MULTI-APPLICATION SOLAR TELESCOPE

COMPLIANCE MATRIX (DDR ISSUE)

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TABLE OF CONTENTS

1. APPLICABLE & REFERENCE DOCUMENTS

Applicable and reference documents are defined here below. This includes documents and drawings.

1.1 APPLICABLE DOCUMENTS

ITEM	TITLE	REFERENCE	ISSUE	DATE
AD01	Tender Specification [PRL/04/05-06]	1967/03/01	-	22/12/05
AD02	User Requirements	1967/03/02	-	-
AD03	MAST Technical Proposal (AMOS)	D1660/technical	2.0	19/05/06
AD04	Compliance Matrix (revised)	-	-	01/06/06

1.2 REFERENCE DOCUMENTS

ITEM	TITLE	REFERENCE	ISSUE	DATE
RD01	Detailed Optical Design Report	1967/30/11	1.A	30/04/08
RD02	Detailed Mechanical Design Report	1967/30/12	1.A	30/04/08
RD03	Detailed Thermal Design Report	1967/30/13	1.A	30/04/08
RD04	Detailed Electrical Design Report	1967/30/14	1.A	30/04/08
RD05	Compliance Matrix (PDR issue)	1967/30/05	1.A	13/07/07
RD06	TCS Software Design Document [OSL]	1967/30/16	2.0	05/03/08
RD07	System Analysis & Error Budgets	1967/01/16	1.A	07/05/08
RD08	Interface Control Document (DDR issue)	1967/30/09	1.A	30/04/08
RD09	Assembly, Integration & Verification Plan	1967/06/01	1.A	29/04/08

1.3 REFERENCE DRAWINGS

ITEM	TITLE	REFERENCE	ISSUE	DATE
DWG01	General View	1967-00-00-00	C	25/04/08
DWG02	Building Interfaces	1967-00-00-90	C	25/04/08
DWG03	Polarimeter Interfaces	1967-10-00-90	B	25/04/08
DWG04	Tube General Assembly	1967-10-00-00	C	25/04/08
DWG05	Fork General Assembly	1967-20-00-00	C	25/04/08
DWG06	Ground Interface General Assembly	1967-30-00-00	C	25/04/08

2. ACRONYMS

ACE	:	Air-Conditioned Environment
AD	:	Applicable Document
Alt.	:	Altitude (axis)
Alt-Az.	:	Altitude-Azimuth (mount)
AMOS	:	Advanced Mechanical & Optical Systems
Az.	:	Azimuth (axis)
C	:	Compliant
DDR	:	Detailed Design Review
DWG	:	Drawing
FFOV	:	Full Field Of View
FOV	:	Field Of View
H/W	:	Hardware
HS	:	Heat Stop
I/F	:	Interface(s)
K-O	:	Kick-Off
MAST	:	Multi-Application Solar Telescope
mNC	:	marginally Non-Compliant
N/A	:	Not Applicable
NC	:	Non-Compliant
NFOV	:	Null Field Of View (= centre of the field)
OSL	:	Observatory Science Ltd.
PDR	:	Preliminary Design Review
pNC	:	partially Non-Compliant
PP	:	Polarimeter Package
PRL	:	Physical Research Laboratory (Govt. of India)
PTV	:	Peak-To-Valley
RD	:	Reference Document
RMS	:	Root Mean Square
RSS	:	Root Sum Square
S/W	:	Software
TBA	:	To Be Approved (by PRL/USO)
TBC	:	To Be Confirmed (by AMOS)
TBD	:	To Be Defined (by AMOS or PRL/USO)
TCS	:	Telescope Control System
USO	:	Udaipur Solar Observatory (PRL – Govt. of India)
WFE	:	WaveFront Error
WFS	:	WaveFront Sensor

3. <u>SCOPE</u>

This document forms a part of the justification of the detailed design done by AMOS for the MAST project. It provides a compliance status of the telescope's design with respect to specifications, at DDR level.

This document should be considered as a living document. This detailed design issue corresponds to AMOS commitment at DDR level with respect to all the specifications (including the "detailed" specification from [AD02]).

4. <u>TELESCOPE DESIGN OVERVIEW</u>

The Multi-Application Solar Telescope (MAST) is a 50 cm diameter class telescope to be installed on the USO Island on the Lake Fatehsagar in Udaipur, India. It is dedicated to solar observation.

The telescope is designed, manufactured, assembled and installed on-site by AMOS. It will be installed on the upper floor of the main existing building. Some appointments of the existing pier, dome and 2nd floor will be necessary for that purpose. Moreover, some additional equipment will be required on-site for proper operation of the telescope.

An overview of the MAST design outlines 3 categories of design elements that drive the structure of the document:

- the *telescope structure*, including the tube, fork and ground interface parts;
- the *mirror units*, including the primary mirror, the secondary mirror and the tertiary mirror units, the Coudé optics unit, the field derotator unit, the back-end folding unit, and the wavefront sensor pick-off unit;
- the *auxiliary equipment*, including a M1 cover and a M1 flushing system, the heat stop, an output pupil stop, a guider telescope, a wavefront sensor, the altitude and azimuth cable-wraps, and the upper sunshield.

The implantation of the telescope in the existing building and the interfaces with the PRL/USO equipment and site also forms an important part of the design.

All the above mentioned design elements concern several aspects of the design:

- the optical design;
- the mechanical design;
- the thermal design;
- the electrical design.

Each of these design aspects is detailed in a separate document (see [RD01] to [RD04], as well as [RD06] for more design details).

5. COMPLIANCE WITH TENDER SPECIFICATION

The following matrix provides the compliance status with respect to the Tender Specification [AD01] (Technical Specifications - §.3 of [AD01]). It should be considered as an update of the compliance matrix [AD04] provided along with the proposal [AD03]. Whenever required, a note comments the compliance status.

Compliance status can take the following values:

- C: Compliant
  - *meaning that the requirement should be fulfilled*
- mNC: marginally Non-Compliant
  - *meaning that the requirement should be almost fulfilled*
- pNC: partially Non-Compliant
  - *meaning that only part of the requirement should be fulfilled*
- NC: Non-Compliant
  - *meaning that the requirement is not expected to be fulfilled*
- N/A: Not Applicable
  - *meaning that the requirement is not to be considered anymore (specification not up-to-date)*

REF.	**SPEC. TITLE**	**REQUIREMENT**	**STATUS**	**NOTE**
	3.1 System Specifications			
3.1 (a)	Input Beam Size	50 cm (clear aperture)	C	
3.1 (b)	Output Beam Size	10 to 12 cm (with 6 arcmin FOV)	N/A	1
3.1 (c)	Output Wavefront Error (at 633 nm)	$\lambda/12$ rms on-axis	C	2
		$\lambda/10$ rms over field of view	C	
		$\lambda/4$ ptv	C	
3.1 (d)	Output Beam Stray-Light	irradiance $\leq 0,2$ % solar flux	C	
3.1 (e)	FOV Stationarity	max. movement $\leq 0,01$ arcsec /min	C	
3.1 (f)	Vibration of Output Beam	≤ 1 arcsec for freq. in [0 – 1] Hz	C	3
		$\leq 0,5$ arcsec for freq. in [1 – 10] Hz	C	
		$\leq 0,0,5$ arcsec for freq. > 10 Hz	C	
3.1 (g)	System Length (M2 – M3)	≤ 2 m	N/A	4
3.1 (h)	System Height (elevation – output)	≤ 2 m	N/A	5
3.1 (i)	Total Transmission	≥ 50 % in [400 – 900] nm range	C	
	3.2 Subsystems Specifications			
3.2.1 Intermediate Collimated Output Beam (Polarimeter allowance)[6]				
3.2.1 (a)	Size (at polarimeter level)	≤ 5 cm – modified to: 5 to 6 cm	C	
3.2.1 (b)	Wavefront Error (polarimeter level)	same as at output level	C	
3.2.1 (c)	Mueller Matrix (polarization status)	(Mueller matrix)	N/A	
3.2.1 (d)	Stray-Light (polarimeter level)	same as at output level	C	
3.2.1 (e)	Polarimeter Package Volume	Ø 10 cm x 15 cm modified to: 13 x 20 x 15 cm^3	C	

REF.	SPEC. TITLE	REQUIREMENT	STATUS	NOTE
3.2.2 Optical Components				
3.2.2 (a)	M1 Material	ULE (or equivalent like ZERODUR®)	C	
3.2.2 (b)	Other Mirrors Material	SiC	C	7
3.2.2 (c)	Mirrors Surface Accuracy	$\lambda/50$ rms (at 632,8 nm)	C	
		$\lambda/4$ ptv (at 632,8 nm)	C	
		Rq $\leq$ 2 nm rms (microroughness)	C	
3.2.2 (d)	Mirrors Coatings Reflectivity	R $\geq$ 95 % in [400 – 900] nm range	C	
		Rq $\leq$ 2 nm rms (with coating)	C	
3.2.2 (e)	Mirrors Coatings Absorption	$\leq$ 10 % incident solar flux	C	
3.2.2 (f)	M1 Front Surface Temperature	$\pm$ 1°C with respect to ambient	C	
3.2.2 (g)	M1 Airflow	1 m/s to 1,5 m/s across front surface	C	
3.2.2 (h)	Other Mirrors Temperature	$\pm$ 0,5°C with respect to ambient	C	8
3.2.3 Mechanical Assembly				
3.2.3 (a)	Mechanical Mount Type	Alt.-Az. mount	C	
3.2.3 (b)	Azimuth Limits	[85° - 275°] from North (NESW)	C	
3.2.3 (c)	Altitude Limits	[5° - 88,5°] (3° zenithal avoidance)	C	
3.2.3 (d)	Mechanical Parts Temperature	$\pm$ 1°C with respect to ambient	C	9
3.2.4 Drive System				
3.2.4 (a)	Pointing Accuracy	$\leq$ 10 arcsec	C	
3.2.4 (b)	Differential Pointing Accuracy	$\leq$ 0,5 arcsec	C	10
3.2.4 (c)	Open-Loop Tracking	$\leq$ 0,25 arcsec rms over 10 min	mNC	11
		$\leq$ 0,05 arcsec rms for 1 s	C	
3.2.4 (d)	Closed-Loop Tracking	$\leq$ 0,1 arcsec for 1 hour	C	12
3.2.4 (e)	M2 Mechanism	tip-tilt or active optics system	C	

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[7] this does not concern mirrors in Air-Controlled Environment, which proposed material is Zerodur® instead of SiC, without loss of coherence with the global specification .

[8] requirement updated at PDR level to be the same as for M1: ±1°C with respect to ambient.

[9] limited to parts close to optical beam or that could affect seeing.

[10] for differential pointing within 1,5 times the solar disk diameter.

[11] possibly slightly out of compliance in some extreme cases (thermal conditions) – refer to [RD07].

[12] provided that USO/PRL closes the loop with an adapted auto-correlation tracker in the output beam to account for misalignment that can't be controlled by the external guider – refer to [RD07] for discussion and justification.

REF.	SPEC. TITLE	REQUIREMENT	STATUS	NOTE
3.2.5 Environment Parameters & Operating Conditions				
3.2.5 (a)	Operational Environment	10°C ≤ T° ≤ 50°C	C	
		0 % ≤ RH ≤ 90 %	C	
		wind speed ≤ 30 km/h	C	
3.2.5 (b)	UPS	30 min backup time	C	
		220 ± 20 V ; 50 ± 2 Hz	C	
3.2.5 (c)	Telescope Location	USO island site – existing pier	C	
3.2.5 (d)	Telescope Control System	TCS is part of deliverables	C	

6. <u>COMPLIANCE WITH USER REQUIREMENTS</u>

The following matrix provides the compliance status with respect to the User Requirements Specification [AD02]. The latter had not been considered explicitly for the proposal [AD03]. Whenever required, a note comments the compliance status.

Main requirements from [AD02] are already part of [AD01] and are considered in the corresponding compliance matrix above (§.5). Most of remaining requirements from [AD02], which are not part of [AD01], concern TCS-related aspects. A compliance matrix dedicated to TCS aspects is already part of the TCS Preliminary Design Report [RD06]. One should refer to this one whenever it is relevant.

Compliance status can take the following values:

- C: Compliant
    - o *meaning that the requirement should be fulfilled*
- mNC: marginally Non-Compliant
    - o *meaning that the requirement should be almost fulfilled*
- pNC: partially Non-Compliant
    - o *meaning that only part of the requirement should be fulfilled*
- NC: Non-Compliant
    - o *meaning that the requirement is not expected to be fulfilled*
- N/A: Not Applicable
    - o *meaning that the requirement is not to be considered anymore (specification not up-to-date)*

		Doc.:	AMOS/1967/30/10
MAST		Issue:	1.A
		Date:	07/05/08
		Page:	12

S.A. AMOS
ADVANCED MECHANICAL AND OPTICAL SYSTEMS

REF.	**SPEC. TITLE**	**REQUIREMENT**	**STATUS**	**NOTE**
II. Constraints				
	Environmental Constraints	located on lake Fatehsagar	C	
		300 m altitude above sea level	C	
		$10°C \leq T° \leq 30°C$ (winter)	C	
		$20°C \leq T° \leq 50°C$ (summer)	C	
		RH typ. 40 % ; up to 90 % (occasionally)	C	
		wind speed up to 30 km/h (max.)	C	
		low damage risk zone (seismic zone II)	C	
5.	International Safety Regulations	CE marked	C	
III. Safety Requirements				
6.	Safety Requirements	safe operation oriented design	C	
		safe operation in responsibility of PRL	C	
7.1	Telescope Interlocks	telescope motion stopped by interlock	C	
7.2	Interlock System	PRL responsible for interlock use	C	
7.3	Input Verification	verification of requests and data by TCS	C	
7.4	Error Logging	logging and propagation of errors	C	13
7.5	Mains Supply	UPS ensured by PRL (5 min warning)	C	
		telescope in safe state within 5 min	C	
7.6	Start-Up after Failure	manual safe reset of telescope	C	
IV. Scientific Requirements				
8.1 to 12.4 and 12.6 to 13.3		refer to Tender Specification's compliance matrix (§.5)		
12.5	Maximum Slewing Speed	slewing speed ≤ 2 °/s max. (Alt. & Az.)	C	
14.1	Mean Time To Failure	MTTF ≥ 2000 h	C	14
14.2	Mean Time To Repair	MTTR ≤ 4 h	C	15
15.	Thermal Output	heat dissipation ≤ 1 kW (vicinity)	C	
		heat dissipation ≤ 300 W (telescope)	C	
16.	Telescope Enclosure	enclosure of PRL responsibility	C	
		i/f requirement document = [RD08]	C	

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[13] TCS being considered as the subsystem, with continuous logging at this level, propagation to OCS (higher level) on request, and broadcast of error messages occurring during operation.
[14] compliance expected – not guaranteed.
[15] not accounting availability of spare parts.

REF.	**SPEC. TITLE**	**REQUIREMENT**	**STATUS**	**NOTE**
V. Operational Requirements				
this part of the compliance matrix refers to information given in [RD06]				
17.	Operating Modes	2 control modes (engineering, user)	C	16
17.1	Disabling Telescope Control	lockout physical switch with status	C	
17.2	Local Engineering Control	control in local engineering mode	C	
17.3	Enabling Engineering Control	engineering mode switch + status	C	
17.4	Local & Remote Interactive Control	dual safe telescope control in user mode	C	
17.5	Change of Operating Mode	control mode change without shutdown	C	
17.6	Changeover Procedures	authorization control of mode switch	C	
17.7	Duration of Changeover	mode switch duration ≤ 5 min	C	
18.	Access to the Control System			
18.1	System User Access	protection from unauthorised access	C	
18.2	Local Access for Eng. Status	local on-line access to eng. status	C	
18.3	Remote Access for Eng. Status	remote on-line access to eng. status	C	
18.4	Software Engineering Access	on-line access to control s/w	C	
18.5	Super User Access	TCS tuning parameter access to authorised users	C	17
19.	Status Information and Alarms			
19.1	Error Trapping & Reporting	fault tolerant software with reporting	C	
19.2	Error Handling	graceful software failures handling	C	
19.3	Logging of Errors and Status	logging of errors and status changes	C	
19.4	Status Alarms	visual + audible alarm system on fault	C	18
19.5	Telescope Status & User Interface	safe & visible status design-oriented UI	C	
20.	Engineering Mode of Operation			
20.1	Engineering Interface Access	access to local & authorised remote eng. i/f for authorised users	C	
20.2	Information Monitoring	monitoring of encoders, signal lines, and PSU voltage by eng. i/f	C	
20.3	Local Parameter Modification	local setting of predefined parameters	C	
21.	Interactive Mode of Operation			
21.1	Interactive Mode User Interface	UI with both command line and GUI	C	

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[16] original requirement for 3 modes (+ super-user mode) amended by e-mail from USO/PRL, dated 11 May 2007.

[17] transferred to engineering mode permission, as amended by e-mail from USO/PRL, dated 11 May 2007.

[18] audible alarms limited to emergency cases with safety issues as agreed at PDR level - audible alarms usually not suitable and disabled by users - refer to [RD06] for detailed considerations.

REF.	SPEC. TITLE	REQUIREMENT	STATUS	NOTE
VI. _Telescope Control Requirements_				
this part of the compliance matrix refers to information given in [RD06]				
22.	Telescope System			
22.1	Control of Power	dual manual & computer controlled operation of power system	N/A	[19]
22.2	Power Monitoring	monitoring & log of power parameters	C	
22.3	Power Safety	carrying safety actions if required	C	
22.4	Alteration of Limits Setting	hardware or on-site only software alteration of ultimate limits	C	
22.5	Hardware Limits Recovery	recovery from hardware limits limited to human intervention	C	
22.6	Software Limits Recovery	recovery from software limits possible remotely from authorised users	C	
23.	Telescope Control System (TCS)			
23.1	TCS General Requirements	primary TCS responsibility	C	
23.2	TCS Computer	stable OS & fully equipped TCS PC	C	
23.4	Position & Status Information	information available to other systems	C	
23.5	TCS Software	software UI for control functions	C	
		source code & documentation	C	[20]
		GUI required	C	
24.	TCS Interfacing to Other Systems	TCS i/f with PRL's OCS required	C	
25.	TCS Co-ordinates			
25.1	Co-ordinate Entry	RA & DEC handled by TCS	C	
25.2	Non Sidereal Tracking Rates	non-sidereal tracking rates in RA & DEC handled by TCS	C	
25.3	Rotator Position Angle	position handled in position on the sky or in Alt.-Az. mount position angles	C	
25.4	Rotator Zero Point	zero setting by authorised user	C	
25.5	Arbitrary Rotator Position Mode	'floating' position setting	N/A	[21]
25.6	Altitude and Azimuth	Alt.-Az. setting	C	

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[19] non-applicability of this requirement agreed at PDR level – refer to [RD05] for justification.
[20] code provided in both source code and compiled format except for third party libraries, which are only available in compiled form – agreed at PDR level.
[21] removed requirement according to e-mail from USO/PRL, dated 11 May 2007.

REF.	**SPEC. TITLE**	**REQUIREMENT**	**STATUS**	**NOTE**
26.	Pointing Model			
26.1	Zeroset	start-of-day zeroset routine (Almanac)	C	
26.2	Start-of-Day Pointing Calibration	automatic start-of-day pointing model calibration routine	C	22
26.3	Basic Pointing Model Adjustment	adjustable basic pointing parameters	C	
26.4	Logging of Calibration Data	logging for manual pointing calibration	C	
26.5	Detailed Pointing Model Adjustment	non-basic pointing parameters alterable by authorised user	C	
27.	Slews & Offsets			
27.1	Keypad	keypad-like i/f for slewing in RA/DEC	C	
27.2	Offset Accuracy	offset during open-loop tracking	N/A	23
27.3	Offset Modes	tangent plane and RA/DEC offsets	C	
27.4	Offset Timing	offset stabilisation time: $\leq$ 2 s for 1 arcmin offset $\leq$5 s for 5 arcmin offset	C	
28.	Telescope Status Display			
28.1	Telescope Status Update	1 Hz status display auto-update	C	
28.2	Display Information	list of status information to be displayed	C	24
29.	Time			
29.1	Time Distribution	UT & LST served by TCS on LAN with accuracy of 1 s rms	C	
VII. Documentation				
30.	User Documentation	complete set of user documentation (printed + CD-ROM)	C	
30.1	Engineering Support Doc.	engineering support documentation	C	
30.2	Scheduled Maintenance Doc.	scheduled maintenance documentation	C	25
30.3	Design Doc.	interface and assembly drawings	C	

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[22] this start-of-day, sun-oriented, pointing model calibration (or check) routine will be available in addition to possible pointing model's calibration routines on stars at night.
[23] this requirement is not well understood: it would be expected to require the 0,5 arcsec differential pointing accuracy – agreed at PDR level.
[24] refer to [AD02] for the list of status information to be displayed.
[25] maintenance not included in existing contract.