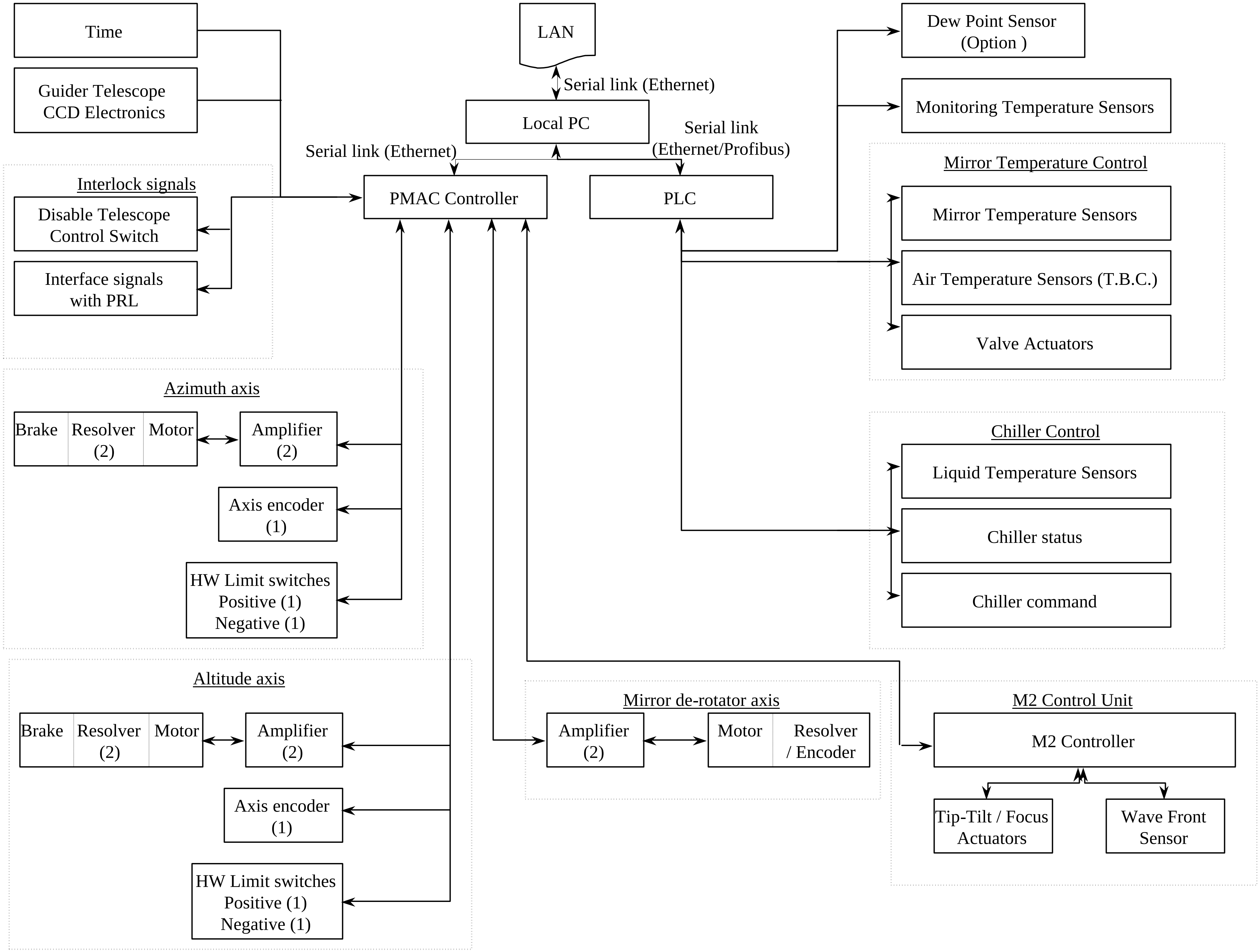
MAST TELESCOPE
THU JAN 19 2006
WAVELENGTH: POLYCHROMATIC
SURFACE: IMAGE

AMOS

MAST.ZMX
CONFIGURATION 1 OF 1

ATT2 : ELECTRICAL AND TCS BLOCK DIAGRAM

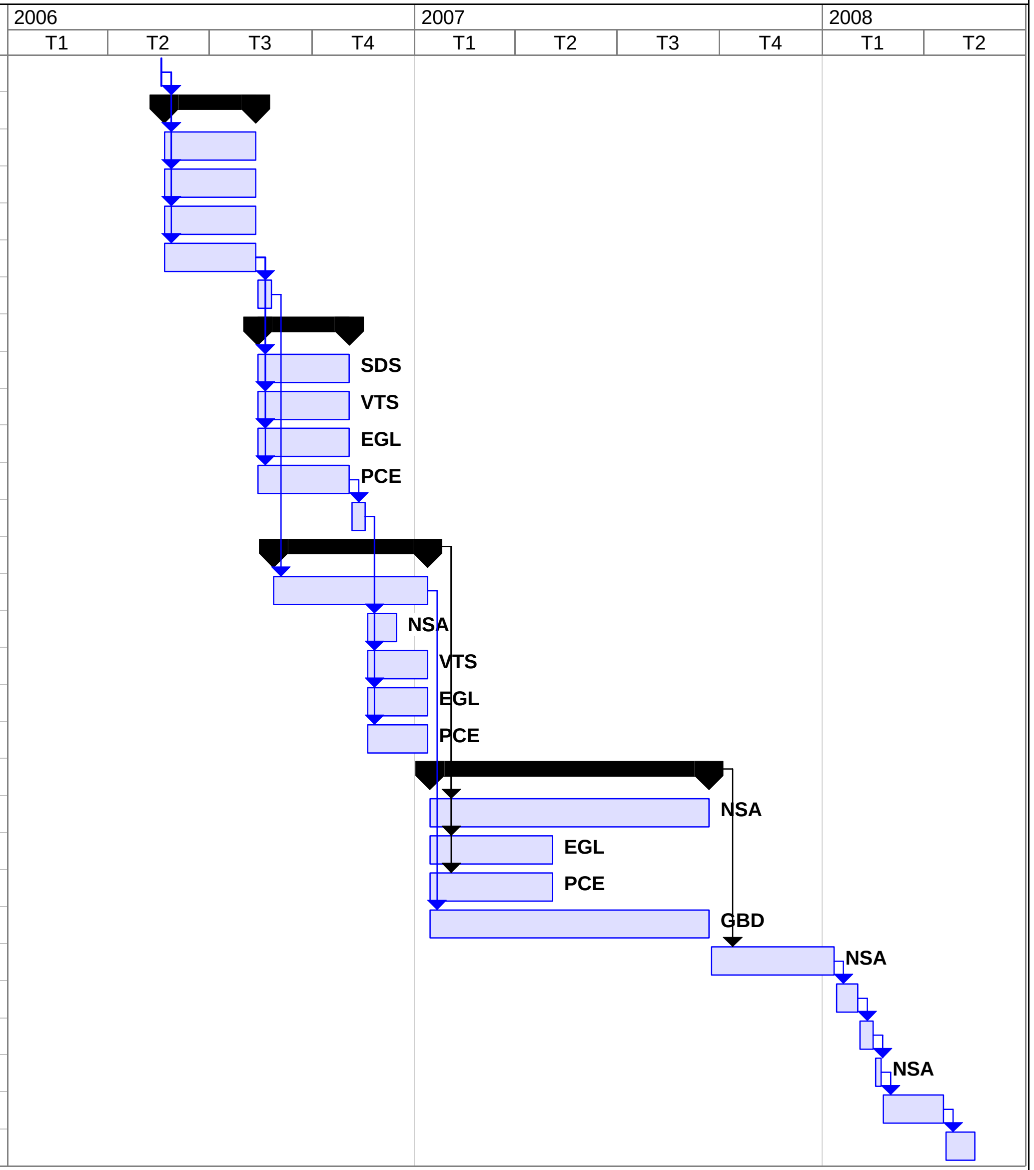
1 page


Time
Guider Telescope CCD Electronics
Interlock signals
Disable Telescope Control Switch
Interface signals with PRL
LAN
Serial link (Ethernet)
Local PC
Serial link (Ethernet)
Serial link (Ethernet/Profibus)
PMAC Controller
PLC
Dew Point Sensor (Option)
Monitoring Temperature Sensors
Mirror Temperature Control
Mirror Temperature Sensors
Air Temperature Sensors (T.B.C.)
Valve Actuators
Azimuth axis
Brake
Resolver (2)
Motor
Amplifier (2)
Axis encoder (1)
HW Limit switches Positive (1) Negative (1)
Chiller Control
Liquid Temperature Sensors
Chiller status
Chiller command
Altitude axis
Brake
Resolver (2)
Motor
Amplifier (2)
Axis encoder (1)
HW Limit switches Positive (1) Negative (1)
Mirror de-rotator axis
Amplifier (2)
Motor
Resolver / Encoder
M2 Control Unit
M2 Controller
Tip-Tilt / Focus Actuators
Wave Front Sensor

ATT3 : MAST AMOS SCHEDULE

1 page

Nº		Nom de la tâche	Durée	Début	Fin
1		**KICK OFF MEETING**	**1 jour**	**19-05-06**	**19-05-06**
2		**PRELIMINARY DESIGN PHASE**	**60 jours**	**22-05-06**	**11-08-06**
3		Optical design	60 jours	22-05-06	11-08-06
4		Mechanical Design	60 jours	22-05-06	11-08-06
5		Electrical Design	60 jours	22-05-06	11-08-06
6		Thermal Design	60 jours	22-05-06	11-08-06
7		**PDR data package**	**10 jours**	**14-08-06**	**25-08-06**
8		**DETAILED DESIGN PHASE**	**60 jours**	**14-08-06**	**03-11-06**
9		Optical design	60 jours	14-08-06	03-11-06
10		Mechanical Design	60 jours	14-08-06	03-11-06
11		Electrical Design	60 jours	14-08-06	03-11-06
12		Thermal Design	60 jours	14-08-06	03-11-06
13		**DDR data package**	**10 jours**	**06-11-06**	**17-11-06**
14		**PROCUREMENT PHASE**	**100 jours**	**28-08-06**	**12-01-07**
15		Long delivery items (mirror blanks, etc)	100 jours	28-08-06	12-01-07
16		Mechanical rough matertial	20 jours	20-11-06	15-12-06
17		Electro-Mechanical components	40 jours	20-11-06	12-01-07
18		Electrical components	40 jours	20-11-06	12-01-07
19		Thermal components	40 jours	20-11-06	12-01-07
20		**MANUFACTURING**	**180 jours**	**15-01-07**	**21-09-07**
21		Mechanical	180 jours	15-01-07	21-09-07
22		Electrical	80 jours	15-01-07	04-05-07
23		Thermal	80 jours	15-01-07	04-05-07
24		Optical	180 jours	15-01-07	21-09-07
25		**ASSEMBLY, INTEGRATION and TESTS**	**80 jours**	**24-09-07**	**11-01-08**
26		**ACCEPTANCE TESTS at AMOS**	**15 jours**	**14-01-08**	**01-02-08**
27		**Final Acceptance data package**	**10 jours**	**04-02-08**	**15-02-08**
28		**PACKING**	**5 jours**	**18-02-08**	**22-02-08**
29		**DELIVERY ON SITE**	**40 jours**	**25-02-08**	**18-04-08**
30		**ON SITE INSTALLATION**	**20 jours**	**21-04-08**	**16-05-08**

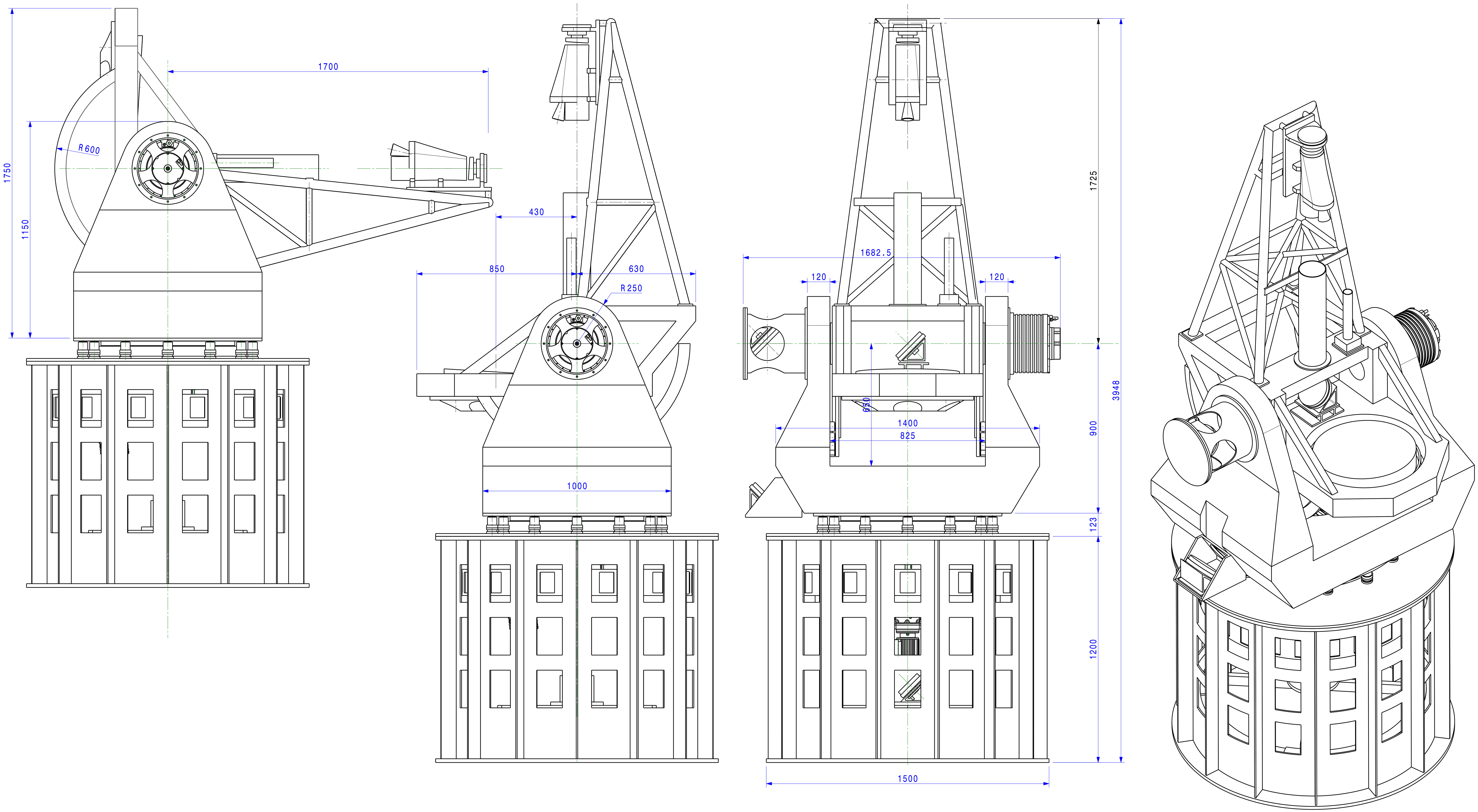


Projet : D1660_MAST_planning_IS2
Date : 19-05-06

Tâche		Jalon		Tâches externes	
Fractionnement		Récapitulative		Jalons externes	
Avancement		Récapitulative de projet		Échéance	

ATT4 : PRELILINARY DESIGN

1 drawing



Rep.	Nbr/Ens	Name	Drawing - Remarks - Material

AFL : Approved for Lay-out	CFA : Certified for Application	ASB : As-Built	FIN : Final - to be Archived

Document 02 | Format A1

Tolerances : Machining DIN 7168-f-R; Welding AE DIN 8570

	Date	Name
Drawn	19-05-2006	BLS
Checked	-	-

SA. AMOS
ADVANCED MECHANICAL AND OPTICAL SYSTEMS
Parc Scientifique du Sart-Tilman
rue des Chasseurs Ardennais
B-4031 ANGLEUR [BELGIUM]

Product Item

MAST

MULTI APPLICATION SOLAR TELESCOPE

General View

Treatment : -

Mass.: - Kg. -

-

Scale 1/10

Drawing D1660-00-00-01

Sheet 1/1

Issue A

Ref. CATIA R:\D1660_MAST\OPY\D1660_MAST black

Orig.