



cherenkov
telescope
array



CTA+ LARGE SIZED TELESCOPE SOUTH



LSTS-SPE-INAF-0006-D04 MIRROR FACETS TECHNICAL REQUIREMENTS

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TABLE OF CONTENT

1	INTRODUCTION	8
1.1	BACKGROUND	8
1.2	THE PNRR NATIONAL PLAN	11
1.3	TELESCOPE OVERVIEW AND GLOSSARY	11
1.4	RELATED DOCUMENTS	12
1.4.1	Applicable documents	12
1.4.2	Reference documents	12
1.5	ACRONYMS AND ABBREVIATIONS	13
2	DEFINITIONS	14
2.1	TELESCOPE LIMIT STATES	14
2.1.1	SL – Serviceability Limit	14
2.1.2	CPL – Collapse Prevention Limit	14
2.2	TELESCOPE CONDITIONS	14
2.2.1	OBC – Observation Conditions	14
2.2.2	PPO – Precision Pointing Conditions	14
2.2.3	NRM – Normal Conditions (Standard Conditions)	14
2.2.4	TRC – Transition Conditions	14
2.2.5	SUR – Survival Conditions	14
2.2.6	ALC – All Conditions	14
2.3	TELESCOPE STATES	15
2.3.1	Machine States	16
2.3.1.1	OFS – Off State	16
2.3.1.2	ONS – On State	16
2.3.1.3	MAS – Maintenance State	16
2.3.2	Operational States (ONS sub-states)	16
2.3.2.1	INS – Initializing State	16
2.3.2.2	SAF – Safe State (Initialized State)	16
2.3.2.3	SBS – Standby State	16
2.3.2.4	RDS – Ready State	17

2.3.2.5 OBS – Observing State	17
2.3.2.6 FLS – Fault State	17
2.3.3 ALS – All States	18
3 VERIFICATION METHODS	19
3.1 D – BY REVIEW OF DESIGN.....	19
3.2 A – BY ANALYSIS	19
3.3 I – BY INSPECTION	19
3.4 T – BY TEST	19
4 ENVIRONMENTAL CONDITIONS.....	20
4.1 OBSERVATION PRE-CONDITIONS.....	20
4.1.1 A-GEN-0450 Rain during observation	20
4.1.2 A-GEN-0510 Observation snow load	20
4.1.3 A-GEN-0610 Observation ice load	20
4.2 TEMPERATURE AND RELATIVE HUMIDITY	20
4.2.1 B-ENV-0135 Atmospheric pressure	20
4.2.2 B-ENV-0210 Observation temperature	20
4.2.3 B-ENV-0220 Survival temperature	20
4.2.4 B-ENV-0225 Survival temperature without power	21
4.2.5 B-ENV-0230 Temperature gradient	21
4.2.6 B-ENV-0235 Precision pointing temperature gradient	21
4.2.7 B-ENV-0250 Survival temperature gradient	21
4.2.8 B-ENV-0310 Observation humidity	21
4.2.9 B-ENV-0320 Survival humidity	21
4.2.10B-ENV-0330 Mirror misting.....	22
4.3 RAIN, SNOW, ICE, HAIL.....	22
4.3.1 B-ENV-0410 Rain in 24 hours	22
4.3.2 B-ENV-0420 Rain in 1 hour	22
4.3.3 B-ENV-0430 Rain wind speed.....	22
4.3.4 B-ENV-0460 Rain during transition.....	22
4.3.5 B-ENV-0525 Survival snow load	22
4.3.6 B-ENV-0530 Hailstone damage	23
4.3.7 B-ENV-0625 Survival ice load.....	23

4.4 WIND	23
4.4.1 B-ENV-0710 Observation wind speed	23
4.4.2 B-ENV-0716 Precision pointing wind speed	23
4.4.3 B-ENV-0720 Transition wind speed	23
4.4.4 B-ENV-0740 Survival wind speed	23
4.4.5 B-ENV-0745 Survival wind gust	24
4.5 RADIATION	24
4.5.1 B-ENV-0810 Solar radiation level	24
4.5.2 B-ENV-0820 UV resistance	24
4.5.3 B-ENV-1430 Survival illumination	24
4.6 DUST AND SAND	24
4.6.1 B-ENV-0915 Dust and sand	24
4.7 AGGRESSIVE ATMOSPHERE	25
4.7.1 B-ENV-1020 Aggressive atmosphere (South)	25
4.8 EARTHQUAKE	25
4.8.1 B-ENV-S-1110 Earthquake damage limitation	25
4.8.2 B-ENV-S-1120 Earthquake collapse prevention	26
4.9 Environmental protection	27
4.9.1 A-GEN-2185 Environmental protection	27
5 INTERFACE REQUIREMENTS	28
5.1 MIRROR SUPPORT INTERFACE	28
5.1.1 LSTS-OPT-0007 Mirror facet pads position	28
5.1.2 LSTS-OPT-0008 Mirror facet pads survival conditions	28
5.1.3 LSTS-OPT-0009 Mirror facet pad loads	29
5.1.4 LSTS-OPT-0010 Mirror facet pads size and number	29
5.1.5 LSTS-OPT-0011 Mirror facet pads material	29
6 OPTICS	30
6.1 MIRROR FACETS FUNCTIONAL REQUIREMENTS	30
6.1.1 LSTS-OPT-0003 Mirror Facet Size	30
6.1.2 LSTS-OPT-0004 Mirror facet thickness	30
6.1.3 LSTS-OPT-0005 Mirror facet mass	30
6.1.4 LSTS-OPT-0020 Mirror Facet Honeycomb principal direction	31

6.1.5 C-ENV-LST-OPT-041001 Mirror Facet Water Tightness	31
6.1.6 C-TEL-LST-OPT-012002 Mirror Facet Protective Layer	31
6.1.7 LSTS-OPT-0018 Mirror Facet Coating Adhesion	31
6.1.8 LSTS-OPT-0035 Mirror Facets Production Technology	31
6.1.9 LSTS-OPT-0014 Mirror Facet Identity Card	31
6.1.10 LSTS-OPT-0015 Mirror Facet ID number	32
6.2 MIRROR FACETS PERFORMANCE REQUIREMENTS	32
6.2.1 LSTS-OPT-0006 Shape of the mirror facets	32
6.2.2 D-LST-OPT-MIR-013001 Mirror Facet PSF	33
6.2.3 C-LST-OPT-013016 Mirror Facet PSF Variability	33
6.2.4 LSTS-OPT-0001 Absolute Mirror Reflectivity	33
6.2.5 LSTS-OPT-0002 Initial reflectivity uniformity	34
6.3 OPTICS RAMS REQUIREMENTS	34
6.3.1 Mirror Facets Reliability	34
<i>6.3.1.1 B-TEL-0125 Mirror Degradation</i>	<i>34</i>
<i>6.3.1.2 B-TEL-0540 Mirror Lifetime</i>	<i>34</i>
<i>6.3.1.3 C-TEL-LST-OPT-012501 Mirror Facet Aging</i>	<i>34</i>
6.3.2 Mirror Facets availability	34
6.3.3 Mount maintainability	34
<i>6.3.3.1 LSTS-MNT-0042 Mount inspection points</i>	<i>34</i>
6.3.4 Mirror Facets safety	35
<i>6.3.4.1 LSTS-CMN-0008 CTAO Telescope safety design specification</i>	<i>35</i>
<i>6.3.4.2 B-ONSITE-0320 Fire protection</i>	<i>35</i>
<i>6.3.4.3 B-ONSITE-0330 Flood protection</i>	<i>35</i>
6.4 MIRROR FACETS HANDLING AND SHIPPING	35
6.4.1 LSTS-OPT-0012 Mirror facets handling and storage requirements	35
6.4.2 LSTS-OPT-0013 Mirror facets packing size	35
6.4.3 LSTS-OPT-0029 Mirror facets packaging regulation	36
6.4.4 LSTS-OPT-0030 Front side protective plastic film	36
6.4.5 LSTS-OPT-0031 Back side protective plastic film	36
6.4.6 LSTS-OPT-0016 Mirror facets packages monitoring devices	36
6.4.7 LSTS-OPT-0017 Mirror Facets Barrier Bags	36

6.5 MOUNT STANDARDS REQUIREMENTS..... 37

6.5.1 LSTS-MNT-0043 Mount applicable standards..... 37

1 INTRODUCTION

The scope of this document is to provide the requirements for the production of the Mirror facets of CTA South Large Sized Telescope. To accomplish this, the document is divided in a set of Environmental Requirements, Interface Requirements and set of requirements dedicated to the Optics subsystem targeting specifically the mirror facets. In particular, the sections will be divided with following criteria:

- Introduction
- Definitions
- Verification Methods
- Environmental requirements
- Optics
 - Functional
 - Performance
 - Handling and Shipping
 - Applicable Standards

Definitions and environmental requirements are applicable throughout all the telescope sub-units. The Introduction section, besides background and PNRR framework descriptions, report also the list of the Applicable and Reference Documents.

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1.1 BACKGROUND

The Cherenkov Telescope Array Observatory is an international user facility distributed over four primary sites: Headquarters (Bologna, Italy), Science Data Management Centre (Zeuthen, Germany) and two array sites located in the northern (Observatorio del Roque de los Muchachos (ORM), La Palma, Spain) and southern hemispheres (between Cerro Paranal and Cerro Armazones ESO observatories in Chile).

The Cherenkov Telescope Arrays consists in many tens of telescopes for Gamma Ray observation, divided in three configurations, in order to cover the energy, range from a tens of GeV (Large Sized Telescope, LST), to a tens of TeV (Medium Sized Telescope, MST), and up to 100 TeV (Small Sized Telescope, SST).

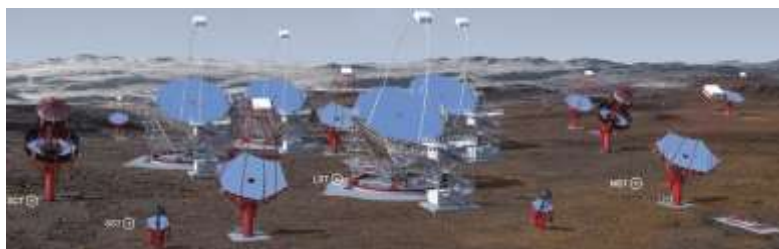


Figure 1.1 Cherenkov Telescope Array artist's impression

Within this framework, INAF is in charge to design, fabricate and test the Large Sized Telescopes located in the southern hemisphere. The location for the LST in the South is approximately located at 24.68°S, 70.32°W at an altitude of ~2150m into the valley between to Paranal and Armazones.



Figure 1.2 CTA South (Chile) location aerial view

The LST is an alt-azimuth telescope which have in a primary mirror of 23 m diameter and 28 m focal length; a larger mirror and higher photo detection efficiency allow to detect smaller atmospheric

showers. These types of telescopes normally are arranged at the centre of the array to lower the energy threshold and to improve the sensitivity of CTA between 20 and 200 GeV.



Figure 1.3 Artist's impression of Large Sized Telescope into Cherenkov Telescope Array

1.2 THE PNRR NATIONAL PLAN

The National Recovery and Resilience Plan (“Piano Nazionale di Ripresa e Resilienza”, PNRR) is part of the Next Generation EU (NGEU) program that the European Union negotiated in response to the pandemic crisis. The total amount of funds envisaged by Italy amounts to several hundreds of billions of euros implemented on specific axes and strategic missions. It is an intervention that aims at repairing the economic and social damage caused by the pandemic crisis, contributing to addressing the structural weaknesses of the Italian economy, and leading the country along a path of ecological and environmental transition and technological advancement.

CTA+ is a program approved by the Italian Ministry to be funded within the PNRR plan. This tender's objective delivers one important task of the project: the optics for the LSTs in the South (CTA+ WP1230).

To reach the program goal, this tender enforces a specific timeline for the execution of the project whose schedule is one of the most demanding achievements since its end is fixed in 2025. Moreover, a strict monitoring of the activities, costs and deliverables will be executed during the whole project by a supervisory body in order to ensure that the development of the project, in terms of time and costs, is in line with the proposal approved by the Ministry.

1.3 TELESCOPE OVERVIEW AND GLOSSARY

Telescope refers to the whole telescope system, hardware, and software. It can be divided in three main subsystems:

- **Telescope structure** (or **Structure**), which is composed by the **Mount** and the **Optics**,
- **Camera** (yellow in Figure 1.4),
- **Telescope Control System (TCS)**, the telescope control software that allows to operate the whole telescope and to interface with ACADA (or OES).

Mount refers to all the telescope systems that allow to support, move, operate, interface, etc. the Optics and the Camera. It can be divided in two main subsystems:

- **Azimuth assembly** (red in Figure 1.4): which is composed by the **Azimuth structure** plus the subsystems located onto it,
- **Elevation assembly** (green in Figure 1.4): which is composed by the **Elevation structure** plus the subsystems located onto it except for the Optics and the Camera.

Mount Structure refers the structural systems only and it is the combination of the Azimuth structure and the Elevation structure.

Axes motion refers to the systems directly responsible for the motion of the telescope. It includes for example Azimuth and Elevation drives, encoders, etc.

Ancillaries refers to the subsystems that support the Axes motion functionalities. It includes for example Azimuth and Elevation cable wraps, locking devices, manual drives, pointing and calibration systems, etc.

Optics refers to the whole optical system. It includes the dish, made of mirror facets (blue in Figure 1.4), and the Active Mirror Control system.

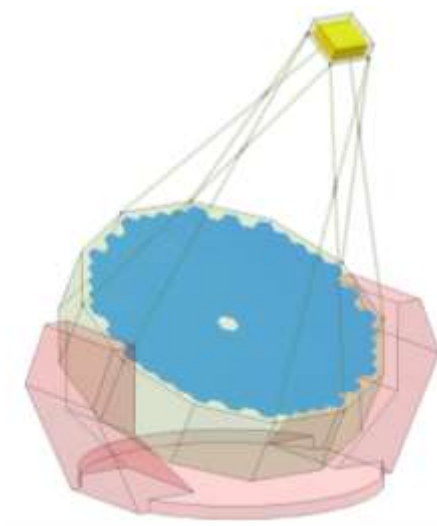


Figure 1.4: telescope sketch for the definition of the glossary used in the document. Yellow: Camera. Red: Azimuth assembly. Green: Elevation assembly. Blue: mirror facets.

1.4 RELATED DOCUMENTS

1.4.1 Applicable documents

AD	Document code	Description
AD01	LSTS-SOW-INAF-0001	Mirror Facets Statement of Work
AD02	CTA-SPE-SEI-400000-0001	CTAO - South Seismic Risk Specification
AD03	CTA-SPE-TEL-000000-0003	Telescope Safety Design Specification
AD04	CTA-PLA-SEI-00000-0001	CTA Product Safety Plan

1.4.2 Reference documents

RD	Document code	Description
RD01	Canestrari, Rodolfo; et al., The glass cold-shaping technology for the mirrors of the Cherenkov Telescope Array, Proceedings of the SPIE, Volume 9151, id. 91512V 10 pp. (2014).	SPIE proceeding: "The glass cold-shaping technology for the mirrors of the Cherenkov Telescope Array"

1.5 ACRONYMS AND ABBREVIATIONS

Acronym/Abbreviation	Full description
AIT	Assembly Integration Test
AMC	Active Mirror Control
CTA	Cherenkov Telescope Array
HW	HardWare
FEA	Finite Element Analysis
FEM	Finite Element Model
FMECA	Failure Mode Effects and Criticality Analysis
INAF	Istituto Nazionale di AstroFisica
LRU	Line Replaceable Unit
LST	Large Sized Telescope
LST-S	Large Sized Telescope South
PA	Product Assurance
PBS	Product Breakdown Structure
PI	Principal Investigator
PM	Project Manager
SE	System Engineer
SW	SoftWare

2 DEFINITIONS

The following definitions describe the telescope states and conditions to which the requirements apply (if applicable), and the telescope limit states to which a requirement refers in case an event occurs for a specific configuration of state and condition (when applicable).

2.1 TELESCOPE LIMIT STATES

2.1.1 SL – Serviceability Limit

The structure has not yielded and retained its strength and stiffness. Damage can be repaired in-situ using available spare parts and a normal level of on-site manpower (CTA Global ID CTA-200485).

2.1.2 CPL – Collapse Prevention Limit

The structure is heavily damaged, with very limited residual strength and stiffness, yet retains structural integrity and resists collapse. Repairs may require additional resources beyond those usually available on-site (CTA Glossary ID CTA-200486).

2.2 TELESCOPE CONDITIONS

2.2.1 OBC – Observation Conditions

Environmental conditions under which full operation of the CTA System must be possible without incurring damage (CTA Glossary ID CTA-200487).

2.2.2 PPO – Precision Pointing Conditions

Environmental conditions under which it is expected that the optimum pointing precision of the CTA System can be achieved (CTA Glossary ID CTA-200488).

2.2.3 NRM – Normal Conditions (Standard Conditions)

Environmental conditions under which standard operation, engineering and maintenance activities may be undertaken, during day or night (CTA Glossary ID CTA-200491).

2.2.4 TRC – Transition Conditions

Environmental conditions under which environmental parameters may exceed those of the observing state, whilst the system transitions into a safe state (CTA Glossary ID CTA-200489).

2.2.5 SUR – Survival Conditions

Environmental conditions expected to occur with a probability of roughly 2% per annum at each array site. The level of damage incurred under survival conditions must not exceed the serviceability limit state (CTA Glossary ID CTA-200490).

2.2.6 ALC – All Conditions

It refers to all telescope conditions regardless its state.

2.3 TELESCOPE STATES

LST-S Telescope States are depicted in the diagram at Figure 2.1. It represents the State Machine for the structure including all the Machine states and Operational states with sub-states. All Transitions (e.g.: switchOn, switchOff) are managed by the TCS but the sub-states of the Structure state machine are managed internally by the Structure.

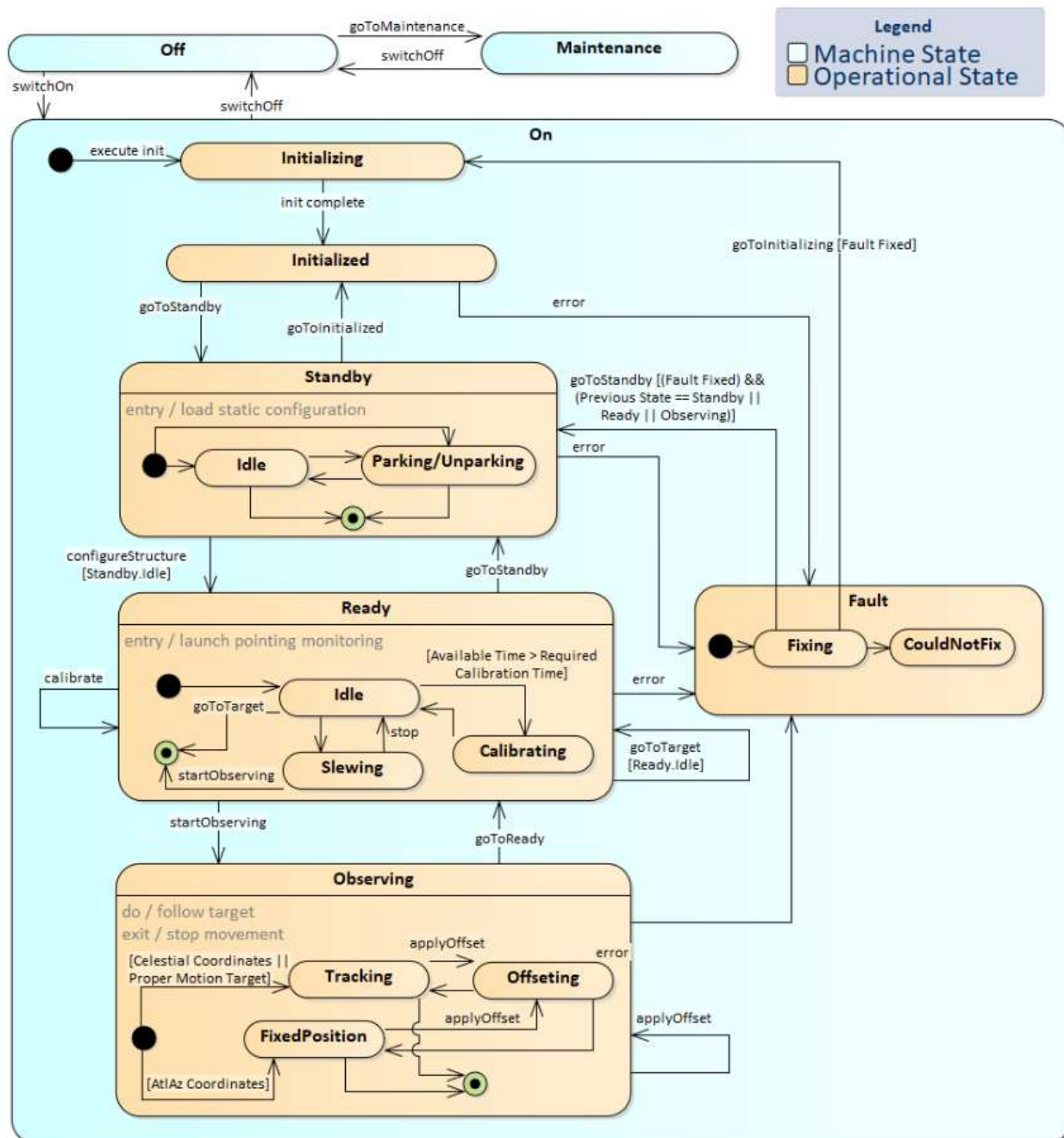


Figure 2.1: State machine of Structure including the states and their sub-states.

2.3.1 Machine States

2.3.1.1 OFS – Off State

The System is entirely without electrical power.

2.3.1.2 ONS – On State

The System is switched on, and available to operate under the operational states described in section 2.3.2.

2.3.1.3 MAS – Maintenance State

The System is in a state designed to perform maintenance activities and is unavailable for scientific operations or any kind of remote control.

Note: monitoring information is still, in general, available for ACADA.

2.3.2 Operational States (ONS sub-states)

2.3.2.1 INS – Initializing State

The System just transitioned to the ON machine state and is initializing all its internal components in order to arrive at the Safe State (also defined as Initialized state).

2.3.2.2 SAF – Safe State (Initialized State)

The System is in a configuration suitable for survival in extreme conditions, minimizing use of power whilst still providing basic status monitoring, and maximizing the instrument lifetime.

Note: It refers to its parking position or special position specifically designed to maintain the telescope safe while not operating.

2.3.2.3 SBS – Standby State

The System is in a state which is still safe with respect to adverse conditions, but has all components activated, with preparations for Observation initiated. Structure has all internal systems on and is unpark.

Sub-states are described as follow:

- **Idle:** already unparked and able to start the transition to “Ready”. Goes to this state if it is already unparked when entering the Standby state.
- **Parking/Unparking:** structure is parking or unparking. When coming from the Initialized state, the Structure starts the unparking procedure, and when done it automatically transition to idle.

2.3.2.4 RDS – Ready State

The System is prepared for a rapid transition to the Observing State. Internal calibration activities may take place.

Sub-states are described as follow:

- **Idle:** Able to go to the Observing state.
- **Calibrating:** Internal telescope calibrations such as when initial mirror alignment for the night happens. Structure cannot be tracking
- **Slewing:** Going to another pointing position. Goes to Ready.Idle, Observing. FixedPosition, or to Observing. Tracking automatically when done, the latter case being when the telescope is instructed to start tracking an Object in the sky upon arrival. Can be cancelled, in that case it goes to the idle sub-state.

2.3.2.5 OBS – Observing State

The System is in a state associated with observatory data taking, with configuration dictated by performance requirements. Data are being taken by Camera, Structure is tracking (or pointing to) the target, calibration activities may take place.

Sub-states are described as follow:

- **Tracking:** Following a position in the sky, or a proper motion target.
- **FixedPosition:** Pointed to a particular fixed position in Alt-Az (e.g. drift scan mode).
- **Offsetting:** Moving to a new position in the same field of view. Goes to the previous sub-state (Tracking or FixedPosition) spontaneously when the operation is finished.

2.3.2.6 FLS – Fault State

The System has encountered a serious problem which means it is currently unable to reach one of the standard states or is unable to continue to maintain the current status. For errors that permit to continue the operation of the corresponding state within requirements, the Element should stay in its correct state while such error is solved (the error is to be logged). Whenever the Element enters in the Fault state, an Alarm shall be raised to IPS and/or ACADA depending on the nature of the Alarm (Safety-related alarms are to be managed by IPS, and operations-related by ACADA.). The transition to this state is automatically performed by the system.

Sub-states are described as follow:

- **Fixing:** Structure is trying self-fix the error. After fixing the error, if the Structure was in the Standby, Ready or Observing state it will try to reach the Standby state. In case the Standby state cannot be reached, or for the other states before the fault and depending on the nature of the error, it will go to the Standby state. Otherwise, it goes to the Initializing states. If the cancelTransition command is issued, the autonomous fixing procedure is interrupted, and the Structure will go to the CouldNotFix state.
- **CouldNotFix:** Structure could not self-fix the error and needs human intervention to fix the problems.

Note: In addition to SwitchOff, other means by manual interventions using the TCS may allow to return the telescope to the Initialized or Standby State directly.

2.3.3 ALS – All States

It generically refers to all the previous states.

3 VERIFICATION METHODS

3.1 D – BY REVIEW OF DESIGN

Verification by Review of design shall consist of using approved records or evidence (e.g. design documents and reports, technical descriptions, engineering drawings) that unambiguously show that the requirement is fully satisfied. The compliance shall be demonstrated by an adequate design, which will be checked by INAF during the design phase of the contract by review of the design documentation.

3.2 A – BY ANALYSIS

Verification by analysis shall consist of performing theoretical or empirical evaluation using techniques agreed with INAF (such as systematic, statistical, and qualitative design analysis, modelling, and computational simulation). The fulfilment of the specified performance shall be demonstrated by appropriate analysis which will be checked by INAF during the design phase.

3.3 I – BY INSPECTION

Verification by inspection shall consist of visual determination of physical characteristics (such fabrication features, hardware conformance to document drawing or workman requirements, physical conditions, software source code conformance with coding standards).

3.4 T – BY TEST

Verification by test shall consist of measuring product performance and functions under representative conditions (i.e., simulated environments), or under conditions that can be clearly traced to operational ones. The analysis of data derived from testing shall be an integral part of the test and the results included in the test report. When the test objectives include the demonstration of qualitative operational performance, the execution shall be observed, and results recorded.

4 ENVIRONMENTAL CONDITIONS

4.1 OBSERVATION PRE-CONDITIONS

4.1.1 A-GEN-0450 Rain during observation

Observations must not occur during rain.

Condition: OBS

Verification: requirement not subjected to verification; for information only.

4.1.2 A-GEN-0510 Observation snow load

Observations must not take place when there is snow on the ground.

Condition: OBS

Verification: requirement not subjected to verification; for information only.

4.1.3 A-GEN-0610 Observation ice load

Observations must not take place when ice is present on any surfaces.

Condition: OBS

Verification: requirement not subjected to verification; for information only.

4.2 TEMPERATURE AND RELATIVE HUMIDITY

4.2.1 B-ENV-0135 Atmospheric pressure

Performance requirements must be met in the atmospheric pressure range of 770 +/- 50 mbar.

Note: this refers to the site altitude of 2150 m an average temperature of 15 °C.

Condition: ALC

Verification: D, A

4.2.2 B-ENV-0210 Observation temperature

Performance requirements for observations must be met within the ambient temperature range -5°C to 25°C.

Condition: OBC

Verification: T, A

4.2.3 B-ENV-0220 Survival temperature

Damage must not occur due to ambient temperatures within the range -15°C to 35°C when in the Safe State.

Condition: SUR

Verification: T, A

4.2.4 B-ENV-0225 Survival temperature without power

Damage must not occur due to ambient temperatures within the range -10°C to 30°C when no power is available (OFS state).

Condition: SUR

Verification: T, A

4.2.5 B-ENV-0230 Temperature gradient

Performance requirements for observations must be met during air temperature gradients of less than 7.5°C/h .

Condition: OBC

Verification: T, A

4.2.6 B-ENV-0235 Precision pointing temperature gradient

It must be possible to achieve precision pointing under temperature gradients of up to 3°C/h .

Condition: PPO

Verification: D, A

4.2.7 B-ENV-0250 Survival temperature gradient

Damage must not occur due to air temperature gradients of up to 0.5°C/min for 20 minutes when in the Safe State.

Condition: SUR

Verification: T, A

4.2.8 B-ENV-0310 Observation humidity

Performance requirements for observations must be met within the relative humidity range 2% to 90%, provided the condition for operation with un-misted mirrors (see 4.2.10 B-ENV-0330) is met.

Condition: OBC

Verification: D, A

4.2.9 B-ENV-0320 Survival humidity

Damage must not occur due to relative humidity within the range 2% to 100% when in the Safe State or when no power is available.

Condition: SUR

Verification: T, A

4.2.10 B-ENV-0330 Mirror misting

Telescopes must operate with un-misted mirrors when the dew point temperature is at least 2°C lower than the ambient temperature.

Condition: ALC

Verification: requirement not subjected to verification; for information only.

4.3 RAIN, SNOW, ICE, HAIL

4.3.1 B-ENV-0410 Rain in 24 hours

Damage must not occur due to rain precipitation of up to 200mm in 24 hours.

Condition: SUR

Verification: T, A

4.3.2 B-ENV-0420 Rain in 1 hour

Damage must not occur due to rain precipitation of up to 70mm in 1 hour.

Condition: SUR

Verification: T, A

4.3.3 B-ENV-0430 Rain wind speed

Damage beyond the Serviceability Limit State must not occur due to precipitation in the form of rain, snow, or hail for (10-minute average) wind speeds of up to 90km/h.

Condition: SUR

Verification: T, A

4.3.4 B-ENV-0460 Rain during transition

During transitions, damage must not occur due to rainfall of up to 2 mm/h.

Condition: TRC

Verification: T, A

4.3.5 B-ENV-0525 Survival snow load

Damage beyond the Serviceability Limit State must not occur on the CTA-S site whilst in the Safe State due to snow loads of up to 20 kg/m².

Condition: SUR

Verification: T, A

4.3.6 B-ENV-0530 Hailstone damage

Damage must not occur due to the impact of 5 mm diameter hailstones with kinetic energy of 0.2 Joule.

Condition: SUR

Verification: T, A

4.3.7 B-ENV-0625 Survival ice load

Damage beyond the Serviceability Limit State must not occur due to an ice thickness (on all surfaces) of up to 20 mm.

Condition: SUR

Verification: T, A

4.4 WIND

4.4.1 B-ENV-0710 Observation wind speed

Performance requirements for observations must be met under 10 minute average wind speeds of up to 36 km/h.

Condition: OBC

Verification: D, A

4.4.2 B-ENV-0716 Precision pointing wind speed

It must be possible to achieve precision pointing on the CTA-S site under 10 minute average wind speeds of up to 11 km/h.

Condition: PPO

Verification: D, A

4.4.3 B-ENV-0720 Transition wind speed

During transitions, damage must not occur on-site due to 10 minute average wind speeds of up to 50 km/h and damage beyond the Serviceability Limit State must not occur due to 10 minute average wind speeds of up to 60 km/h.

Condition: TRC

Verification: D, A

4.4.4 B-ENV-0740 Survival wind speed

Damage must not occur at the CTA-S site due to 10 minute average wind speeds of up to 80 km/h, and damage beyond the Serviceability Limit State must not occur due to 10 minute average wind speeds of up to 100 km/h when in the Safe State.

Condition: SUR

Doc.: LSTS-SPE-INAF-0006 Title: Mirror Facets Technical Requirements Issue: D04 Date: 14/03/2024 Page: 22 of 36	   LARGE SIZED TELESCOPE SOUTH	 
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Verification: T, A

4.4.5 B-ENV-0745 Survival wind gust

Damage beyond the Serviceability Limit State must not occur on the CTA-S site due to wind gusts (1s) of up to 170 km/h.

Condition: SUR

Verification: T, A

4.5 RADIATION

4.5.1 B-ENV-0810 Solar radiation level

Damage must not occur due to solar radiation of up to 1200 W/m² (averaged over 1 hour) at a maximum ambient temperature of 35°C when in the Safe State.

Condition: ALC

Verification: D, T

4.5.2 B-ENV-0820 UV resistance

All components exposed to direct solar radiation must be UV resistant.

Condition: ALC

Verification: D, T

4.5.3 B-ENV-1430 Survival illumination

Damage must not occur due to illumination levels of up to 10⁶ photons ns⁻¹ cm⁻² in any state.

Condition: ALC

Verification: D

4.6 DUST AND SAND

4.6.1 B-ENV-0915 Dust and sand

Damage must not occur due to an environment with up to 2.9 x 10⁵ particles of ≥5µm size per m³ of air for 90% of the time at 2m above ground.

Condition: ALC

Verification: D, T

4.7 AGGRESSIVE ATMOSPHERE

4.7.1 B-ENV-1020 Aggressive atmosphere (South)

Damage must not occur on the CTA-S site due to the following Aggressive Atmospheric Concentration ranges when in the Safe State: NO, NO₂, SO₂<4ppb.

Condition: ALC

Verification: D, A, T

4.8 EARTHQUAKE

The equations here below represent the ground acceleration elastic response spectra. The corresponding parameter, as defined by Eurocode 8 are defined in the following subsections for horizontal and vertical direction for both damage limitation and collapse prevention seismic cases.

Here is presented the table with the formulas for the determination of the elastic response spectrum:

Period range	$S_e(T)$
$0 \leq T \leq T_B$	$a_g \cdot S \cdot [1 + T/T_B \cdot (\eta \cdot c - 1)]$
$T_B \leq T \leq T_C$	$a_g \cdot S \cdot \eta \cdot c$
$T_C \leq T \leq T_D$	$a_g \cdot S \cdot \eta \cdot c \cdot [T_C/T]$
$T_D \leq T \leq 4s$	$a_g \cdot S \cdot \eta \cdot c \cdot [T_C \cdot T_D / T^2]$

Where:

- $S_e(T)$ is the elastic acceleration response spectrum in [g]
- T is the vibration period in [s]
- a_g is the peak ground acceleration in [g]
- c is the ratio between the maximum and the peak ground acceleration
- T_B is the lower limit of constant spectral acceleration branch in [s]
- T_C is the upper limit of constant spectral acceleration branch in [s]
- T_D is the value defining the beginning of the constant displacement response range in [s]
- S is the soil factor (amplification factor)
- $\eta = [10 / (5 + \xi)]^{1/2}$ is the damping correction factor
- ξ is the damping ratio in percent.

Please refer to AD02 for further details.

4.8.1 B-ENV-S-1110 Earthquake damage limitation

Damage beyond the Serviceability Limit State must not occur at the CTA-S site due to the following ground accelerations: Peak horizontal ground acceleration up to 0.25 g, peak vertical ground acceleration up to 0.15 g, with a 10% probability of exceeding these figures within 10 years (reference return period 95 years).

The corresponding parameter for Damage Limitation earthquake, as defined by Eurocode 8 are defined as per following table and figures for horizontal and vertical directions.

Parameters	a_g [g]	S	T_B [s]	T_C [s]	T_D [s]	c
Horizontal	0.25	1.80	0.10	0.35	2.0	2.0
Vertical	0.15	2.10	0.05	0.30	2.0	2.2

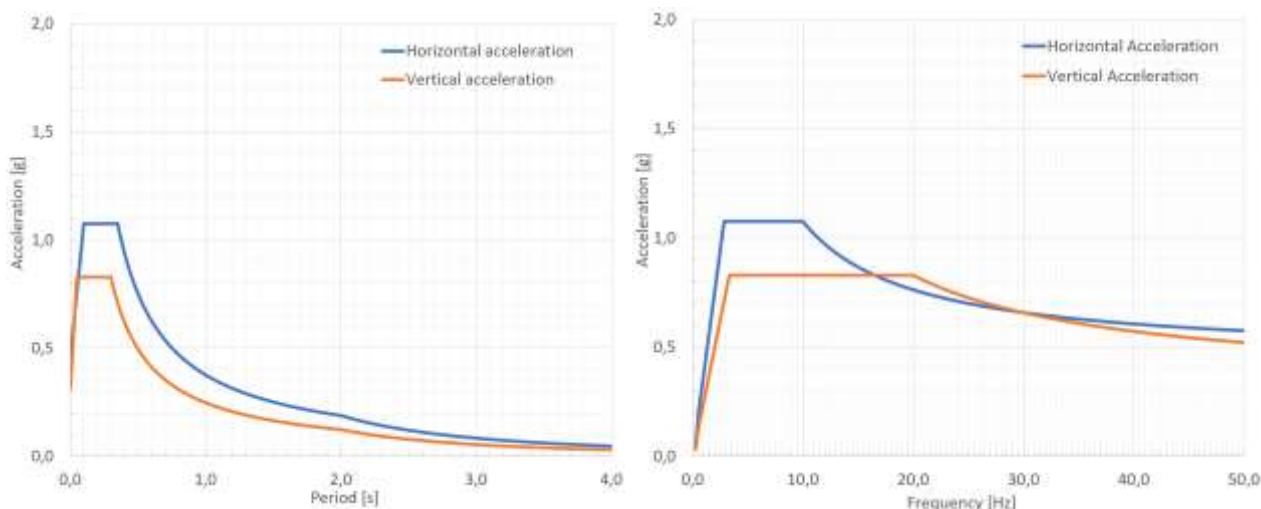


Figure 4.1: Damage Limitation Requirement earthquake spectra expressed as a function of the Period (left) and as a function of the Frequency (right) with damping of 2% for medium soil of CTA Southern site.

Condition: ALC

Note: Verification: requirement not subjected to verification; for information only.

4.8.2 B-ENV-S-1120 Earthquake collapse prevention

Damage beyond the Collapse Prevention Limit State must not occur at the CTA-S site due to the following ground accelerations: Peak horizontal ground acceleration up to 0.43 g, peak vertical acceleration up to 0.26 g, with a 10% probability of exceeding these figures within 50 years (reference return period 475 years).

The corresponding parameter for No-Collapse Requirements (NCR) earthquake, as defined by Eurocode 8 are defined as per following table and figures for horizontal and vertical directions.

Parameters	a_g [g]	S	T_B [s]	T_c [s]	T_D [s]	c
Horizontal	0.43	1.80	0.10	0.35	2.0	2.0
Vertical	0.26	1.60	0.05	0.30	2.0	2.2

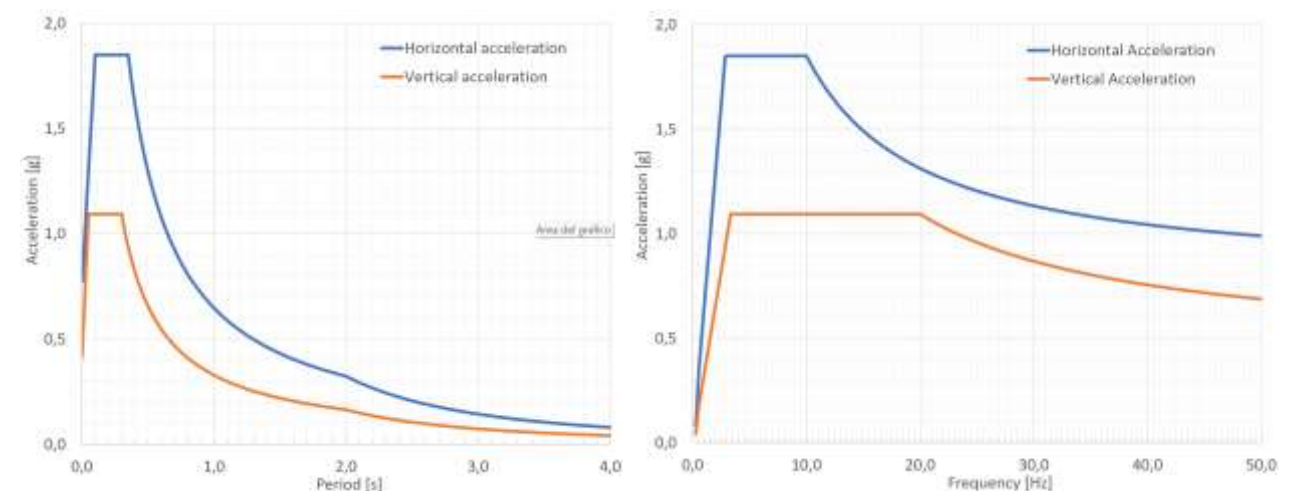


Figure 4.2: No-Collapse Requirement earthquake spectra expressed as a function of the Period (left) and as a function of the Frequency (right) with damping of 2% for medium soil of CTA Southern site.

Condition: ALC

Note: Verification: requirement not subjected to verification; for information only.

4.9 Environmental protection

4.9.1 A-GEN-2185 Environmental protection

Construction, operation and decommissioning of the CTA systems must comply with applicable regulations on the protection of the environment.

Condition: ALC

Verification: D

5 INTERFACE REQUIREMENTS

5.1 MIRROR SUPPORT INTERFACE

5.1.1 LSTS-OPT-0007 Mirror facet pads position

Each mirror facet will be connected to its support (AMC support) through the 3 pads described in 5.1.4.

The 3 pads shall be glued on the mirror facet back side on a circle of diameter 1300mm, a span between each other of 120degrees and aligned with the longest diagonals of the facet “hexagon” (those one passing for the centre) (see Figure 3).

The pads positioning shall be provided with a tolerance of $\pm 1\text{mm}$.

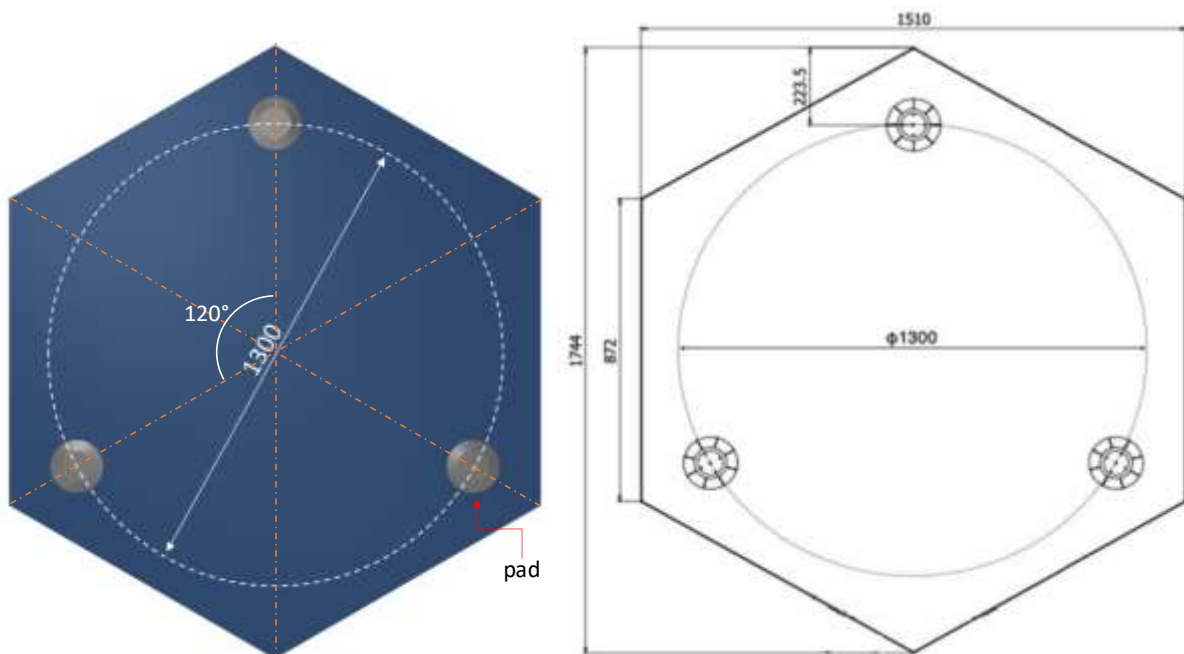


Figure 3: Mirror facet back side view with pads configuration.

Condition: N/A

Verification: D, I, T

5.1.2 LSTS-OPT-0008 Mirror facet pads survival conditions

The pads shall not suffer any damage due to survival conditions.

The adhesive bonding technique used to install the 3 pads on the mirror facet back side shall not suffer any damage or degradation over the entire mirror lifetime in order to ensure the connection between pads and mirror when exposed up to the survival conditions.

Condition: SUR

Verification: D, A

Doc.: LSTS-SPE-INAF-0006 Title: Mirror Facets Technical Requirements Issue: D04 Date: 14/03/2024 Page: 27 of 36	   LARGE SIZED TELESCOPE SOUTH	 
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5.1.3 LSTS-OPT-0009 Mirror facet pad loads

The adhesive bonding technique used to install the 3 pads on the mirror facet back side shall withstand a maximum acceleration (combination of x, y, z components) of 4.25g up to 10Hz occurred under collapse prevention earthquake. Therefore, the connection between pads and mirror facets shall be preserved under and after those loads.

Condition: SUR

Verification: I, T

Note: replacement can be taken in consideration after strong seismic events.

5.1.4 LSTS-OPT-0010 Mirror facet pads size and number

The pads will have a circular shape with diameter of 150mm and a thickness of 10mm.

The final design details and drawings will be agreed between INAF and the contractor after the start of the activities.

The final design must be optimized for the application of the selected adhesive bonding technique.

The provider shall provide a total of at least 1230 pads (3 for each mirror facet) to allow the assembly of all the facets.

Condition: N/A

Verification: D, I, T

Note: the pads design shall allow to interface correctly with the external devices. A detailed ICD will be provided by INAF and agreed with the provider during the contract.

5.1.5 LSTS-OPT-0011 Mirror facet pads material

The pads shall be made of stainless steel (AISI304).

Condition: N/A

Verification: D, I

6 OPTICS

6.1 MIRROR FACETS FUNCTIONAL REQUIREMENTS

6.1.1 LSTS-OPT-0003 Mirror Facet Size

The Mirror Facets shall be hexagonal with a size of 1510mm flat to flat.

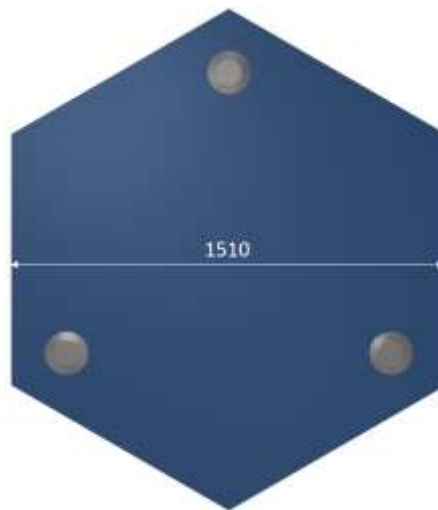


Figure 4: Mirror facet overall size

Condition: ALC

Verification: D, I, T

6.1.2 LSTS-OPT-0004 Mirror facet thickness

The thickness of the mirror facets shall be less than 46mm.

Condition: N/A

Verification: D, T

Note: the final thickness of the facet should be provided as soon as possible to allow the definition of the ICD toward external systems.

6.1.3 LSTS-OPT-0005 Mirror facet mass

The mass of the Mirror Facets shall be less than 47,5kg per facet including pads.

Condition: N/A

Verification: D, T

Note: the final mass of the facet should be provided as soon as possible to allow the definition of the ICD toward external systems.

Doc.: LSTS-SPE-INAF-0006 Title: Mirror Facets Technical Requirements Issue: D04 Date: 14/03/2024 Page: 29 of 36	    LARGE SIZED TELESCOPE SOUTH
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6.1.4 LSTS-OPT-0020 Mirror Facet Honeycomb principal direction

The honeycomb principal direction shall be identified in coordination with INAF and aligned with a vertex of the facet. Once identified it shall be kept unchanged for every facet and clearly marked on the back or the side of the facet.

Condition: N/A

Verification: I

6.1.5 C-ENV-LST-OPT-041001 Mirror Facet Water Tightness

The mirror facets shall be watertight, conforming to IP67, so they do not get damaged by water entering the panel. Alternatively, the facets shall include water taps to evacuate water and prevent large pressure differentials.

Condition: ALC

Verification: D

6.1.6 C-TEL-LST-OPT-012002 Mirror Facet Protective Layer

The mirror facets shall be coated with a protective layer to prevent damage of the reflective surface from degradation due to environmental parameters (e.g., humidity, acid rain).

Condition: N/A

Verification: D

6.1.7 LSTS-OPT-0018 Mirror Facet Coating Adhesion

The mirrors coating shall guarantee adhesion to the substrate when subject to a pulling force of at least 16 N.

Condition: N/A

Verification: T

6.1.8 LSTS-OPT-0035 Mirror Facets Production Technology

The technology used for the construction of the mirror facets must be based on a thin sheet glass shaping technique attained with the “cold-shaping” technology (or “Glass Cold Slumping”) (see RD01 and AD01).

Condition: N/A

Verification: I

6.1.9 LSTS-OPT-0014 Mirror Facet Identity Card

Each mirror facet shall be provided with an identity card reporting at least the following information:

- a) Mirror Facet ID (see 6.1.10)
- b) RoC-ID (see 6.2.1)

- c) RoC (see 6.2.1)
- d) PSF containment diameter (D80) (see 6.2.2)
- e) Initial Absolute Reflectivity (see 6.2.4) where available.
- f) Initial Reflectivity Uniformity (see 6.2.5) where available.

Condition: N/A

Verification: I

Note: points e) and f) will be available based on a sample checking approach: one each five produced facets as described in the SoW (AD01) and in the Requirement (6.2.4 and 6.2.5).

6.1.10 LSTS-OPT-0015 Mirror Facet ID number

An ID code shall be printed on the back side of each Mirror Facet. The ID code shall be built with the Roc-ID (see 6.2.1) plus a unique (over the entire production) incremental number. For example: COR1-012.

Condition: N/A

Verification: I

6.2 MIRROR FACETS PERFORMANCE REQUIREMENTS

6.2.1 LSTS-OPT-0006 Shape of the mirror facets

The mirror facets shall be spherical, with radii of curvature as shown in the Table 1.

RoC-ID	RoC [m]	# of facets
COR1	56.3 ± 1.5	124 (60 + 60 + 4)
COR2	57.1 ± 1.5	124 (60 + 60 + 4)
COR3	57.9 ± 1.5	162 (78 + 78 + 6)

Table 1: Summary table of the proposed discrete RoC distribution, grouped by corona.

For each RoC-ID shall be provided the number of facets reported in the above table.

Condition: OBS

Verification: D, A, T

Note: the tolerance of $\pm 1.5\text{m}$ on the RoC due to the manufacturing is intended to be P-V.

Note2: Each facet shall be optically tested. One each ten produced facet for the same RoC-ID shall be also tested with a probe in order to measure the shape of the entire facet.

Note3: a proposed telescope configuration based on the distribution of the mirror facets on the full reflector in 3 coronas characterised by the different RoC reported in Table 1, is depicted in Figure 5.

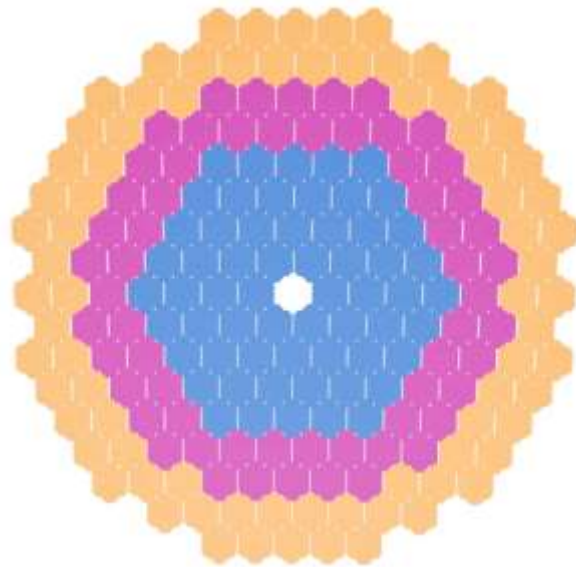


Figure 5: Proposed coronas distribution on the full reflector

6.2.2 D-LST-OPT-MIR-013001 Mirror Facet PSF

The optical PSF containment diameter (D80) of a single mirror facet shall be below 33.4 mm as measured in a 2f setup (below 16.7 mm in a 1f setup).

Condition: OBS

Verification: T

Note: Each facet shall be optically tested. One each ten produced facet for the same RoC-ID shall be also tested with a probe in order to measure the shape of the entire facet.

6.2.3 C-LST-OPT-013016 Mirror Facet PSF Variability

The PSF containment diameter (D80) of a single mirror facet shall change by less than 5% when considering gravity, wind loads, or thermal expansion during observing conditions.

Condition: OBS

Verification: A

6.2.4 LSTS-OPT-0001 Absolute Mirror Reflectivity

The initial absolute mirror facet reflectivity shall be at least 90% between 300 and 550 nm.

Condition: ALC

Verification: D, T

Note: the reflectivity Test shall be carried out for at least one each five produced facets.

6.2.5 LSTS-OPT-0002 Initial reflectivity uniformity

The non-uniformity of the initial reflectivity over the entire surface of the mirrors shall be less than 8% in the 300-550nm wavelength range.

Condition: ALC

Verification: T

Note: the reflectivity test shall be carried out at least on seven positions: one in the centre of the facet and the other six on the major diagonals. Final measurement point positions should be agreed with INAF.

6.3 OPTICS RAMS REQUIREMENTS

6.3.1 Mirror Facets Reliability

6.3.1.1 B-TEL-0125 Mirror Degradation

The loss in specular reflectivity of all Telescope Structure reflective surfaces must be <4% per year at all wavelengths from 300-550 nm.

Condition: ALC

Verification: requirement not subjected to verification; for information only.

6.3.1.2 B-TEL-0540 Mirror Lifetime

Mirror facets must be designed for an operational Lifetime of 15 years, during which recoating may be expected on a frequency of less than once every 6 years.

Condition: ALC

Verification: D, A

6.3.1.3 C-TEL-LST-OPT-012501 Mirror Facet Aging

The degradation of the reflectivity of the Mirror Facets shall be less than 2% per year.

Condition: ALC

Verification: D, A

6.3.2 Mirror Facets availability

6.3.3 Mount maintainability

6.3.3.1 LSTS-MNT-0042 Mount inspection points

All key Telescope Structure elements shall have inspection points to allow the verification of the moving parts.

Condition: ALC

Verification: D, A, I

6.3.4 Mirror Facets safety

6.3.4.1 LSTS-CMN-0008 CTAO Telescope safety design specification

Telescope safety design shall be compliant with the principles included in AD03 and AD04.

Condition: ALC

Verification: D, A, I, T

6.3.4.2 B-ONSITE-0320 Fire protection

Systems must be designed for compliance with fire regulations as stipulated in the European standard EN 1991.

Condition: ALC

Verification: D, A, I

6.3.4.3 B-ONSITE-0330 Flood protection

Systems must be designed to prevent all effects of water collection caused by surface water runoff.

Condition: ALC

Verification: D, I

6.4 MIRROR FACETS HANDLING AND SHIPPING

6.4.1 LSTS-OPT-0012 Mirror facets handling and storage requirements

Mirror facets shall be handled and stored carefully in order to avoid damages. The requirements to be respected are listed here below:

- Maximum acceleration: 4.25 g
- Temperature range: -10°C to 35°C
- Relative humidity range: 20% to 90%

Condition: N/A

Verification: D, A, I

6.4.2 LSTS-OPT-0013 Mirror facets packing size

Each mirror package will have the following characteristics:

- Mass: 600 kg
- Size: x=1900mm by y=1900mm by z=1000mm
- CoG: x=00mm, y=00mm, z=00mm
- Number of facets included per package: max 10
- Number of packages: at least 41

Condition: N/A

Doc.: LSTS-SPE-INAF-0006 Title: Mirror Facets Technical Requirements Issue: D04 Date: 14/03/2024 Page: 34 of 36	   LARGE SIZED TELESCOPE SOUTH	 
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Verification: D, A, I

6.4.3 LSTS-OPT-0029 Mirror facets packaging regulation

The mirrors packaging shall be compliant with national regulations (Italy/Chile).

Condition: N/A

Verification: D, I

6.4.4 LSTS-OPT-0030 Front side protective plastic film

A removable plastic film shall protect the front of coated mirrors during transportation, storage and installation. The plastic film shall not leave any residual material on the mirror surface.

Condition: N/A

Verification: D, I

6.4.5 LSTS-OPT-0031 Back side protective plastic film

The mirrors' back-structure shall be protected by a plastic film.

Condition: N/A

Verification: D, I

6.4.6 LSTS-OPT-0016 Mirror facets packages monitoring devices

Each mirror facet package shall implement monitoring device to track their location and condition during the shipping. They shall monitor location, temperature, relative humidity and shocks as minimum.

Condition: N/A

Verification: D, I

6.4.7 LSTS-OPT-0017 Mirror Facets Barrier Bags

Each mirror facet shall be packaged with a proper Barrier Vacuum Bag to provide protection against moisture, dust and any other harmful substances during shipping and storage.

Condition: N/A






Verification: D, I

6.5 MOUNT STANDARDS REQUIREMENTS

6.5.1 LSTS-MNT-0043 Mount applicable standards

The design of the Mount shall make use of adequate set of standards. A table including applicable standards for the Mount design is included here, but it must not be considered complete.

Standard code	Description
	Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on Machinery, and amending Directive 95/16/EC
MIL-HDBK-338B	MILITARY HANDBOOK: ELECTRONIC RELIABILITY DESIGN HANDBOOK
MIL-HDBK-217F	MILITARY HANDBOOK: RELIABILITY PREDICTION OF ELECTRONIC EQUIPMENT
EN Eurocode 0	Basis of Structural Design
EN Eurocode 1	Actions on Structures – All parts
EN Eurocode 2	Design of Concrete Structures – All parts
EN Eurocode 3	Design of Steel Structures – All parts
EN Eurocode 4	Design of Composite Steel and Concrete Structures – All parts
EN Eurocode 8	Design of Structures for Earthquake Resistance – All parts
EN Eurocode 9	Design of Aluminium Structures – All parts
EN 61010-1	Safety requirements for electrical equipment for measurement, control, and laboratory use - Part 1: General requirements
EN 62061	Safety of machinery, Functional safety of safety-related electrical, electronic and programmable electronic control systems
EN ISO 13849-1	Safety of machinery -- Safety-related parts of control systems -- Part 1: General principles for design
EN ISO 13850	Safety of Machinery – Emergency Stop – Principles for design
EN 60364 series	Low-voltage electrical installations
EN 60445	Basic and safety principles for man-machine interface, marking and identification - Identification of equipment terminals, conductor terminations and conductors, 2010
EN 60664 series	Insulation coordination for equipment within low-voltage systems
MIL-STD-756B	Reliability Modelling and Prediction reference
MIL-STD-882E	System Safety
MIL-STD-1629A	Procedures for performing a Failure Mode, Effects and Criticality Analysis reference
2004/108/EC	EMC Directive
EN 61000 series	Electromagnetic Compatibility (EMC)
Functional Safety and IEC 61508	Functional safety of electrical/electronic/programmable electronic safety-related systems
IEC 61131-3	Programmable controllers - Part 3: Programming languages
EN 62305:2011	Lightning protection standard
ISO 14644-1:2015	Cleanrooms and associated controlled environments — Part 1
ECSS-Q-ST-80C Rev.1 (15 February 2017)	Space product assurance – Software product assurance

Doc.: LSTS-SPE-INAF-0006 Title: Mirror Facets Technical Requirements Issue: D04 Date: 14/03/2024 Page: 36 of 36	   LARGE SIZED TELESCOPE SOUTH	 
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Condition: ALC

Verification: D, A

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