SST Mechanical Structure Subsystem Technical Requirements Specification

SST-MEC-SPE-002

Version 2b

Prepared by:		
Gino Tosti (INAF)		SST-STR SE
Salvatore Scuderi (INAF)		SST-STR PM
Alessio Trois (INAF)		SST-PRO PRM
Nicola La Palombara (INAF)		SST-PRO PRQM
Approved by:		
Gianpiero Tagliaferri		SST-ESC

Current Release				
Ver.	Created	Comment	Distribution	Editor(s)
2b	09/06/2023	Product Review RIX implemented	SST Team, CTAO	Gino Tosti

Version History				
Ver.	Created	Comment	Distribution	Editor(s)
1.aD1	06/09/2022	First draft	SST-PO	
1.aD2	09/11/2022	Second draft	SST-PO	
1.aD3	30/11/2022	Comments to second draft Implemented	SST-PO	
2a	09/06/2023	Product Review issue	SST Team, CTAO, PR Board	

Table of Contents

Table of Contents 3
List of Figures 4
List of Tables 4
1 Introduction 5
1.1 Scope & Purpose 5
1.2 Content 5
1.3 Applicable Documents 5
1.4 Reference Documents 6
1.5 General Specification and Standard Documents 6
1.6 Definition of Terms and Abbreviations 7
2 System Overview 16
2.1 Scope of the SST Telescope 16
3 Telescope Requirements Tree 18
3.1 High-level SST Telescope Product tree and Flow Requirements 18
3.2 SST-CTAO Requirements 19
3.3 SST-CTAO Interface Control Documents 19
3.4 Requirements structure 20
3.5 Shall, Should, May 20
3.6 Definition of Type of Technical Requirements 20
3.7 Definition of the verification methods 21
4 General Requirements 23
4.1 Mechanical Structure Decomposition 23
4.2 Lifetime 23
4.3 Availability 24
4.4 Maintainability 24
4.5 Documentation 24
4.6 Safety and protection 25
5 Environmental 28
5.1 Earthquake 31
6 Functional 34

7 Performance 39
8 Design 42
9 Interfaces 49
10 Quality 51
11 Subsystems Specification 54
11.1 Mount Subassembly 54
11.2 Optical Support Structure 57
11.3 Electrical System 61
11.4 Auxiliary Devices 64
11.5 Mechanical structure maintenance tools 65
11.6 Foundations 66

List of Figures

Figure 1-1: SST Structure State Machine. On/Off states are triggered by the connection/disconnection of the SST to power. 12
Figure 3-1 SST Requirements Flow 18
Figure 3-2: Telescope Product Tree 19
Figure 5-1: CTA South NCE seismic spectra for the SST 33
Figure 6-1 – Control Software Hierarchy of an SST Telescope 34

List of Tables

Table 1. Small-sized telescope main properties. 16

1 Introduction

1.1 Scope & Purpose

This document is the SST Mechanical structure Technical Requirements Specification. It comprises all D-level requirements that are to be respected in the design, manufacturing, assembly, integration, verification and test of the SST mechanical structure subassembly.

Requirements are derived:

- By transposition or decomposition from the SST-TEL C-level requirements from [AD1];
- From relevant ICDs documents.

This document is the source of level D requirements, which are collected in the set of SST Sub-System specifications.

1.2 Content

This document is organised as follows:

Chapter	Content
1	Introduction
2	System Overview
3	Telescope Requirements Tree
4	General
5	Environmental
6	Functional
7	Performance
8	Design
9	Interfaces
10	Quality
11	Subsystems Specification

1.3 Applicable Documents

[AD1] SST-PRO-SPE-001 Telescope Technical Requirements Specification

[AD2] SST Requirements - V1, JAMA REF: SET KEY: PROD_SST; GLOBAL ID: CTA-160212; ID: CTA_-SET-54

[AD3] Common Telescope Requirements - V1, JAMA REF: SET KEY: PROD_TEL; GLOBAL ID: CTA-200234; ID: CTA_-SET-67

[AD4] Environmental Requirements - V1, JAMA REF: SET KEY: PROD_ENV; GLOBAL ID: CTA-200109; ID: CTA_-SET-66

[AD5] SST-PRO-DSR-002 - SST Telescope Architecture and Design Report

[AD6] CTA-ICD-SEI-000000-0002_2h - Generic Telescope Control

[AD7] CTA-ICD-SEI-000000-0016 - ICD between the CTAO-SOUTH Power Distribution System and Small Sized Telescopes

[AD8] Spatial Coordinate Reference Systems

[AD9] CTA-STD-OSO-000000-0001 - Software Programming Standards

[AD10] CTA-TRE-SEI-000000-0016-Draft 04 - CTAO System Control Concept

[AD11] CTA-STD-SEI-000000-0004-1a-DRAFT02 - CTAO System Control Standards

[AD12] CTA-TRE-SEI-000000-0017-1a-Draft 05 - CTAO System Control Development Guidelines

[AD13] CTA-SPE-SEI-400000-0001-1c CTAO South Seismic Risk Specification

[AD14] CTA-TEL-SPE-000000-002_01c Telescope Grounding - Lightning and LEMP Protection

[AD15] CTA-ICD-TEL-405000-0001 ICD between Small Sized Telescopes (SST) and Foundation at CTAO-South

[AD16] CTA-SPE-TEL-000000-0001_2h_Generic Telescope State Machine

[AD17] CTA-TRE-SEI-000000-0015 2i Generic Telescope Use Cases

[AD18] CTA-SPE-TEL-000000-0004_1a_Structural -Analysis-Guidelines

[AD19] SST-PRO-ICD-007-1b_STR-CAM Interface Control Document

1.4 Reference Documents

-

1.5 General Specification and Standard Documents

[SD1] Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on Machinery, and amending Directive 95/16/EC

[SD2] MILITARY HANDBOOK: ELECTRONIC RELIABILITY DESIGN HANDBOOK - MIL-HDBK-338B

[SD3] MILITARY HANDBOOK: RELIABILITY PREDICTION OF ELECTRONIC EQUIPMENT- MIL-HDBK-217F

[SD4] Basis of Structural Design - EN Eurocode 0

[SD5] Steel – Design of Steel Structures – All parts - EN Eurocode 3

[SD6] Design of Composite Steel and Concrete Structures – All parts - EN Eurocode 4

[SD7] Design of Aluminium Structures – All parts - EN Eurocode 9

[SD8] Safety requirements for electrical equipment for measurement, control, and laboratory use - Part 1: General requirements - EN 61010-1

[SD9] Safety of machinery, Functional safety of safety-related electrical, electronic and programmable electronic control systems - EN 62061,

[SD10] Safety of machinery -- Safety-related parts of control systems -- Part 1: General principles for design - EN ISO 13849-1

[SD11] Safety of Machinery – Emergency Stop – Principles for design - EN ISO 13850

[SD12] Low-voltage electrical installations - EN 60364 series

[SD13] Basic and safety principles for man-machine interface, marking and identification - Identification of equipment terminals, conductor terminations and conductors, 2010 - EN 60445,

[SD14] Insulation coordination for equipment within low-voltage systems - EN 60664 series,

[SD15] Reliability Modelling and Prediction reference - MIL-STD-756B

[SD16] System Safety - MIL-STD-882E

[SD17] Procedures for performing a Failure Mode, Effects and Criticality Analysis reference - MIL-STD-1629A

[SD18] EMC Directive 2004/108/EC

[SD19] Electromagnetic Compatibility (EMC) - EN 61000 series

[SD20] Functional Safety and IEC 61508, Functional safety of electrical/electronic/programmable electronic safety-related systems

[SD21] IEC 61131-3, Programmable controllers - Part 3: Programming languages

[SD22] Lightning protection standard - EN 62305:2011

[SD23] Cleanrooms and associated controlled environments — Part 1 - ISO 14644-1:2015

[SD24] ECSS-Q-ST-80C Rev.1 (15 February 2017)

[SD25] CTA-STD-OSO-000000-0002 1h CTA SW Licensing Policy

[SD26] CTA-SPE-OSO-000000-0001 1b Top-level Data Model

[SD27] CTA-SPE-COM-000000-0002 1e R1-Event Data Model

[SD28] CTA-STD-OSO-000000-0001 1a Software Programming Standards

1.6 Definition of Terms and Abbreviations

1.6.1 Abbreviations and Acronyms

ACADA	Array Control and Data Acquisition System
AIT	Assembly Integration and Testing
AIV	Assembly Integration and Verification
ASTRI	Astrophysics with Italian Replicating Technology Mirrors
BKO	Bridging phase Kick-Off
CDR	Critical Design Review
CTA	Cherenkov Telescope Array

CTAO	Cherenkov Telescope Array Observatory
DR	Delivery Review
DVER	Design Verification Engineering Review
ERIC	European Research Infrastructure Consortium
ESC	Executive Steering Committee
FAR	Final Acceptance Review
FRC	France Contribution
IKC	In Kind Contribution
INAF	Istituto Nazionale di Astrofisica
INSU	Institut National des Science de l'Univers
KO	Kick-Off
MPIK	Max-Planck-Institut für Kernphysik
NTP	Network Time Protocol
OP	Observatoire de Paris – PSL, CNRS
PA	Product Assurance
PBS	Product Breakdown Structure
PM	Project Manager
PMC	Pointing Monitoring Camera
PMP	Programme Management Plan
PO	Project Office
PQR	Production Qualification Review
PR	Product Review
PR	Product Review
PRM	Programme Manager
PRR	Production Readiness Review
PSE	Programme System Engineer
QA	Quality Assurance
RAMS	Reliability, Availability, Maintainability & Safety
SE	System Engineer
SST	Small-Sized Telescope
SST-CAM	Small-Sized Telescope Cherenkov Camera
SST-MEC	Small-Sized Telescope Mechanical Structure
TRR	Test Readiness Review
WBS	Work Breakdown Structure
WP	Work Package
WPD	Work Package Description

1.6.2 Glossary

1.6.2.1 General

TERM	DEFINITION
"As Built" Configuration	The as-built configuration or applied configuration is defining the as-built status per each serial number of Configuration Item (CI) subject to formal acceptance.
"As Designed" Configuration	The as-designed configuration or Applicable configuration is defining the current design status of a Configuration Item (CI)
AIV	AIV is the Assembly Integration and Verification, which is referred to the integration activities related with the verification of the system or sub-system. In the framework of SST for briefness this term also includes the Assembly Integration and Testing which is related with the integration activities and testing to be performed during the integration at system and subsystem levels
Baseline	Set of information which describes exhaustively a situation at a given instant of time or over a given time interval.
Change	Vehicle for proposing modifications to an approved baselined data or the business agreement.
Configuration	Functional or physical Characteristics of a product defined in configuration definition documents subject to configuration baseline.
Configuration Item	Aggregation of hardware, software, processed materials, services or any of its discrete portions, that is designated for configuration management and treated as a single entity in the configuration management process. **NOTE:** A configuration item can contain other lower-level configuration item(s).
Deviation	Written authorization to depart from the originally specified requirements for a product prior to its production.
Firmware	Firmware is software programmed onto an electronic device which is treated like a pure hardware.
Executive Steering Committee	The SST Executive Steering Committee (ESC) is the high-level decision-making body which will manage the strategic direction of the Programme and will be in charge of overseeing progress and facilitating global collaboration among the participating groups.
Institutes	Research Institutes involved in the SST Programme.
Contractor	Industry involved in the SST Programme which has a contract with an institute
SST-PRO	It is the team composed by Institutes and Contractors responsible, involved in the production of SST telescopes elements, which coordinate the project level activities.
Hardware	Hardware is a single or an assembly of physical electronic devices which cannot be changed in its user environment.
Item	Any part, component device, sub-unit, unit, equipment, or device that can be individually considered.
Model	Physical or abstract representation of relevant aspects of an item or process that is put forward as a basis for calculations, predictions, or further assessment useful for the preparation of SST production
Partners	are those entities taking responsibility for IKC delivery by signing IKC agreements with CTAO, plus any organisation identified by these signing entities as playing an essential role in SST delivery. The institutes are the partners of the CTA-SST consortium.
Product	A product (hardware, software, service) required in the frame of the program and included as element of the product tree having a unique identifier. A product may be deliverable or not.
Product Breakdown Structure	Hierarchical structure depicting the product orientated breakdown of the project into successive levels of detail down to the configuration items necessary to deliver the required functions. The Product Breakdown Structure (PBS) in general is influenced by Institutes/partners decisions to group certain products or by program history. It identifies products and their interfaces; it serves as the basis for the WBS
Service	Service is the result of at least one activity necessarily performed at the interface between the SST consortium and CTA and is generally intangible.
Software	Set of computer programs, procedures, documentation and their associated data.
SST-E2E	The SST end-to-end telescope, or simply SST, will consist of the SST Structure and the SST Camera (including all mechanics, mirrors, auxiliary devices and required software), integrated and commissioned on-site including all required documents. It ends at (and integrates into CTA via) the system interfaces specified by the CTA PBS.
SST Consortium	The SST Consortium then consists of the Partners and their associated Teams, where a Team is a set of individuals within a single organisation at a single location (such as a university group).
System	An entity of products assembled or working together for a well-defined specified purpose. In SST the term system can be utilised in alternative to Telescope End-to-End.
Sub-System	Like a system but a lower level. In SST the SST system is composed by the subsystem SST-MECH, SST-OPT, SST-TCS and SST-CAM.
Waiver	Written authorization to use or release a product which does not conform to the specified requirements
Work Breakdown Structure	Hierarchical representation of the activities necessary to complete a project.

1.6.2.2 Conditions and Limits

TERM	DEFINITION
Observation Conditions	Environmental conditions under which full operation of the CTA System must be possible without incurring damage.
Precision Pointing Conditions	Environmental conditions under which it is expected that the optimum pointing precision of the CTA System can be achieved.
Normal Conditions	Environmental conditions under which standard operation, engineering and maintenance activities may be undertaken, during day or night.
Transition Conditions	Environmental conditions under which environmental parameters may exceed those of the observing state, whilst the system transitions into a safe state.
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.
Serviceability Limit	Damage can be repaired in-situ using available spare parts and a normal level of on-site manpower.
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.

1.6.2.3 States and Modes

TERM	DEFINITION
State	A State represents a situation where some invariant conditions hold; this condition can be static (waiting for an event) or dynamic (performing a set of activities). The behaviour of a system can be described through its state at different points in time. When a system is in a given state, it can perform different actions or do a transition to another state so that other actions can be performed
Sub-state	A state within another state, where transitions can be managed and triggered internally by the system according to external conditions (e.g. available time inside the current state).
Transition	A Transition defines the logical movement from one State to another.
Mode	The condition of a system or subsystem in a certain state when specific capabilities (or functions) are valid.
Local Mode	Mode of operation of a field-deployed Controllable System activated and deactivated by a person physically present at the location of the system. Whilst in Local Mode the remote execution of all actions that could endanger the safety of a local person is prevented. Local Mode supports engineering and maintenance activities.
Remote Mode	Mode of operation of a Controllable System to allow control by a person not present at the location of the system. Whilst in Remote mode all actions, even those that could endanger the safety of a person present at the system location, are allowed. Remote mode supports observatory science operation mode and system/array-level technical operations mode.
Science Operations Mode	Mode of operation of the Telescope suitable for Science Observations.
Technical Operations Mode	Mode of operation of the Telescope suitable for maintenance and engineering activities, with basic monitoring ongoing, corresponding to typical day-time operations.
Element	May refer to the whole Telescope, or one of its two logical constituents, Structure or Camera

1.6.2.3.1 Machine States

TERM	DEFINITION
Off (State)	The Telescope is without electrical power and beyond the control of the Telescope Control System.
On (State)	The Telescope electrical power is switched on, and it is available to operate under the operational states described below.

TERM	DEFINITION
Maintenance (State)	The Telescope is in a state designed to perform maintenance activities and is unavailable for scientific operations or any kind of remote control. Monitoring information is still, in general, available for ACADA.

1.6.2.3.2 Operational States

TERM	DEFINITION
Configuration (Settings)	Ensemble of settings for a hardware or software system, service, process or any of its discrete portions, determining its functional and/or physical characteristics at a given moment of time.
Initializing (State)	The Telescope just transitioned to the ON machine state and is initializing all its internal components in order to arrive at the Initialized state.
Initialized (State)	The Telescope is in a configuration suitable for survival in extreme conditions, minimising use of power whilst still providing basic status monitoring, and maximising the instrument lifetime.
Standby (State)	The Telescope 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 its internal systems on and is unparked, and Camera is warmed up, but not yet ready for observations (e.g. lids are closed).
Ready (State)	The Telescope is prepared for rapid transition to the Observing State. Internal calibration activities may take place in this state.
Observing (State)	The Telescope 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, and calibration activities may take place.
Fault (State)	The Telescope 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 Telescope should stay in its correct state while such error is solved (the error is to be logged). Whenever the Telescope enters in the Fault state, an Alarm shall be raised to IPS and/or ACADA depending on the nature of the Alarm. The transition to this state is automatically performed by the system.
Technical (State)	This is a special operation mode that allows ACADA to get control of the Structure and the Camera Controller components. It can be used to perform array-level technical operations such as “pointing runs” and special cam-era calibration operations.

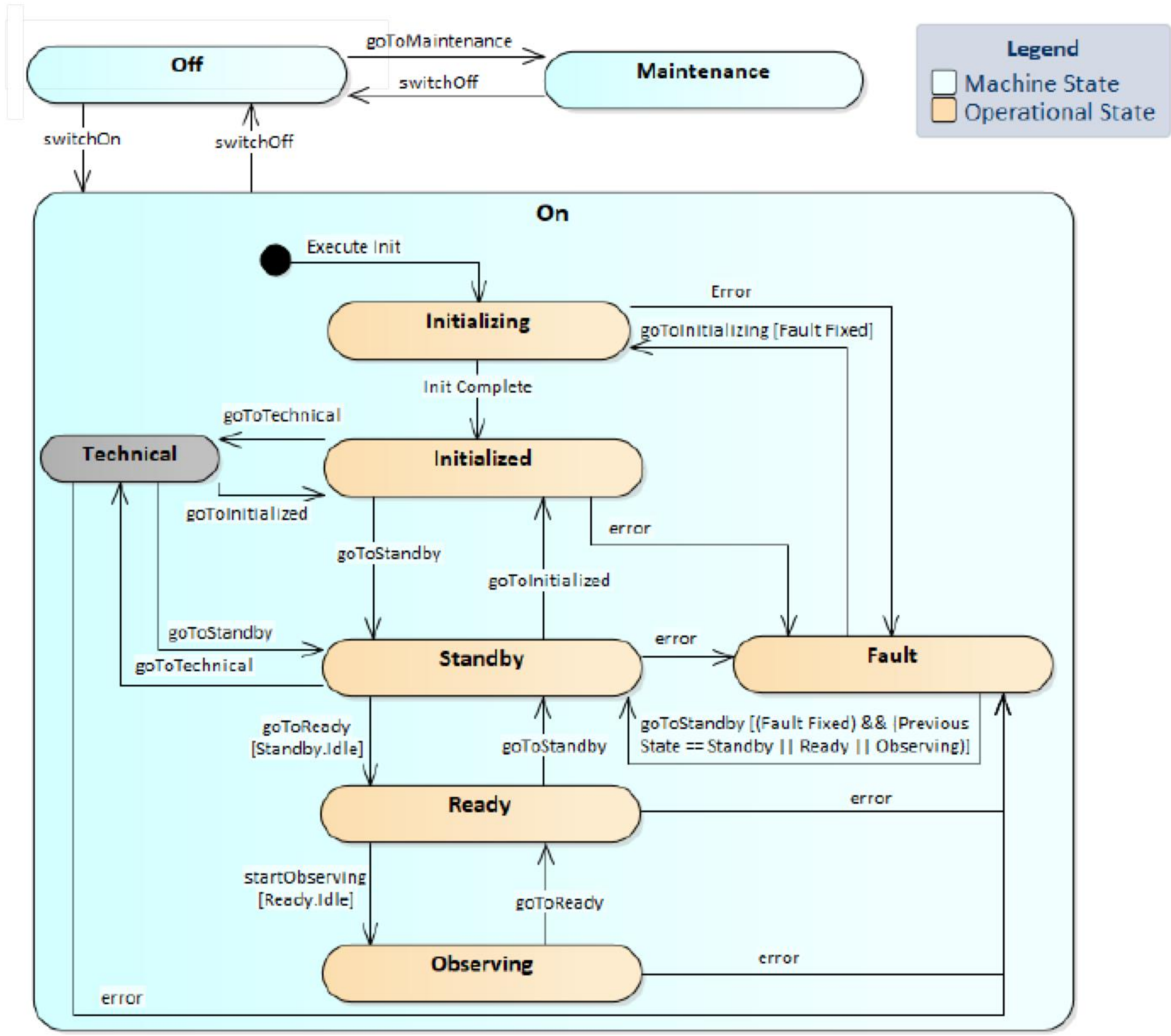


Figure 1-1: SST Structure State Machine. On/Off states are triggered by the connection/disconnection of the SST to power.

1.6.2.4 RAMS Related

TERM	DEFINITION
Emergency stop button	A red mushroom-headed button that, when activated, will immediately start the emergency stop sequence.
Emergency stop (E-Stop)	An E-Stop is a function that is intended to avert harm or to reduce existing hazards to persons, machinery, or work in progress. E-Stop is not a safeguard but is considered to be a complementary protective measure.
Detection Ranking (DET)	DET is a relative numerical scale estimating the effectiveness of the controls to prevent or detect the cause or failure mode before the failure reaches the customer. The assumption is that the cause has occurred.
Occurrence Ranking (OCC)	OCC is a relative numerical scale estimating the probability that the cause, if it occurs, will produce the failure mode and its particular effect.
Emergency situation	An immediately hazardous situation that needs to be ended or averted quickly in order to prevent injury or damage.

TERM	DEFINITION
Severity Ranking (SEV)	SEV is a relative numerical scale estimating how severe the end user (customer) will perceive the Effect of a failure.
Reliability	The probability that an item or system can perform a required function under given conditions for a given time interval.
Risk Priority Number (RPN)	The RPN is a number which quantifies the risk and the impact of failures modes. The RPN is obtained as the product between 'Severity', 'Occurrence' and 'Detection' Ranking numbers.
Maintenance Logistic Time (MLT)	MLT is the time not associated with the Corrective Maintenance work itself (i.e. time for the maintenance technician to prepare work, to order or to obtain spares or special tools if not available on site etc.).
Preventive Maintenance	The maintenance carried out at pre-determined intervals or according to prescribed criteria and intended to reduce the probability of failure or the degradation of the functioning of an item. This shall include First, Second- and Third-Line Maintenance.
Maintenance Person-Hours per Operating Hour (MPH/OH)	The total number of Person-Hours expended divided by the total Operating Hours. Note that MPH/OH is expressed in Maintenance Person-Hours per million Operating Hours.
Maintenance Person-Hours (MPH)	The sum of the individual task hours to: troubleshoot, fault isolate, replace, align or adjust and function check, multiplied by the number of personnel required to do each task.
Maintenance Labour Cost (MLC)	The sum of all direct ACMT cost per unit measure and the direct Preventive Maintenance per unit measure. Note: The unit measure may be per hour, calendar time, kilometre, etc.
Maintenance	All activities necessary to keep an asset in, or restore it to a specified condition, keep it safe, reliable and fit for service throughout the operational lifecycle phase.
Mean Time to Failure (MTTF)	The average lifespan of a given device. MTTF is a reliability measure for non-repairable systems/components. MTTF is calculated as the total operating hours during a specific interval of time divided by the total number of confirmed failures during that same interval of time.
Mean Time Between Failures (MTBF)	The average time between failures of something that can be repaired. MTBF is a reliability measure for repairable systems/components. MTBF is calculated as the total operating hours during a specific interval of time divided by the total number of confirmed failures during that same interval of time. Alternately, MTBF is also known as the reciprocal of the Failure Rate.
Mean Time to Repair (MTTR)	MTTR can be stated, at a given level of maintenance, as the average repair time for individual faults over the life of the equipment. MTTR may include response time (where applicable), diagnostics and rectification of the failure (including software reboot) up to the point that the system is restored to full functionality. In the event that the failure of an item of equipment cannot be rectified, this time measurement includes the time necessary to remove the failed item and replace it with a functioning one. Note: Maintenance Logistic Time required to obtain any special tools or spares is excluded.
Lowest Level Replaceable Unit (LLRU)	The LLRU is the smallest faulty unit the maintenance personnel can identify and isolate at all levels of maintenance within a given Mean Time to Repair (the smallest part of an item that can be replaced to provide an effective repair). Repairs of LLRUs will be undertaken in the specialized workshop.
Line Replaceable Unit (LRU)	The LRU is the smallest faulty unit the maintenance personnel can identify and correct at the First Level of Maintenance to restore system availability within a given Mean Time to Repair (MTTR). Each LRU should be designed for ease of replacement and fault isolation.
Third Level Maintenance (TLM)	If testing, repairing or replacement of a faulty LRU/LLRU, requires specialized skills or test equipment and facilities (typically at manufacturer's site).
Second Level Maintenance (SLM)	If testing, repairing or replacement of a faulty LRU/LLRU, has to be undertaken in a specialized workshop on site.
First Level Maintenance (FLM)	FLM is the maintenance procedure, usually at the location of the failure which consists of diagnosis, recovery of the diagnosis made by the system and possibly its analysis, LRU's/LLRU's replacement and final functional test. This procedure is designed to return the system to service in minimum time, using minimum specialized tools.
Failure Modes, Effects (Criticality) Analysis - FME(C)A	An extension of FMEA in which the "criticality" of the effects is also assessed (identifying risk associated with those failure modes, ranking issues in terms of importance and carrying out corrective actions to address the most serious concerns).

TERM	DEFINITION
Failure Mode and Effects Analysis (FMEA)	A reliability evaluation and design review methodology to analyse system design and performance to determine the effects of each potential failure mode on the system. FMEA uses inductive logic (a process of finding explanations) on a "bottom up" system analysis. Information developed in this procedure is integrated with reliability, logistics, operations, maintainability and troubleshooting procedures.
Systematic Failure	An equipment failure due to an error in the specification, design, construction, installation, operation or maintenance.
Observing Affecting Failure (OAF)	A system failure, which causes an interruption of the Observing time.
Single Point of Failure (SPF)	A failure of a single item which can result in the failure of the system and it is not compensated for by redundancy or alternative operational procedures.
Human Error	A human action (mistake), which can result in unintended system behaviour/failure.
Error	A deviation from the intended design which could result in unintended system behaviour or failure. Note: This definition is usually applicable in reliability discussions and assessments to make a difference between two terms "failure" and "error". This term could have a different meaning in some other fields (i.e. Software).
Fault	An abnormal condition that could lead to a failure in a system. A fault can be random or systematic.
Failure Rate (FR)	The number of failures expected in a given interval of time. Failure rates are usually expressed in failures per million operating hours. For constant failure rate items (i.e. exponentially distributed failures), the failure rate is the numerical inverse (the reciprocal) of the Mean Time Between Failures (MTBF).
Failure	A failure is any incident, malfunction, intermittent condition or a deviation from the specified performance of equipment that prevents it from performing its intended functions or requires manual intervention for safe operation. A failure is considered independent when it is not caused by the malfunction of other equipment, component abuse or incorrect maintenance procedure.
Downtime	The interval of time from the declaration of an Observing Affecting Failure (OAF) to the time that service is fully restored (considering only Observing State time).
Degraded Mode	A system condition with a known but reduced level of functionality in which the System continues to operate, following fault detection and reaction, or when manually selected.
Corrective Maintenance (CM)	The maintenance carried out after a fault recognition and intended to put a product into a state in which it can perform a required function. A CM can be postponed (see DCM) or trigger an emergency (see ECA).
Common Cause Failure	An issue that can cause multiple failures across the system.
Emergency Corrective Action (ECA)	Emergency Corrective Action is when immediate and rapid corrective action is taken, if a breakdown may have consequences for safety or equipment availability, or may have high economic impact.
Deferred Corrective Maintenance (DCM)	All Corrective Maintenance actions that are postponed. For any system breakdown the corrective action can be postponed (becoming a DCM) or a decision may be taken to implement Emergency Corrective Actions (ECA).
Availability	The ability of an item or system to be in a state to perform a required function under given conditions over a given time interval assuming that the required external resources are provided. Generally, the Availability is defined by the formula A = (Uptime) / (Uptime + Downtime), where "Uptime" is the total time that the system is performing required functions and "Downtime" is the time where the system is not able to perform (can include the "time off" if corrective maintenance activities are deferred to be performed during daytime, or "MTTR" if corrective maintenance activities can be done during night in safe conditions, see ECA).
Active Corrective Maintenance Time (ACMT)	The direct time spent by maintenance personnel after the arrival at the location of a failure; to troubleshoot, isolate the fault, repair and complete a functional check and verify that the equipment has been restored to operational status. The ACMT assumes that all documentation, spare parts and minimum required tools and test equipment for First Level Maintenance are available at the specialized workshop on site; Note: Maintenance Logistic Time required to obtain any of above items is excluded from the ACMT.

1.6.2.5 Telescope-Related

TERM	DEFINITION
(Optical) Point-Spread-Function (PSF)	The optical point-spread-function (PSF), as measured in the telescope focal plane, describes the response of the optical system to a point-like source of light. In general, this is a function of the position within the field of view and the pointing direction of the telescope and is affected by the environmental conditions. The optical PSF is typically characterised by the 80% angular light containment diameter Theta_80.
Theta_80	Theta_80 (θ_{80}) is the standard parameter for characterising the optical PSF of a telescope. It is the opening angle (diameter) relative to the light centroid at a specific place within the focal plane, within which 80 percent of those photons that are reflected into a 1 o diameter circle on the camera fall. Unless otherwise specified, the source of light should be assumed to be at infinity. Photons in the wavelength range 300 - 550 nm with the Cherenkov Reference Spectrum. Operating Illumination should be assumed.
Mirror Reflectivity	The fraction of photons incident on an optical element (facet) of a reflector dish, that are focussed into the required FoV. The mirror reflectivity does not include any effects from shadowing by, for example, the support structure of either incoming or outgoing light.
Geometrical Mirror Area	It is the projected area of the primary mirror multiplied by (1-f), where f is the fraction of photons lost due to shadowing (for example by support structures, secondary mirror, camera etc.). The geometrical mirror area is generally a function of the position within the field of view.
Effective Mirror Area	The effective mirror area characterises the light-collection power of the optical system. This quantity is the average of the product of the Geometrical Mirror Area and the mirror reflectivity weighted, in the range 300-550nm, by the Cherenkov Reference Spectrum . The effective mirror area is generally a function of the position within the field of view.
Optical Efficiency	The overall optical efficiency of the system for signal photons, ε_{sig}, is defined as: $\varepsilon_{\mathrm{sig}} = \int_0^\infty F(\lambda)\varepsilon(\lambda)d\lambda / \int_{300\mathrm{nm}}^{550\mathrm{nm}} F(\lambda)d\lambda$ where F (λ) is the nominal Cherenkov Reference Spectrum and ε is the probability that a photon of a given wavelength, incident on the primary mirror and parallel with the optical axis, results in the generation of a detectable photoelectron. This efficiency therefore includes the reflectivity of the mirrors, of light concentrators if present, camera dead space and the quantum and collection efficiencies of photosensors. The optical efficiency for background, ε_{bg} , is defined in an identical way but with F (λ) replaced by the Background Light Reference Spectrum .
Astrometric Accuracy	The accuracy with which a physical position on the focal surface can be mapped to a celestial coordinate in off-line analysis, averaged over the required field of view and expressed as the root-mean-square space-angle deviation from the true value over all pixels, averaging over a timescale of 1 minute.
Post-Calibration Astrometric Accuracy	Astrometric Accuracy achieved after application of full calibration procedure applied as part of the routine production of DL3 data
Online Astrometric Accuracy	Astrometric Accuracy achieved online using fast calibration procedures applied as part of the production of DL0 data

2 System Overview

2.1 Scope of the SST Telescope

When a VHE gamma-ray interacts with the atoms and ions in the upper levels of the atmosphere, it induces a cascade of secondary particles which propagate over many kilometres at a speed higher than the speed of light through the atmosphere. These particles emit Cherenkov light, forward-beamed with an opening angle of about one degree. A Cherenkov light event consists of a time-correlated multi-photon image with a typical timescale of ~10 ns. When a cascade originates at an altitude of 10 km from the telescopes it illuminates a light pool on the ground of about 120 m radius. Imaging cameras specifically designed to this scope detect the Cherenkov light produced by the secondary charged particles. To provide a high imaging sensitivity over an extensive energy range, from a few tens of GeV up to a few hundreds of TeV, the Cherenkov Telescope Array Observatory (CTAO, see web page link at https://www.cta-observatory.org) will be made of sub-arrays with three different types of telescopes: large-sized (LST, 23 m diameter), medium-sized (MST, 12 m diameter) and small-sized (SST, 4 m diameter) telescopes. They are distributed in two observing sites, the Northern one in La Palma, the Canary Islands, and the Southern one in the Chilean Andes in the Paranal area. The CTA South “Alpha Configuration” would include LSTs, MSTs and SSTs. In particular, it envisages the construction and installation of 42 SSTs (a number that could increase up to 70 in future upgrades).

The SSTs are developed by an international consortium of institutes that will provide them as an in-kind contribution to CTAO. The SSTs rely on a Schwarzschild-Couder-like dual-mirror polynomial optical design, with a primary mirror of 4 m diameter, and are equipped with a focal plane camera based on SiPM detectors covering a field of view of ~9°. They are sensitive in the band from ~0.5 TeV up to ~300 TeV, providing the system sensitivity to the highest energies. The current SST concept was validated by developing the prototype dual-mirror ASTRI-Horn Cherenkov telescope and the CHEC-S SiPM focal plane camera. Table 1 reports main properties of the Small-Sized telescope (SST).

Table 1. Small-sized telescope main properties.

Small-Sized telescope (SST) main properties:	
Optical Design	modified Schwarzschild-Couder
Primary reflector diameter	4.3 m
Secondary reflector diameter	1.8 m
Effective mirror area (including shadowing)	>5 m2
Focal length	2.15 m
Total weight	17.5 t
Field of view	> 8.8 deg
Number of pixels in the SST Camera	2048
Pixel size (imaging)	0.16 deg
Photodetector type	SiPM
Telescope data rates (before array trigger)	>600 Hz

Telescope data rates (readout of all pixels; before array trigger)	2.6 Gb/s
Positioning time to any point in the sky (>30° elevation)	90s
Pointing Precision	< 7 arcsecs

3 Telescope Requirements Tree

3.1 High-level SST Telescope Product tree and Flow Requirements

The SST Requirements flow is reported in Figure 3-1.

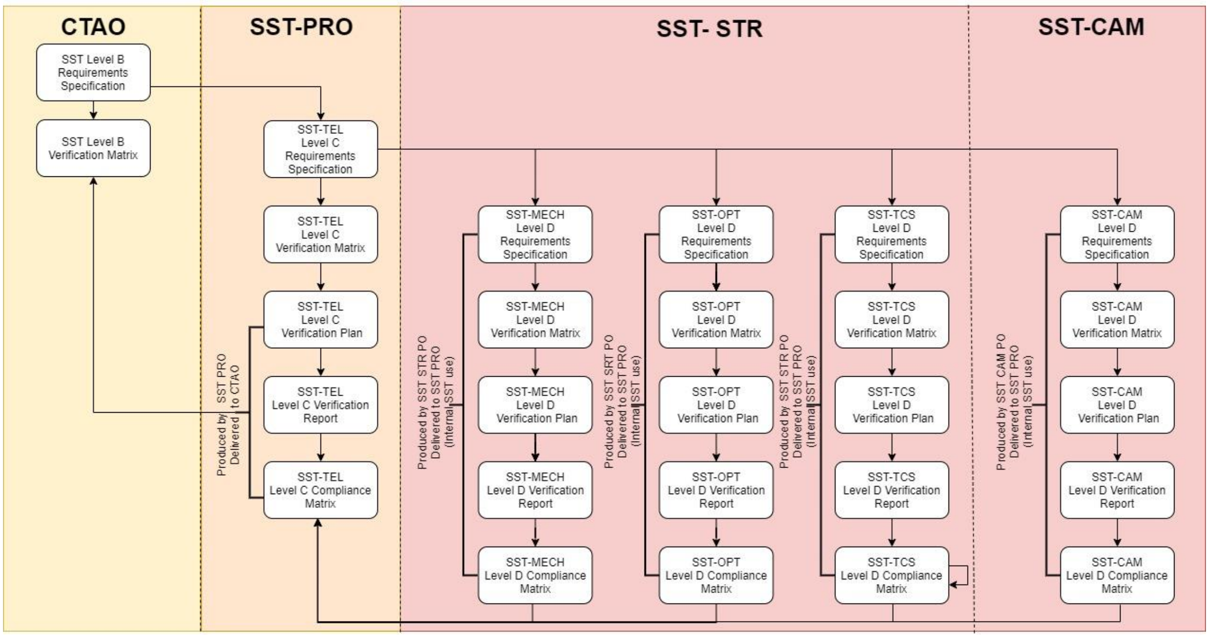


Figure 3-1 SST Requirements Flow

The Product Tree provides the hierarchical product breakdown of the SST Telescope and is reported in Figure 3-2.

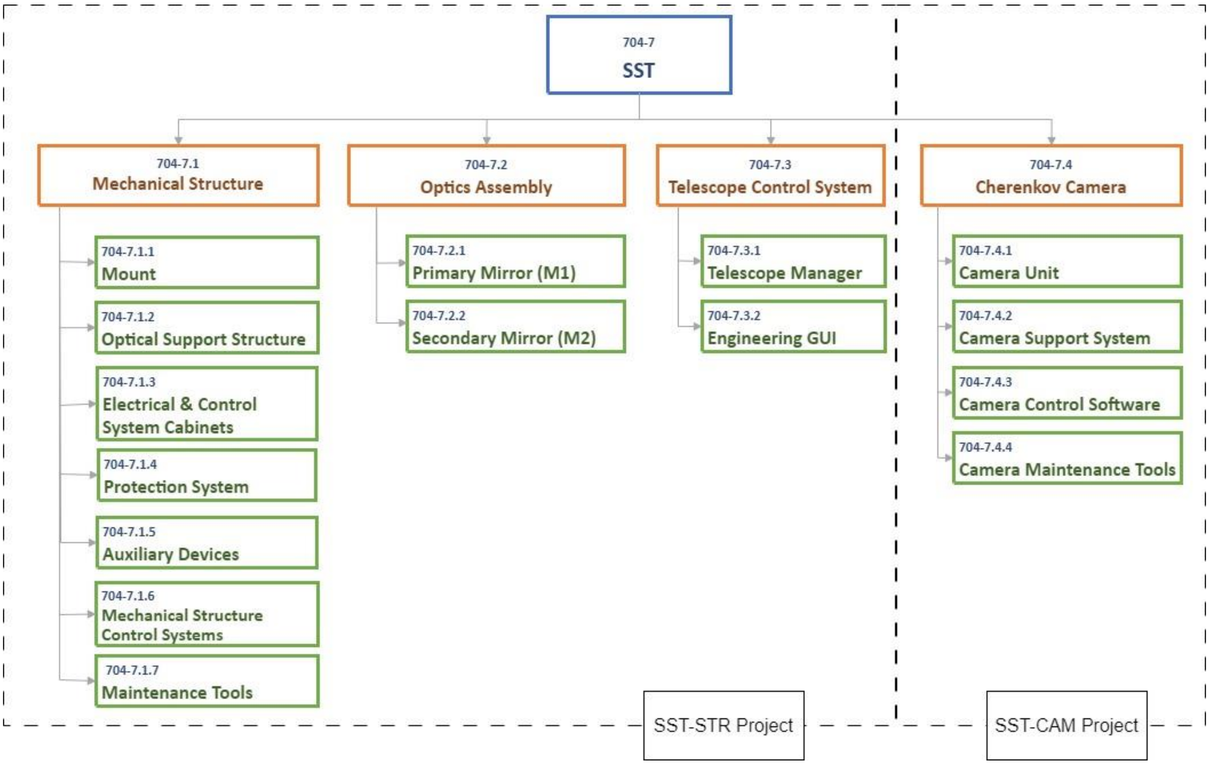


Figure 3-2: Telescope Product Tree

The product tree includes the main physical elements that allocate the function and sub-functions of an SST Telescope (see section 5.2 of the Architecture & Design Summary Report [AD5]).

The levels of the SST product tree shown in figure correspond to the following system hierarchy:

- **System** (Level C Requirements)
  - Telescope (SST-TEL)
- **Subsystems** (Level D Requirements)
  - Mechanical Structure (SST-MEC)
  - Optics (SST-OPT)
  - Camera (SST-CAM)
  - Telescope Control System (SST-TCS)

3.2 SST-CTAO Requirements

The SST-CTAO Requirements applicable are referenced in section 1.3.

3.3 SST-CTAO Interface Control Documents

The SST-CTAO Interface Control Documents applicable are referenced in section 1.3.

3.4 Requirements structure

In order to facilitate later the requirements management, the requirements provided in this document respect editorial conventions to enable the identification of key attributes of requirements and facilitate the transfer of requirements to the requirement management system (JAMA).

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
D-SST-MEC-****	Requirement Name	Requirement Statement	Higher-Level Requirement(s)	$VALUES = {A; C; D; I; R; T} Values are first letter of: Analysis (A), Certification (C), Demonstration (D), Inspection (I), Review of Design (R), Test (T) Renamed from "Verification Method"

3.5 Shall, Should, May

In this document:

Shall – Shall is used to designate a mandatory requirement.

Should – Should is used for requirements that are considered good and are recommended but are not absolutely mandatory.

May – May is used for requirements that are optional. RAL 3016

3.6 Definition of Type of Technical Requirements

The definitions for the various categories of requirements listed in this document are the following:

- **Environmental**. These are all the requirements related to a product or the system environment during its life cycle; this includes the natural environments and induced environments (e.g. radiation, electromagnetic, heat, vibration and contamination).
- **Functional.** These are all the requirements that define what the product shall do, in order to conform to the needs statement or requirements of the user.
- **Lifetime.** These are all the requirements that define the lifetime of the various subsystems.
- **Performance.** These are the requirements that define the quantitative performance metrics of the Telescope.
- **Maintainability**. These are requirements stating all types of maintenance, their frequency, and the conditions under which they are allowed.

- **Availability.** These are the requirements that define the requirements on the availability of the product, i.e. the minimum time between failures requiring maintenance actions.
- **Design**. These are all the requirements related to the imposed design and construction standards such as design standards, selection list of components or materials, interchangeability, safety or margins.
- **Interface**. These are all the requirements related to the interconnection or relationship characteristics between the product and other items.
- **Documentation**. These are all the requirements related to the documentations to be provide be the products.
- **Safety and protection**. These are all the requirements related to the safety/protection systems to be implemented in the Telescope and its subsystems.

3.7 Definition of the verification methods

Verification shall be accomplished by one or more of the following verification methods:

- test;
- analysis (including similarity);
- review-of-design;
- inspection;
- demonstration;
- certification.

All safety critical functions shall be verified by test.

Verification of software shall include testing in the target hardware environment.

3.7.1 Analysis

Verification by Analysis consists of the use of analytical data or simulations under defined conditions to show theoretical compliance. Analysis (including simulation) is used where verifying to realistic conditions cannot be achieved or is not cost-effective and when such means establish that the appropriate requirement, specification, or derived requirement is met by the proposed solution.

3.7.2 Certification

Certification is a written assurance that the product or article has been developed and can perform its assigned functions in accordance with legal or industrial standards. The development reviews and verification results form the basis for certification; however, certification is typically performed by outside authorities, without direction as to how the requirements are to be verified. For example, this method is used for electronics devices via CE certification in Europe and UL certification in the United States and Canada.

3.7.3 Demonstration

Verification by Demonstration consists of a qualitative exhibition of functional performance, usually accomplished with no or minimal instrumentation. Demonstration (a set of verification activities with system stimuli selected by the system developer) may be used to show that system or subsystem response to stimuli is suitable. Demonstration may also be appropriate when requirements or specifications are given in statistical terms.

3.7.4 Inspection

Verification by Inspection consists of performing an examination of the item against applicable documentation to confirm compliance with requirements. Inspection is used to verify properties best determined by examination and observation.

3.7.5 Review-of-design (ROD)

Verification by Review of Design consists of using approved records or evidence that unambiguously show that the requirement is met. For example, design documents and reports, technical description documents, and engineering drawings.

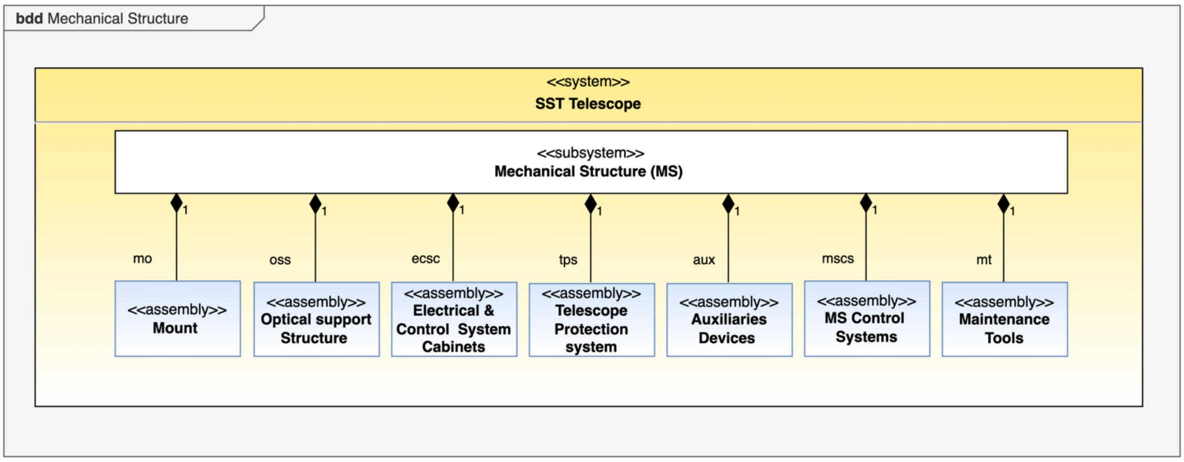
3.7.6 Test

An action by which the operability, supportability, or performance capability of an item is verified when subjected to controlled conditions that are real or simulated. These verifications often use special test equipment or instrumentation to obtain very accurate quantitative data for analysis.

4 General Requirements

4.1 Mechanical Structure Decomposition

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
D-SST-MEC-0003	Mechanical Structure Decomposition	The Telescope Mechanical Structure (SST-MEC) decomposition is given in the figure. Each assembly/subsystem shall be designed and built to be compliant with the functional decomposition described in [AD5]	C-SST-TEL-0003	R



4.2 Lifetime

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
D-SST-MEC-0520	Structural Elements Lifetime	The structural elements of the SST-MEC shall be designed and built for an operational Lifetime of 30 years.	C-SST-TEL-0520	A
D-SST-MEC-0530	Drive Lifetime	The SST-MEC drive systems, including servos and gearboxes, shall be designed and built for an operational Lifetime of 15 years.	C-SST-TEL-0530	A

4.3 Availability

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
D-SST-MEC-0310	Telescope availability	The availability of the SST-MEC shall be > 98.5% of the observation time.	C-SST-TEL-0310	A

4.4 Maintainability

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
D-SST-MEC-0320	Structure Preventive Maintenance	The on-site SST-MEC preventive maintenance activities shall require on average < 0.5 person hours / week	C-SST-TEL-0320	A
D-SST-MEC-0332	Structure Corrective Maintenance	The on-site SST-MEC corrective maintenance activities shall require on average < 1 person hours / week	C-SST-TEL-0332	A
D-SST-MEC-2100	Interchangeability	The design of SST-MEC shall consider interchangeability requirements related to the long lifetime of the instrument. Standardized components shall be adopted in the design as much as possible, so that in case of future unavailability of spare parts, equivalent ones from other manufacturers may be found on the market. In particular, the probable non-availability or poor availability of electronic components over the long instrument lifetime shall be considered.	C-SST-TEL-2100	R

4.5 Documentation

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
D-SST-MEC-0508	Maintenance Plans	The SST-MEC Maintenance plan and Maintenance procedures to access, and repair / replace any LRU shall be prepared in compliance with CTAO Maintenance Concept.	C-SST-TEL-0508	R

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
D-SST-MEC-0522	Spare parts	The level of spare parts needed for the SST-MEC maintenance shall be documented.	C-SST-TEL-0522	R
D-SST-MEC-0532	Documentation	The SST-MEC and its subsystems shall be fully documented in terms of operational use and composition/design.	C-SST-TEL-0532	R
D-SST-MEC-0340	Camera Loading and Unloading Procedure Documentation	The SST-MEC Camera Unit loading and unloading system and procedures shall be clearly documented, specifying the levels of personnel and equipment needed for the procedure to be safely completed within one working day.	C-SST-TEL-0340	R
D-SST-MEC-0501	Fixation to Foundation Documentation	The SST-MEC shall be fixed to the Telescope Foundation according to [AD15].	C-SST-TEL-0501	R
D-SST-MEC-2170	Local control system Interfaces	The SST-MEC local control system (LCS) interface with the Telescope Control system (TCS) shall be described in the Interface Control Document.	C-SST-TEL-2170	R
D-SST-MEC-2180	LCS – SST TCS Interface Control document	The SST-MEC LCS – TCS Interface Control document shall be provided as an Excel file and a Word document following the dedicated templates.	C-SST-TEL-2180	R
D-SST-MEC-2190	Local control system ICD	Each SST-MEC LCS shall use the Ethernet OPC-UA communication protocol (IEC 62541) to exchange with the TCS the information described in the Interface Control Document.	C-SST-TEL-2190	R

4.6 Safety and protection

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
D-SST-MEC-0170	Safety Signalling	The SST-MEC shall be designed and built including safety subsystems, signs, acoustic and light signalling according to ISO 7010:2019 and EN 981:1996+A1:2008 and subsequent	C-SST-TEL-0170	R, C

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
		amendments - needed to prevent human injuries.		
D-SST-MEC-0142	Sudden Loss of Power	SST-MEC shall be designed and built to prevent Damage beyond the Serviceability Limit State in case of sudden loss of electrical power.	C-SST-TEL-0142	D
D-SST-MEC-0160	Movement notification	The SST-MEC Control System shall be designed and implemented to be able to generate an audible and visible alarm signals before any potentially dangerous mechanical motion of the system commences according to Machinery Directive, Directive 2006/42/EC	C-SST-TEL-0160	D
D-SST-MEC-0322	Fire Protection	The SST-MEC and its subsystems shall be designed and built according to the fire regulations described in the Guide to application of the Machinery Directive 2006/42/EC, Edition 2.2 – October 2019, Annex I, 1.5.6 §227, 3.5.2 §321.	C-SST-TEL-0322	R, C
D-SST-MEC-0580	Drive Control Safety	The SST-MEC control systems and any other moving part shall be provided with safety interlocks to prevent injury to personnel or damage to telescopes that might result from inadvertent operation, human error, or mechanical or control system failure as described in the Guide to application of the Machinery Directive 2006/42/EC, Edition 2.2 – October 2019 for the safety of the machinery.	C-SST-TEL-0580	R
D-SST-MEC-0180	Movement Control	The SST-MEC shall implements hardware and software Safety mechanisms to ensure that the Telescope can never move in an uncontrolled manner.	C-SST-TEL-0180	R
D-SST-MEC-0190	Emergency Stop	The SST-MEC shall have a general emergency stop function to eliminate the risk of human injury or death associated with mechanical motions of the System. The Emergency Stop function shall be provided according to Guide to application of the Machinery Directive 2006/42/EC Edition 2.2 – October 2019, 1.2.4.3 Emergency stop, §202 Emergency stop devices. In case of an emergency situation, the general emergency stop function will stop all significant motions of all moving structural elements with the fastest controllable	C-SST-TEL-0190	R, C

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
		deceleration, such that no additional risks would be introduced.		
D-SST-MEC-0312	Lightning Protection	The SST-MEC shall implement a Class 1 lightning protection system in accordance with the international lightning protection standard IEC 62305-1-4:2010.12 and with the CTAO specification [AD14]	C-SST-TEL-0312	R, C
D-SST-MEC-2370	Error Recovery procedure failure	In case an error recovery procedure for any SST-MEC subsystem fails, the SST-MEC LCS shall automatically transit to Fault state that prevents damage. The SST-MEC LCS shall notify the fault State to the TCS on the basis of the SST-MEC to TCS Interface Control Documents.	C-SST-TEL-2370	D
D-SST-MEC-2380	Alarm Generation	If an error recovery procedure for any SST-MEC subsystem fails, the SST-MEC LCS shall send an alarm to the TCS on the basis of the SST-MEC LCS to TCS Interface Control Documents.	C-SST-TEL-2380	D
D-SST-MEC-2390	Performance monitoring	The SST-MEC Control systems shall monitor the performances of any SST-MEC subsystem and notify an alarm to the TCS, if they do not met the requirements.	C-SST-TEL-2390	R
D-SST-MEC-2400	Support for troubleshooting activities	The SST-MEC LCS shall provide the support to all troubleshooting activities down to the level of LRUs of each SST-MEC Subsystem.	C-SST-TEL-2400	R

5 Environmental

Parameter	Precision	Observation	Transition	Survival
Air Pressure	770 ±50 mbar			
Air Temperature	-5°C < T < 25°C		T<-5°C or T>25°C	-15°C < T < 35°C
Temperature gradient	≤ 3°C/h	≤ 7.5°C/h	>7.5°C/h	0.5°C/min for 20 min
Relative Humidity	2% < RH < 90%		RH < 2% or RH > 90%	2% < RH < 100%
Misting	T is >2°C greater than dew point		-	
Rain	-		≤2mm in 1h	≤70mm in 1h; ≤200mm in 24h;
Snow load	-			<20 kg/m2
Ice load	-			20mm thickness (on all surfaces)
Hailstone	-			Ø=5mm, E=0.2 J
Wind, sustained for 10 min	≤11km/h	≤36km/h	≤50 km/h	≤100 km/h parked; ≤60 km/h in transitions
Wind gusts (1 sec)	-	-	-	≤170 km/h parked
Solar radiation				1200 W/m^2 averaged over 1 hour
Dust and sand				2.9 x 10^5 particles of ≥5µm size per m^3 of air for 90% of the time at 2m above ground
Illumination	-			≤10^6 photons ns−1 cm−2

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
D-SST-MEC-0060	Electromagnetic Compatibility	The **SST-MEC** and its subsystems shall be designed and built in compliance with the Electromagnetic Compatibility (EMC) Directive 2014/30/EU.	C-SST-TEL-0060	R, C

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
D-SST-MEC-0235	Precision Pointing Stability Temperature Gradient	The SST-MEC and its subsystems shall be able to satisfy the precision pointing requirements under temperature gradients of up to 3ºC/h	C-SST-TEL-0235	A
D-SST-MEC-0310	Observation humidity	The SST-MEC and its subsystems shall be designed and built to meet the scientific performance requirements for observations within the relative humidity range 2% to 90%.	C-SST-TEL-0310	R
D-SST-MEC-0324	Survival humidity	The SST-MEC and its subsystems shall be designed and built do not suffer damage when the on-site relative humidity of the atmosphere is within the range 2% to 100%, when the SST-MEC is the Initialized State or when no electrical power is available.	C-SST-TEL-0324	R
D-SST-MEC-0420	Radio Frequency Interference	The SST-MEC and its subsystems shall be shall be designed and built according to the Directive 2014/30/EU on radio frequency interference.	C-SST-TEL-0420	R, C
D-SST-MEC-0422	Rain	The SST-MEC and its subsystems shall be designed and built do not suffer damage when the on-site rain precipitation is of up to 70 mm in 1 hour, or is of up to 200 mm in 24 hours	C-SST-TEL-0422 C-SST-TEL-0412 C-SST-TEL-0460	R, D
D-SST-MEC-0525	Survival snow load	The SST-MEC and its subsystems shall be designed and built do not suffer damage beyond the Serviceability Limit State when is in the Initialized state and the snow loads is of up to 20kg / m^2.	C-SST-TEL-0525	A
D-SST-MEC-0810	Solar radiation level	The SST-MEC and its subsystems components shall be designed and built do not suffer damage when regularly exposed to direct solar radiation of up to 1200 W/m^2 (averaged over 1 hour) at a maximum ambient temperature of 35 C.	C-SST-TEL-0810	R, A
D-SST-MEC-0915	Dust and sand	The SST-MEC and its subsystems components shall be designed and built do not suffer damage due to an environment with up to 2.9 x 10^5 particles of ≥5µm size per m^3 of air for 90% of the time at 2m above ground. Note: This limit corresponds to the definition of ISO-Class 9 of ISO14644-1 for particles of this size	C-SST-TEL-0915	R

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
D-SST-MEC-1020	Aggressive atmosphere	The SST-MEC and its subsystems components shall be designed and built do not suffer damage when installed at the CTA-S site, due to the following Aggressive Atmospheric Concentration ranges: NO, NO2, SO2 < 4ppb.	C-SST-TEL-1020	R
D-SST-MEC-1112	Earthquake damage limitation (South)	The SST-MEC and its subsystems shall meet the Damage Limitation Requirement (DLR) as defined in Eurocode 8 based on the earthquake excitation at ground level defined in [AD13]	C-SST-TEL-1112	A
D-SST-MEC-1120	Earthquake collapse prevention (South)	The SST-MEC and its subsystems shall meet the No-Collapse Requirement (NCR) as defined in Eurocode 8, based on the earthquake excitation at ground level defined in [AD13]	C-SST-TEL-1120	A
D-SST-MEC-0135	performance Atmospheric Pressure	The SST-MEC and its subsystems shall be designed and built to meet the performance requirements in the on-site atmospheric pressure range of 770 +/- 50 mbar.	C-SST-TEL-0135	R, A
D-SST-MEC-0210	Performance Temperature	The SST-MEC and its subsystems shall be designed and built to meet the on-site performance requirements in the temperature range [-5 C;+25 C]	C-SST-TEL-0210	R, A
D-SST-MEC-0225	Survival Temperature	The SST-MEC and its subsystems shall be designed and built to suffer no damage beyond the Serviceability Limit State for on-site ambient temperatures in the range [-15 C;+35 C]	C-SST-TEL-0225	R
D-SST-MEC-0230	Temperature Gradient	The SST-MEC and its subsystems shall be designed and built to meet the performance requirements during on-site air temperature gradients of less than 7.5 C/h.	C-SST-TEL-0230	A
D-SST-MEC-0530	Hailstone damage	The SST-MEC and its subsystems shall be designed and built do not suffer Damage due to the impact of 5 mm diameter hailstones with kinetic energy of 0.2 Joule.	C-SST-TEL-0530	A
D-SST-MEC-0625	Survival ice load	The SST-MEC and its subsystems shall be designed and built do not suffer Damage beyond the Serviceability Limit State due to an ice thickness (on all surfaces) of up to 20 mm.	C-SST-TEL-0625	A

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
D-SST-MEC-0710	Observation Wind Speed	The **SST-MEC** and its subsystems shall be designed and built to meet the Scientific performance requirements for observations under 10-minute average wind speeds of up to 36 km/h.	C-SST-TEL-0710	T, A
D-SST-MEC-0716	Precision Pointing Wind Speed	The **SST-MEC** S and its subsystems shall be designed and built to achieve precision pointing fulfilling B- SST-0020 under 10-minute average wind speeds of up to 11 km/h.	C-SST-TEL-0716	T, A
D-SST-MEC-0724	Wind Speed during Transitions	The SST-MEC and its subsystems shall be designed and built to suffer no damage during transitions due to wind speeds of up to 50 km/h averaged over 10 minutes	C-SST-TEL-0724	T, A
D-SST-MEC-0725	Maximum Wind Speed during Transitions	The SST-MEC and its subsystems shall be designed and built to suffer no damage beyond the Serviceability Limit State due to wind speeds up to 60 km/h, averaged over 10 minutes.	C-SST-TEL-0724	A
D-SST-MEC-0743	Damage Wind Speed	The **SST-MEC** and its subsystems shall be designed and built to suffer no damage due to wind speeds of up to 80 km/h averaged over 10 minutes, when in parking position.	C-SST-TEL-0428 C-SST-TEL-0743	A
D-SST-MEC-0745	Survival Wind Gusts	The SST-MEC and its subsystems shall be designed and built to suffer no damage beyond the Serviceability Limit State at the CTA site due to wind gusts (duration 1 s) of up to 170 km/h, when in parking position.	C-SST-TEL-0744 C-SST-TEL-0745	A
D-SST-MEC-0746	UV radiation level	The SST-MEC and its subsystems components exposed to direct solar radiation shall be UV resistant and not suffer degradation which cannot be recovered during the normal maintenance conditions defined in the RAMS requirements.	-	R

5.1 Earthquake

The SST-MEC seismic analysis shall be performed according to the Seismic risk specifications for the CTA South site released by CTAO in [AD13].

Seismic design and analysis of the SST shall be performed in accordance with EN 1998-1 (Eurocode 8).

5.1.1 Seismic analysis parameters

Seismic effect on the SST-STR shall be assessed by means of a modal response spectrum analysis (RSA).

A critical damping ratio of 2% shall be assumed when calculating the seismic spectra, as it the standard ratio adopted for welded steel structures (or bolted steel structure with no sliding of friction joints).

Behaviour factor q shall be equal to 1.

Seismic spectra as s function of period shall be calculated according to the following formulae (Eurocode8 - EN 1998-1 section 3.2.2.2):

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

- $\eta = [10 / (5 + \xi)]^{½}$ (see also EC 8, Section 3.2.2.2)
- Se (T) is the elastic acceleration response spectrum in [g]
- T is the vibration period in [s]
- a_g Peak Ground Acceleration in [g]
- c is the ratio between the maximum and the peak ground acceleration
- T_B is the lower limit of the constant spectral acceleration branch in [s]
- T_C is the upper limit of the constant spectral acceleration branch in [s]
- T_D is the value defining the beginning of the constant displacement response range in [s]
- η is the damping correction factor
- ξ is the damping ratio in percent

5.1.2 Damage limitation Requirement (DLR)

Peak horizontal ground acceleration at 5% damping ratio: 0.25g

Peak vertical ground acceleration at 5% damping ratio: 0.15g

10% probability of exceeding these figures in 10 years (reference return period 95 years).

Other parameters for the seismic spectra calculation are reported in the following table:

- DLR SST (Soft Soil, 5% damping)

Parameters	a_g	S	T_B	T_C	T_D	c
	[g]	[-]	[s]	[s]	[s]	[-]
Horizontal	0.25	1.80	0.10	0.35	2.00	2.5
Vertical	0.15	2.30	0.05	0.30	2.00	3.0

With these conditions, all system shall meet the Damage Control Limit requirement. If DCL criteria are satisfied for the NCR earthquake level, it is not necessary to verify DLR itself.

5.1.3 No Collapse Requirement (NCR)

Peak horizontal ground acceleration at 5% damping ratio: 0.43g

Peak vertical ground acceleration at 5% damping ratio: 0.26g

10% probability of exceeding these figures in 50 years (reference return period 475 years).

Other parameters for the seismic spectra calculation are reported in the following table:

- NCR SST (soft Soil. 5% damping)

Parameters	a_g	S	T_B	T_C	T_D	c
	[g]	[-]	[s]	[s]	[s]	[-]
Horizontal	0.43	1.70	0.10	0.35	2.00	2.5
Vertical	0.26	1.80	0.05	0.30	2.00	3.0

With these conditions, all systems shall meet the Collapse Prevention Limit state.

The seismic spectra at 2% damping ratio as a function of frequency is given in the following plot:

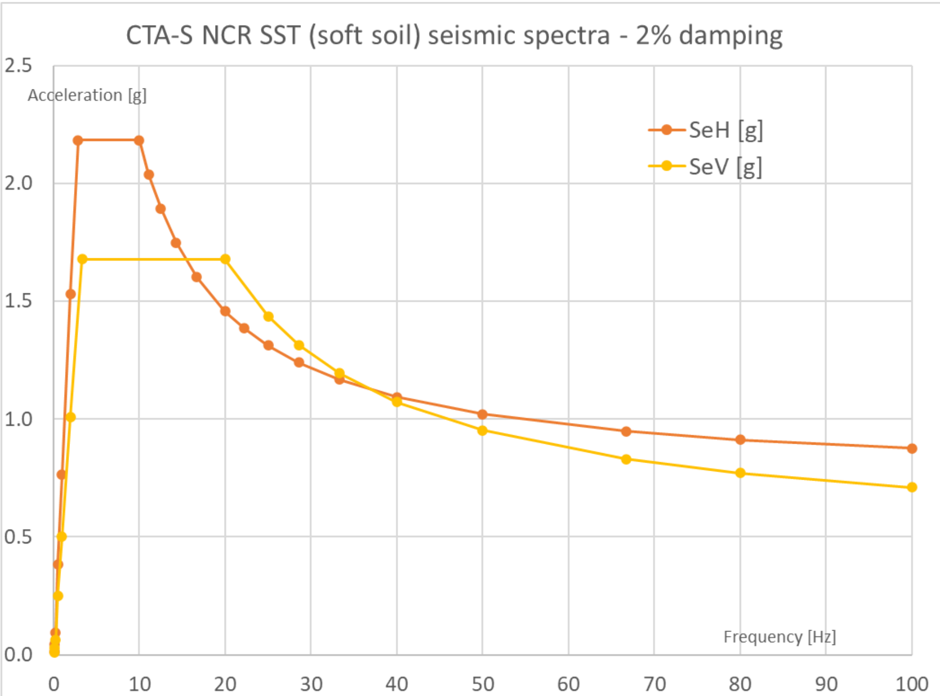


Figure 5-1: CTA South NCE seismic spectra for the SST

6 Functional

These requirements are related to the functions implemented by the SST-MEC Control system, that is by the hardware and software components of the SST-MEC.

The SST-MEC includes multiple Local Control Systems which control the field devices (actuators and sensors). The local control system concept is defined in [AD10] and are parts of the full CTAO Array Elements Control Hierarchy. The SST Control Software hierarchy is reported in Figure 6-1.

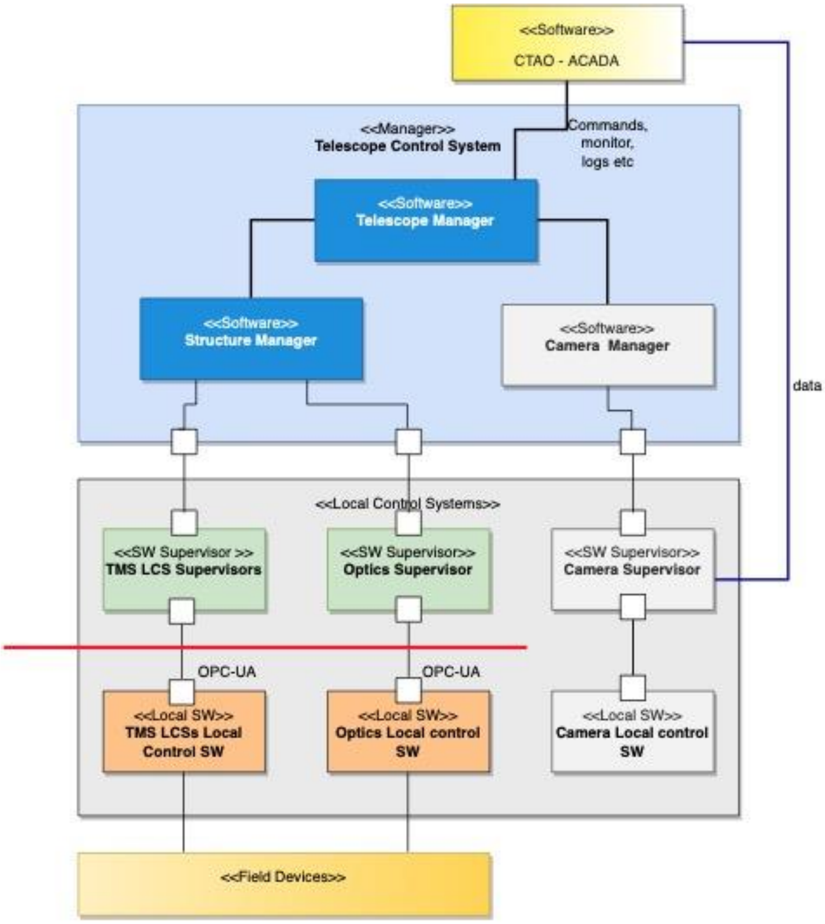


Figure 6-1 – Control Software Hierarchy of an SST Telescope

The Telescope Control System is the software deployed at the central computing cluster providing the high-level control interface to the ACADA for an individual SST Telescope. The TCS implements at least the functions described in [AD17]. The TCS has a Camera Manager and a Structure manager functional unit, both coordinated by a Telescope Manager component. The Telescope Manager is responsible for managing the Telescope system as a whole, delegating to Camera and Structure subsystems the implementation of associated operations. The TCS is a composition of Alma Common Software (ACS) components.

The SST-MEC functions are coordinated by the ACS Structure manager component. The Structure Manager coordinates all the Local control systems (LCSs) of the SST-MEC. The high-level functionalities of each LCS are provided by the LCS Supervisor. The LCS Supervisor is an ACS component that is directly used by the Structure manager and is deployed, like the Structure managed and the other TCS components, at the CTAO Data Centre. The Supervisor control and monitor one or more Local Control software running on the LCS local Controllers (e.g. PLC, PC etc) installed on the Telescope control cabinet. The Local Controller, or local Control Unit, run the local control software needed to control and monitor the field devices. The Supervisors communicates with the local control software via the OPC-UA protocol.

The CTAO System Control Concept [AD10] defines the State machine of the Telescope, Structure and Camera. These states correspond to the Operating Mode and Access Mode of a Machine as defined in the in the 2006/42/EC Machine Directive.

The SST-MEC shall implement the OFF, ON and Maintenance states and transitions described in [AD10].

The CTAO Generic Telescope State Machine applicable document [AD16], define the Operational States (On-State Sub-states) that shall be implemented by the Telescope Structure. The SST-MEC LCS shall implement the Structure operational states and transitions.

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
D-SST-MEC-0112	Power On Transition	The SST-MEC LCSs shall automatically transit to the Initialized State, when the Telescope is powered (On State).	C-SST-TEL-0112	D,T
D-SST-MEC-0150	Transitions out of Initialized State	The SST-MEC LCSs shall not automatically initiate a transition from Initialized State to higher states (Standby, Technical) according to [AD6] and [AD16].	C-SST-TEL-0150	D,T
D-SST-MEC-0280	Condition Monitoring	The condition of the SST-MEC critical subsystems (drive systems, etc.) shall be continuously monitored by a dedicated Local Control System, to allow early identification of problems and increased availability due to replacement of parts prior to failure, following the Condition Monitoring Plan.	C-SST-TEL-0280	R, D,T
D-SST-MEC-0622	State Machine	The SST-MEC and its subsystems shall implement the states and the machine states as defined in [AD16] and [AD6].	C-SST-TEL-0622	R, D,T
D-SST-MEC-0632	State Transitions	The SST-MEC and its subsystems shall implement the transitions between state machine states defined in [AD6] and [AD16].	C-SST-TEL-0632	R, D,T

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
D-SST-MEC-0633	LCS Internal States and State Transitions	The SST-MEC Local Control systems shall implement the internal states and transitions as defined in [AD6] and [AD16].	C-SST-TEL-0633	R, D,T
D-SST-MEC-0700	LCS Fault Detection Isolation Recovery	The ST-MEC and its Local Control Systems shall implement a fault detection, isolation and recovery system.	C-SST-TEL-0700	R, D,T
D-SST-MEC-0740	LCS Fault Recovery Behaviour	The SST-MEC Local Control system shall prevent damage to instrumentation in case of Fault Recovery actions fail.	C-SST-TEL-0740	R, D,T
D-SST-MEC-0750	LCS Fault State Transition	The SST-MEC Local Control Systems shall automatically transition to the Fault State in compliance to [AD6] and [AD16], whenever a Critical or Catastrophic Error happens (as defined in a dedicated Document).	C-SST-TEL-0750	R, D,T
D-SST-MEC-0729	Local Control Software Internal Error Notification	The SST-MEC LCS Local Control Software shall notify any error to the LCS supervisor.	C-SST-TEL-0729 C-SST-TEL-2220	D
D-SST-MEC-0441	Mount Pointing Information	The SST-MEC Mount LCS Local Control software shall provide its nominal current pointing direction (in Horizon coordinates) on request from the Mount LCS Supervisor.	C-SST-TEL-0441	D,T
D-SST-MEC-2210	Local Control Software Local Errors	The SST-MEC LCS Local control software shall monitor all parameters needed to assess the health and status of SST-MEC and its subsystems.	C-SST-TEL-2210	R, D,T
D-SST-MEC-2230	Local Control Software Automatic recovery procedure	Each SST-MEC LCS Local control software, when possible, shall implement automatic error recovery procedures.	C-SST-TEL-2230	R, D,T
D-SST-MEC-2240	Local Control Software Recovery reporting to upper level	Each SST-MEC LCS Local control software shall notify to the LCS Supervisor the results of the error recovery procedure on the basis of the SST-MEC LCS Local Control Software to LCS Supervisor Interface Control Document.	C-SST-TEL-2240	D,T

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
D-SST-MEC-2250	Local Control Software State Change Notification	Each SST-MEC LCS Local control software shall notify to the LCS Supervisor the change of state of the SST-MEC on the basis of the LCS Local Control Software to LCS Supervisor Interface Control Document.	C-SST-TEL-0761 C-SST-TEL-2250	D,T
D-SST-MEC-2270	Transition Interruption	The SST-MEC LCS shall allow to interrupt transitions between states upon request by the TCS. The SST-MEC LCS shall return to the previous state within the corresponding transition time.	C-SST-TEL-2270	D,T
D-SST-MEC-2280	Time Synchronization	The SST-MEC LCS internal time shall be synchronized to the CTAO NTP Time provided by the CTAO Time synchronization system.	C-SST-TEL-2280	D,T
D-SST-MEC-2290	Local Control Software Monitoring Data	The SST-MEC LCS Local Control Software shall provide monitoring information to the LCS Supervisor on the basis of the LCS local Control Software to LCS Supervisor Interface Control Document.	C-SST-TEL-2290	D,T
D-SST-MEC-2300	Local Control Software Logging	The SST-MEC LCS Local Control Software shall provide logging information to the LCS Supervisor on the basis of the LCS local Control Software to LCS Supervisor Interface Control Document.	C-SST-TEL-2300	D,T
D-SST-MEC-2310	Local Control Software Configuration	The SST-MEC LCS Local Control Software shall receive configuration from the LCS Supervisor on the basis of the LCS local Control Software to LCS Supervisor Interface Control Document.	C-SST-TEL-2310	D,T
D-SST-MEC-2320	Local Control Software Command	The SST-MEC LCS Local Control Software shall receive commands from the LCS Supervisor on the basis of the LCS local Control Software to LCS Supervisor Interface Control Document.	C-SST-TEL-2320	D,T
D-SST-MEC-2330	Mount Autostow	The SST-MEC Mount LCS shall provide a configurable time period for stow after losing communication (default to 5 minutes).	C-SST-TEL-2330	D,T
D-SST-MEC-0424	Mount Home Position	SST-MEC shall have a "Home" position to which the Mount LCS moves to during the unparking procedure, and return to prior to the Parking, at the minimum elevation at which all azimuthal angles are accessible.	C-SST-TEL-0424	D,T

7 Performance

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
D-SST-MEC-0020	Post-Calibration Astrometric Accuracy	The SST-MEC and its subsystems shall be designed and built to reach the Post-Calibration Astrometric Accuracy <7 arcseconds whilst Tracking during Precision Pointing Conditions.	C-SST-TEL-0020	A, T
D-SST-MEC-0040	Online Astrometric Accuracy	The SST-MEC and its subsystems shall be designed and built to reach the Online Astrometric Accuracy of the Telescope whilst Tracking shall be < 60 arcseconds.	C-SST-TEL-0040	A, T
D-SST-MEC-0110	Mirror Area	The SST-MEC and its subsystems shall be designed and built to introduce no effects of shadowing that in addition to the shadowing introduced by the by the camera and its support structure and by the secondary mirror, reduce the Geometrical Area of the Primary Mirror to <=5 m^2 for all angles within the required Camera Field of View.	C-SST-TEL-0110	R
D-SST-MEC-0030	Standard Post-Calibration Astrometric Accuracy	The SST-MEC and its subsystems shall be designed and built to reach the Post-Calibration Astrometric Accuracy < 20 arcseconds under standard observing conditions.	C-SST-TEL-0030	A, T
D-SST-MEC-0214	Repositioning Time	The SST-MEC shall be able to slew from any point in the to any other point above 30° in elevation within 70 seconds if the wind speed is below 36 km/h and making use of the full azimuthal and elevation movement ranges, in response to a repositioning request flagged as time critical.	C-SST-TEL-0214	A, T
D-SST-MEC-0232	Tracking Accuracy in Azimuth	The SST-MEC shall be able to Track any Astrophysical Target having the Horizontal Coordinate System Azimuth angle within the range 0 - 360 degrees with an instantaneous accuracy of <0.1 degrees on both axes for 99% of the tracking time.	C-SST-TEL-0232	A, T
D-SST-MEC-0254	Tracking Accuracy in Elevation	The SST-MEC shall be able to Track any Astrophysical Target having the Horizontal Coordinate System Elevation angle within the range 20° - 89.2° with an instantaneous accuracy of <0.1 degrees on both axes for 99% of the tracking time.	C-SST-TEL-0254	A, T

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
D-SST-MEC-0610	Average Structure Power Consumption during Observations	The average power consumption of the SST-MEC during Observations shall not exceed 3 (TBC) kW.	C-SST-TEL-0610	A, T
D-SST-MEC-0620	Peak Structure Power Consumption during Observations	The peak power consumption by a single SST-MEC during Observations shall not exceed 7 kW.	C-SST-TEL-0620	A, T
D-SST-MEC-0630	Peak Structure Power Consumption in the Initialized State	The peak power consumption by a single SST-MEC in the Initialized State shall not exceed 2.2 kW.	C-SST-TEL-0630	A, T
D-SST-MEC-0640	Annual Average Power Consumption in the Initialized State	The average power consumption over a full year by a single SST-MEC in the Initialized State shall not exceed 0.5 (TBC) kW.	C-SST-TEL-0640	A, T
D-SST-MEC-0650	Azimuth speed and acceleration	The SST-MEC shall rotate around the Azimuth axis with a speed > 4.7deg/s and an acceleration of at least 1 deg/s^2.	-	A, T
D-SST-MEC-0651	Elevation speed and acceleration	The SST-MEC shall rotate around the Elevation with a speed > 1.1deg/s and an acceleration of > 0.8 deg/s^2.	-	A, T
D-SST-MEC-0660	Braking	The SST-MEC Azimuth and Elevation motors shall use safety (fail-safe) brakes able to stop the telescope in azimuth with a stroke < 2deg and in elevation with a stroke < 1deg in <=2 seconds granting a deceleration < 1.5g on M2.	C-SST-TEL-0190	A, T
D-SST-MEC-0670	Non-corrected pointing accuracy	The SST-MEC shall be able to reach a rms space-angle pointing accuracy (without pointing model strategy correction), i.e. the precision with which a physical position in the camera can be mapped to a celestial coordinate at a given time, during precision conditions, including repeatable errors induced by the SST-MEC, < 35arcsec.	-	A, T

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
D-SST-MEC-0680	Main axes Eigenfrequencies	The SST-MEC Azimuth and Elevation axes shall have a minimum eigen-frequency > 2.5Hz in their worst position configuration.	-	A
D-SST-MEC-0690	Position closed loop bandwidth	The SST-MEC Azimuth and Elevation Control loops shall be designed and built to reach a position closed loop bandwidth > 1Hz.	-	T
D-SST-MEC-0691	Control loop gain margin	The SST-MEC Azimuth and Elevation Control loops shall have a gain margin >= 6 dB over all conditions.	-	T
D-SST-MEC-0692	Control loop phase margin	The SST-MEC Azimuth and Elevation Control loops shall have a phase margin >= 30 degrees over all conditions.	-	T
D-SST-MEC-0700	M1 calibration system	The SST-MEC primary mirror segments supports and calibration control system shall be designed and built to be able to adjust and maintain the mirror segment in the calibrated position with a tip-tilt accuracy of 30 arcsec and piston accuracy of 0.1 mm.	-	R, T
D-SST-MEC-0701	M2 positioning system	The SST-MEC secondary mirror supports and positioning control system shall allow to adjust and maintain the M2 in the calibrated position with a tip-tilt accuracy of 10 arcmin and piston accuracy of 0.02mm.	-	R, T

8 Design

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
D-SST-MEC-0330	Flood Protection	The SST-MEC and its subsystems shall be designed to prevent all effects of water collection caused by surface water runoff.	C-SST-TEL-0330	R, D
D-SST-MEC-0410	Light Pollution	The SST-MEC and its subsystems shall not produce light with an isotropic equivalent flux greater than 3x10^6 photons ns^-1 at source in the wavelength range 300-550 nm during observations in the absence of specific calibration instructions from ACADA.	C-SST-TEL-0410	R
D-SST-MEC-2030	Reference System	The SST-MEC and its subsystems design, construction shall be compliant with [AD8].	C-SST-TEL-2030	R
D-SST-MEC-2035	Structural Guidelines	The process of structural design verification of SST-MEC and its subsystems shall be complaint with [AD18]		R
D-SST-MEC-0722	Local Control Mode	The SST-MEC shall implement a manual selector to switch the SST-MEC in maintenance mode during which it is unavailable for scientific operations or any kind of remote control, in compliance to [AD6]	C-SST-TEL-0722	R
D-SST-MEC-2110	SST-MEC Design	The design, construction and test of the SST-MEC and its subsystems shall consider only methods and procedures which are state-of-the-art in high precision mechanics, hydraulics and pneumatics, optical, electrical and electronics engineering, design and fabrication. These methods and procedures shall be appropriate for the applicable extreme environmental conditions and the long lifetime of the instrument. Preferable are those technologies which have been proven to lead to high reliable equipment for application at remote astronomical observatories at an altitude of >2300m above sea level	C-SST-TEL-2110	R
D-SST-MEC-1110	Focal Plane Maximum Tilt Positioning	The SST-MEC shall allow to positioning the centre of the focal plane instrumentation of the Camera Unit, in the direction perpendicular to the optical axis, within 0.12 degrees of the optical axis.	C-SST-TEL-1110	A

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
D-SST-MEC-0712	SST-MEC Transition Time: Initialized to Standby	The SST-MEC LCSs shall allow to perform the transition from the Initialized to the Standby State in less than 30 minutes.	C-SST-TEL-0712	D
D-SST-MEC-0720	SST-MEC Transition Time: Standby to Ready	The SST-MEC LCSs shall allow to perform the transition from the Standby State to the Ready State in less than 3 minutes	C-SST-TEL-0720	D
D-SST-MEC-0730	SST-MEC Transition Time: Ready to Observing	The SST-MEC LCSs shall allow to perform the transition from the Ready State to the Observing State in less than 2 minutes. The opposite transition shall be possible on the same timescale.	C-SST-TEL-0730	D
D-SST-MEC-0731	SST-MEC Transition Time: Observing to Ready	The SST-MEC LCSs shall allow to perform the transition from the Ready State to the Observing State in less than 2 minutes. The opposite transition shall be possible on the same timescale.	C-SST-TEL-0731	D
D-SST-MEC-0742	SST-MEC Transition Time: Return to Initialized	The SST-MEC LCSs shall allow to perform the transition from the Observing, Ready or Standby State to the Initialized in less than 5 minutes.	C-SST-TEL-0742	D
D-SST-MEC-0752	SST-MEC Transition Time: Off to Initialized	The SST-MEC LCSs shall allow to perform the transition from the Off State to the Initialized in less than 4 minutes.	C-SST-TEL-0752	D
D-SST-MEC-0100	SST-MEC Power Control	The SST-MEC Power Control System shall allow to Power-On/Off the SST-MEC both remotely and by a person present at the System location according to [AD6]	C-SST-TEL-0100	D
D-SST-MEC-0231	Mechanical Range of Motion in Azimuth	The SST-MEC Mount shall be able to rotate, in a controlled manner, both clockwise and counter-clockwise, in the range from -270° to +270° starting from the West geographical direction.	C-SST-TEL-0231 C-SST-TEL-2050	R, D
D-SST-MEC-0234	Azimuth Observation Range	The SST-MEC shall be able to access any Azimuth angle in the range 0 - 360 degrees. Regular observations should be mostly confined to a central 360° range; a buffer zone of ~75° at each end should be reserved primarily for ToOs, as indicated by an urgency flag, and engineering purposes.	C-SST-TEL-0234	R, T

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
D-SST-MEC-0240	Elevation Observation Range	The SST-MEC shall be able to access any Elevation angle in the range 20 - 89.2 degrees while tracking.	C-SST-TEL-0240	R, T
D-SST-MEC-0241	Mechanical Range of Motion in Elevation	The SST-MEC Mount shall be able to rotate, in a controlled manner, in the elevation range 0-91 degrees, starting from the horizontal direction.	C-SST-TEL-0241 C-SST-TEL-2050	R, D
D-SST-MEC-0400	Parking Position	The SST-MEC shall have one or more reference "Parking" positions in which the Mount is mechanically locked, and the locked status is signaled by the SST-MEC safety System to the IPS (TBC). The "Parking" position may vary during a year but shall always be fixed for any given 24 hour period.	C-SST-TEL-0400	R, D
D-SST-MEC-0462	Field of View Obstruction	The full field of view of the Camera shall not be obstructed by any part of the SST-MEC in an azimuth range of at least 270º for all elevation angles >= 0°.	C-SST-TEL-0462	R
D-SST-MEC-2040	Structure Pointing Capability	The SST-MEC shall include all the hardware and software to allow the telescope to point different parts of the sky with the required performances and all mechanical parts needed to support the telescope optics for collecting light.	C-SST-TEL-2040	R, T
D-SST-MEC-2080	SST-MEC local control system Design	The SST-MEC Local control system shall be designed, implemented and tested in compliance with [AD10], [AD11] and [AD12].	C-SST-TEL-2080	R, T
D-SST-MEC-2090	SST-MEC hand-paddle	The SST-MEC local control system (LCS) shall allow to safely control its motion locally through a dedicated hand-paddle for diagnostic or maintenance purpose.	C-SST-TEL-2090	R, T
D-SST-MEC-2120	SST-MEC LCS Software Design	The SST-MEC LCS Software shall run on the Local Control Units (LCU) and Safety Unit (SU).	C-SST-TEL-2120	R
D-SST-MEC-2130	Mount LCU Design	The SST-MEC Mount LCU shall be an industrial grade PC (IPC).	C-SST-TEL-2130	R

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
D-SST-MEC-2140	Mount Local Control Software System	The SST-MEC Mount Local Control software shall run as PLC programs under the Beckhoff TwinCAT software system which turn any IPC into a real-time controller with a multi- PLC system.	C-SST-TEL-2140	R
D-SST-MEC-2150	Mount Local Control Software Programming Languages	The SST-MEC Mount Local Control software running on the PLC created by TwinCAT shall be written using the IEC61131-3 PLC programming languages.	C-SST-TEL-2150	R
D-SST-MEC-2160	Sudden Loss of Power	In the exceptional cases of a sudden loss of power all SST-MEC subsystems shall not suffer any damage.	C-SST-TEL-2160	I, D
D-SST-MEC-2430	Pointing Monitoring Camera	The SST-MEC shall include a pointing monitoring camera subsystem as defined in [AD5].	C-SST-TEL-2430	R
D-SST-MEC-2020	Optical System Mount	The Optical System shall be mounted on an altitude–azimuth SST-MEC .	C-SST-TEL-2020	R
D-SST-MEC-2450	Mirror Alignment System support	The M1 and M2 Optical Support System shall be designed to mount a motorized system to allow the tip, tilt, and piston movements of each mirror segment.	C-SST-TEL-2450	R, T
D-SST-MEC-3010	Total Mass	The total mass of the telescope shall not exceed 18 metric tons. The mass shall include all payloads.	-	R
D-SST-MEC-3020	Optical elements location	The SST-MEC shall be designed to allow to mount the M1 mirror and the M2 mirror at the Nominal distance (centre-to-centre) of 3108.4 mm.	-	R
D-SST-MEC-3030	M2 - Focal Plane distance	The SST-MEC shall be designed to allow the positioning of the centre of the focal plane of the Cherenkov Camera at a Nominal distance of 519.6 mm from centre of the outer surface of the M2 mirror.	-	R

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
D-SST-MEC-3040	Accuracy of the M1 Mirror segment positioning	The M1 segments support assemblies shall allow a positioning accuracy between each segment of: • M1 segments in plane alignment error: ±2 mm along X_{ERS} • M1 segments in plane alignment error: ±2 mm along Y_{ERS} • M1 segment axial error: ±2 mm along Z_{ERS} • M1 segment tilt around X_{ERS} -axis: 30 arcsec RMS • M1 segment tilt around Y_{ERS} -axis: 30 arcsec RMS • M1 segment tilt around Z_{ERS} -axis: 4 arcmin RMS	-	R, I
D-SST-MEC-3041	M1 Segment Alignment tool	The M1 Segments alignment Control system shall allow to calibrate the position of each segment at regular intervals over the full tip-tilt range of 3.0° with an accuracy of 30 arcsec and piston range of 15 mm with an accuracy of 0.1mm.	-	R, T
D-SST-MEC-3042	M2 Displacement tolerances	The SST-MEC shall allow the positioning of M2 with a maximum displacement error of: • In plane error with respect to M1: ±3 mm along X_{ERS} • In plane error with respect to M1: ±3 mm along Y_{ERS} • Axial error with respect to M1: ±2 mm along Z_{ERS} • Axial error with respect to Camera: ±1 mm along ZERS The maximum allowed rotation with respect to its nominal position shall be within 10 arcmin along all axes.	-	R, I
D-SST-MEC-3042	M2 Positioning system	The secondary mirror positioning LCS shall include three actuators, featuring a tip-tilt accuracy of 10arcmin and piston accuracy of 0.02mm. Each actuator shall feature a minimum range of 15 mm.	-	R, T

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
D-SST-MEC-3043	M2 Positioning system absolute encoder	The M2 positioning LCS shall use absolute encoders to measure the actual position and attitude of the mirror with an of 0.001 mm.	-	R, T
D-SST-MEC-3050	Parallelism between gravitational vector and Azimuth axis	The SST-MEC azimuth axis shall remain parallel to the gravitational vector to within 30 arcsec over the entire azimuth axis operational range.	-	A
D-SST-MEC-3051	Perpendicular condition between Elevation and Optical Axes	The SST-MEC elevation and azimuth axes shall remain perpendicular to within 60 arcsec over the entire operational range of both axes.	-	A
D-SST-MEC-3060	Balancing system	The SST-MEC shall include a system to balance the elevation assembly as required to allow correct telescope functioning at any elevation angle. The balancing system shall be able to balance the elevation assembly in the direction along the optical axis and perpendicular to both the optical axis and the elevation axis.	-	R
D-SST-MEC-3070	Base inner volume control	The SST-MEC shall provide Conditioning LCS to control and monitor the inner environment of the SST-MEC base, so to prevent excessive humidity to interfere with the installed electronics.	-	R, D
D-SST-MEC-3100	Networking Devices	The SST-MEC shall provide a network switch and all patch-panels needed to establish the Telescope internal networking system and its connection with the CTAO network.		R

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
D-SST-MEC-3110	Network Switch	The SST-MEC network switch shall provide as a minimum the following features: • Industrial Grade • At least 8 (TBC) 10/100/1000BASE-T copper RJ45 copper ports • At least 2 (TBC) 1000BASE-X SFP uplink ports • internal or external Power supply • DIN-Rail or 19"-Rack mount • Remote management via CLI, API and WEB Based GUI • SNMP/SMTP protocols support • SFP Port: At least 1000BASE-LH/XZ • SFP Port: At least distance 10 km on monomode fibre • SFP Port: Wavelength either 1310nm or 1550nm • Link aggregation group (LAG)		R

9 Interfaces

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
D-SST-MEC-0511	Interface to Site Network Infrastructure	The SST-MEC Networking interfaces to the on-site network infrastructures shall be defined, specified and controlled by dedicated Interface Control Document.	C-SST-TEL-0511	R
D-SST-MEC-0512	Interface to Site Timing Infrastructure	The SST-MEC LCS time reference interfaces to the on-site timing distribution infrastructures shall be defined, specified and controlled by dedicated Interface Control Documents.	C-SST-TEL-0512	R
D-SST-MEC-0512	Interface to optical camera	The SST-MEC interfaces to the optical camera shall be defined, specified and controlled by dedicated Interface Control Document.		R
D-SST-MEC-0050	Camera Fixation	A suitable SST-MEC/SST-CAM mechanical interface shall be provided to ensure safe and stable fixation which ensures appropriate focal plane positioning.	C-SST-TEL-0050	R
D-SST-MEC-0051	SST-MEC to SST-CAM Interface Positioning Accuracy	The SST-MEC/SST-CAM mechanical interface shall ensure focal plane positioning accuracy compliant with Online Astrometric Accuracy of the Telescope whilst Tracking < 60 arcseconds	C-SST-TEL-0051	R
D-SST-MEC-0051	SST-MEC to SST-CAM Interface Positioning Reproducibility	The SST-MEC/SST-CAM mechanical interface shall ensure that the focal plane positioning is reproducible with the same accuracy upon Camera replacement.	C-SST-TEL-0051	R
D-SST-MEC-0510	Interface to site civil infrastructure	The SST-MEC interface to the on-site civil infrastructure is described in [AD15].	C-SST-TEL-0510	R
D-SST-MEC-0514	Interface to on-site IPS and Alarm Infrastructure	The SST-MEC interfaces to the on-site IPS and alarm infrastructures shall be defined, specified and controlled by dedicated Interface Control Documents.	C-SST-TEL-0514	R
D-SST-MEC-2360	Power Interface	The SST-MEC shall receive power from CTAO Power distribution system as prescribed by the associated Interface Control Document [AD7]	C-SST-TEL-2360	R

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
D-SST-MEC-2050	Electrical and Communication Connections	All the electromechanical part of the SST-MEC shall be provided with power and data communication via dedicated supply lines.	C-SST-TEL-2050	R

10 Quality

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
D-SST-MEC-5001	Hardware quality	All materials used to build the SST-MEC shall be new, of high-grade commercial quality, and fulfilling the requirements of a standard commercial specification. They shall be consistent with all requirements in this document, including life cycle, reliability, and maintainability. They shall be sound and free from defects, both internal and external, such as cracks, laminations, inclusions, blow holes or porosity.	-	R, C
D-SST-MEC-5002	Workmanship	SST-MEC Workmanship shall be of a high grade of commercial practice and adequate to achieve the accuracies and surface finishes called for on all drawings and in the specifications. All manufacturing processes, such as plating, welding, or heat treatment, shall be specified and performed in such a manner as to achieve the strength and properties required without introducing any material defects such as hydrogen embrittlement, excessive grain growth, or residual stress concentrations.	-	R, C
D-SST-MEC-5003	Edge finished	All SST-MEC metal edges shall be free of burrs and sharp corners. No sharp edges that might constitute a hazard to personnel or equipment (cabling) shall remain on the finished components of the Assembly. The edges and ends of all plates, tubes, and fabricated sections shall be finished using appropriate methods.	-	I
D-SST-MEC-5004	Fasteners	The SST-MEC Assembly and tightening of all bolted connections shall be performed in conformance with a common industrial approved standard. All bolted and dowelled connections shall be designed to preclude the possibility of joint movement, slippage, local yielding and/or hysteresis under operational loading.	-	I
D-SST-MEC-5005	Welding	All the SST-MEC Welding shall be performed in accordance with a common industrial approved standard.	-	I, C

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
D-SST-MEC-5006	Stress relieving	Any fabrication processing that imparts substantial stress into a SST-MEC component requires stress relieving. This includes all structural welds, which shall be stress relieved after welding and/or prior to final machining. Shop drawings shall include heat treatment specifications for all parts requiring heat treating. Temperature-time charts and records of heating, quenching treatments, material tests, etc., shall be kept and identified with the parts and submitted to INAF as required for approval. Manufacturing processes such as forging that require substantial yielding shall require stress relieving.	-	C
D-SST-MEC-5007	Surface coating	All materials used in the construction of the SST-MEC that are subject to corrosion shall have surface treatments that are consistent with the design life of the telescope. All surface treatments shall be performed in accordance with a common industrial approved standard.	C-SST-TEL-0520	C
D-SST-MEC-5008	Electromagnetic Compatibility	The SST-MEC shall exhibit complete electromagnetic compatibility (EMC) among its parts, components, devices, and equipment (intra-system electromagnetic compatibility). Prevention of electromagnetic interference (EMI) between the telescope in its environment (inter-system electromagnetic compatibility) shall be a major driver in the design and construction.	C-SST-TEL-0060	R
D-SST-MEC-5009	IP Protection	All components mounted onboard of the SST-MEC, but the electrical cabinets on the fork, shall be certified to have a minimum protection grade IP65.	-	R
D-SST-MEC-5020	Color of SST-MEC	All the SST-MEC external parts but the mast and the central tube shall be painted in RAL 3016 opaque	-	IR
D-SST-MEC-5020	Color of must and central tube	The mast and the central tube shall be painted in RAL 9005 opaque	-	IR

11 Subsystems Specification

11.1 Mount Subassembly

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
D-SST-MNT-1000	Mount Subassembly decomposition	The Mount Subassembly comprises all parts of the SST-MEC below the M1 dish, including the Elevation actuator and drive system. This decomposition is given in [AD5]. Each of its parts shall be designed and built to be compliant with the functional decomposition described in [AD5].	C-SST-TEL-0030	R
D-SST-MNT-1001	Base definition	The Base is the subassembly of the Mount, which is fixed to the ground, whose main function is to support the azimuth bearing.	C-SST-TEL-0030	R
D-SST-MNT-1002	Fork definition	The Fork is the subassembly of the Mount, which provides a rotation in Azimuth of the Azimuth Bearing and support the Elevation axis	C-SST-TEL-0030	R
D-SST-MNT-1003	Azimuth Bearing definition	The Azimuth bearing is a mechanical component that connects the Base of the Fork and allows Azimuth rotation of the Fork.	C-SST-TEL-0030	R
D-SST-MNT-1010	Azimuth Bearing	The Azimuth bearing shall be a preloaded crossed-roller slewing ring featuring an external gear.		R
D-SST-MNT-1011	Azimuth bearing runout	The axial and radial runout of the azimuth bearing shall be lower than 50 µm Peak-to-Valley.		T
D-SST-MNT-1012	Azimuth bearing stiffness	The minimum stiffness characteristics (tangential stiffness) of the azimuth bearing, considering preload and operational load, shall be: - 3 kN/µm for radial loads - 6 kN/µm for axial loads - 0.9 kNm/µrad for titlting moments		C

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
D-SST-MNT-1013	Azimuth bearing encoder groove	The azimuth bearing shall feature on its inner ring a precisely machined groove for the installation of the azimuth encoder tape.		R, I
D-SST-MNT-1018	Backslash	All reduction stage mounted on motors user for the SST-MEC shall have a reduced backlash (<6').		R
D-SST-MNT-1020	Azimuth drive system	The azimuth drive system shall be composed of two counteracting pinions acting on the external gear of the azimuth bearing, with reduction gears and brushless motors.		R, A
D-SST-MNT-1021	Azimuth brake	One of the two azimuth motors shall be equipped with a fail-safe brake. The brake shall be easily unlockable for maintenance purposes, even when no power is available to the telescope (e.g. by hand lever, portable battery). According to Guide to application of the Machinery Directive 2006/42/EC Edition 2.2 – October 2019, 1.2.4.3 Emergency stop, §202 Emergency stop devices.	C-SST-TEL-0190	R, D
D-SST-MNT-1022	Azimuth motor encoder	The other azimuth motor shall be equipped with an absolute multi-turn encoder.		R, D
D-SST-MNT-1030	Azimuth encoder	The azimuth drive system shall be provided with an encoder measuring directly the azimuth axis orientation, providing RMS accuracy over 360deg of 2.5 arcsec or better.		R, A,T
D-SST-MNT-1040	Azimuth limit switches	The azimuth axis motion limits shall be determined by two sets of safety mechanical limit switches. Each set shall comprise a pre-limit switch a safety operational switch, giving the STO to the motor drive and allowing only reverse motion, and a safety emergency switch, cutting-off power to the drive.		R, T
D-SST-MNT-1050	Azimuth Stow Pin	An Azimuth Stow pin system shall be present to safely lock the azimuth axis in any of the parking position. The stow pin shall be easily operable for maintenance purposes, even when no power is available to the telescope.		R, A, T

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
D-SST-MNT-1051	Stow Pins maintenance	Stow pins are considered LRUs, which shall be easily replaceable at the telescope without the need of a crane or of a cherry picker.		R, D
D-SST-MNT-1052	Stow Pins torque limiters	The Stow pin motors shall be equipped with Torque limiting devices (either mechanical or electrical).		R
D-SST-MNT-1060	Elevation Bumper	An elevation bumper shall be located on the Azimuth Fork to absorb the effects of a possible impact of the OSS, due to unbalance or accidental motion.		R, A
D-SST-MNT-1070	Elevation drive system	The elevation drive system shall be composed of a ball screw jack with reduction gears, and a brushless motor.		R, A
D-SST-MNT-1071	Elevation drive backlash	The elevation drive system shall implement measures to minimize backlashes. The residual amount of backlash is to be measured and considered in the design and implementation of the Elevation control system.		R, T
D-SST-MNT-1072	Elevation brake	The elevation motor shall be equipped with a fail-safe brake. The brake shall be easily unlockable for maintenance purposes, even when no power is available to the telescope (e.g. by hand lever, portable battery), according to Guide to application of the Machinery Directive 2006/42/EC Edition 2.2 – October 2019, 1.2.4.3 Emergency stop, §202 Emergency stop devices	C-SST-TEL-0190	R, D
D-SST-MNT-1073	Elevation ball screw size	The minimum size of the elevation ball screw shall be 80 mm in nominal diameter.		R
D-SST-MNT-1074	Elevation ball screw protection	The ball screw shall be protected by an easily replaceable bellow. The replacement procedure shall not require a crane.	C-SST-TEL-0332	R, D

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
D-SST-MNT-1080	Elevation encoder	The elevation drive system shall be provided with an absolute encoder measuring directly the elevation axis orientation, providing RMS accuracy over 360 deg of 2.5 arcsec or better.		R, A
D-SST-MNT-1090	Elevation limit switches	The elevation axis motion limits shall be determined by two sets of safety mechanical limit switches. Each set shall comprise a pre-limit switch a safety operational switch, giving the STO to the motor drive and allowing only reverse motion, and a safety emergency switch, cutting-off power to the drive.		R, T
D-SST-MNT-1100	Elevation bearings	Elevation bearings shall be preloaded and provide resistance to tilting moments. The amount of preload shall be adjustable by means of set screws.		R
D-SST-MNT-1110	Elevation Stow Pin	An Elevation Stow pin system shall be present to safely lock the elevation axis in the parking position. The stow pin shall be easily operable for maintenance purposes, even when no power is available to the telescope.		R, A, T
D-SST-MNT-1120	Base environmental monitoring	The temperature and humidity of the base inner environment shall be monitored.		R,T
D-SST-MNT-1121	Base environmental control	The temperature and/or humidity of the base inner environment shall be actively controlled, so to prevent condensation.		R, T
D-SST-MNT-1130	Azimuth floor access	The azimuth floor, i.e. the surface of the Fork above the Azimuth bearing, shall feature a permanent mean of access to it from the ground level. Hooking points for personnel harness are to be foreseen.		R
D-SST-MNT-1131	Cabinets access	The electrical cabinets shall feature a permanent mean of access to them from the ground level.		R
D-SST-MNT-1132	Base access	The telescope Base shall be provided with a door to access the inner volume. The inner volume shall be enough for a tall person to be able to stand and turn around freely.		R

11.2 Optical Support Structure

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
D-SST-OSS-2000	Optical Support Structure decomposition	The Optical Support Structure (OSS) comprises all parts of the SST-MEC above the Elevation axis. This decomposition is given in [AD5]. Each of its parts shall be designed and built to be compliant with the functional decomposition described in [AD5].	C-SST-TEL-0030	R
D-SST-OSS-2001	M1 Dish definition	The M1 Dish is the structure interfacing to the Elevation bearings, which supports the M1 mirror, the counterweights, and the mast.	C-SST-TEL-0030	R
D-SST-OSS-2002	Counterweights definition	The counterweights provide the function of balancing the OSS.		R
D-SST-OSS-2003	Mast definition	The Mast consists in three legs and a central tube, with the function of supporting the Camera (on the central tube) and the M2 support structure (on top of the three legs).		R
D-SST-OSS-2004	M2 structure definition	The M2 support structure houses and protects the M2 mirror and its mechanical supports and actuators. It also houses the Pointing Monitoring Camera.		R
D-SST-OSS-2005	M1 supports definition	The M1 supports provide support and actuation to the M1 segments.		R
D-SST-OSS-2006	M2 support definition	The M2 support provides support and actuation to the M2 mirror.		R
D-SST-OSS-2010	OSS Balance	The balance of the whole OSS about the Elevation axis shall be possible by adding/removing small mass elements to the Counterweights.		R, A

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
D-SST-OSS-2011	OSS balance resolution	It shall be possible to adjust the balance about the Elevation axis with a resolution of 250 Nm, in the range of 0-5000 Nm. Positive unbalance is towards the front of the telescope.		R, A
D-SST-OSS-2020	OSS Cabling and piping	The OSS shall foresee routes for electrical cabling and cooling pipes to all the hosted utilities (Camera, PMC, M2 Support) coming from the cabinets.		R
D-SST-OSS-2030	M1 Actuator passive range	The passive mechanical range of the M1 actuators shall be at least 16 mm.		R, T
D-SST-OSS-2031	M1 segment kinematic mount	A Kelvin kinematic coupling shall be foreseen at the interface to the M1 segment so to provide protection to extreme differential thermal expansion.		R
D-SST-OSS-2032	M1 calibration actuator interface	The OSS shall provide the interface and the allowed volume to install the M1 calibration actuators on the backside of the M1 Dish.		R, D
D-SST-OSS-2033	M1 calibration actuator mounting	The backside of the M1 Dish shall be easily accessible by an operator, either standing on top of the Fork floor or on a cherry picker, in all positions where the M1 calibration actuators are installed.		R, D
D-SST-OSS-2034	M1 Supports marking	M1 support structures and actuators shall be permanently marked to provide unambiguous mounting.		R
D-SST-OSS-2035	M1 Actuators locking	Locking devices shall be foreseen for the M1 actuators to provide stability over time of the achieved calibration. The installation of such locking devices shall not induce any unwanted motion of the actuators.		R, T
D-SST-OSS-2040	M2 Support structure alignment	The M2 Support structure shall be mechanically aligned w.r.t to the Camera interface with an in-plane and out-of-plane tolerance of ±1 mm. The achieved alignment shall be pinned to be able to restore it.		R, A

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
D-SST-OSS-2041	M2 Support as LRU	The entire M2 support, with the M2 mirror, shall be conceived as an LRU, allowing simple swapping in case of M2 recoating.		R
D-SST-OSS-2042	M2 Driving Units as LRU	It shall be possible to replace the M2 driving units directly at the telescope as LRUs.		R, D,T
D-SST-OSS-2043	M2 Lateral Fix points as LRU	It shall be possible to replace the M2 Lateral fixed points directly at the telescope as LRUs.		R, D,T
D-SST-OSS-2044	M2 Actuators passive range	The passive mechanical range of the M2 actuators shall be at least 18 mm.		R, T
D-SST-OSS-2045	M2 Support encoders	M2 driving units shall be equipped with absolute multiturn encoders.		R,D,T
D-SST-OSS-2050	M1 and M2 cover	A sun cover for M1 and M2 shall be designed. Easy deployment of such cover shall be possible, using dedicated attachment points on the telescope structure.		R, D,T
D-SST-OSS-2060	M1 segment maintenance	It shall be possible to easily remove and replace any of the M1 segments without the need of removing any of the adjacent segments, with the telescope in the parking position.		R, D,T
D-SST-OSS-2100	PMC adjustment	Manual tip-tilt adjustment of the PMC shall be possible with a resolution of 1 arcmin, so to align the Camera with the telescope optical axis.		R, T

11.3 Electrical System

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
D-SST-ELS-3000	Electrical cabinets definition and normative	The SST-MEC shall house two electrical cabinets: The Telescope Power Cabinet and the Telescope Control Cabinet. Cabinets for mounting of electronic equipment shall be according to IEC 60297. All cabinets shall have opaque (steel) doors and panels in order to eliminate light pollution. If LED or other light indicators are mounted on the cabinet exterior there must be a switch to disable them.		R,D
D-SST-ELS-3001	Electrical boxes definition	Electrical boxes shall be present in proximity to objects in the field (e.g. Camera, PMC, etc), to provide housing for the necessary protection devices.		R, I
D-SST-ELS-3002	Cabling definition	Predefined cable routes towards all objects in the field (e.g. Camera, PMC, etc) shall be foreseen in the design.		R, I
D-SST-ELS-3003	Applicable normative	All the SST electrical equipment and installations shall conform to the standards IEC 60364 and CEI 64-8 (Low-voltage electrical equipment and installations standardization)		R, I, C
D-SST-ELS-3004	Fire propagation	Cables installed for any purpose and application shall be non-propagating fire also when laid as vertically-mounted bunched wires or cables. To this purpose they shall conform to the standards IEC 60332.		R, I, C
D-SST-ELS-3005	Cables color codes	The colors of the electrical cables shall be chosen according to the following criteria: - 230/400Vac cables (L1, L2, L3, N, PE) as per IEC 60364 and CEI 64-8 - 24Vdc, 5Vdc cables with colors different from the L1, L2, L3, N, PE colors		R, I
D-SST-ELS-3006	Cable bending radius	Cables accommodation shall guarantee the compliance with the minimum bending radius recommended by the manufacturer for that cable		R, I, C

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
D-SST-ELS-3007	Maintainability/ Ergonomics	All the SST electrical equipment and installations shall guarantee easy access in order to allow trouble-shooting and easy replacement. Indicators, displays, control actuators and the like shall be mounted on the front panel. All other elements and devices (including screw terminals) shall be mounted on the back panel of the cabinet; mounting on the side walls should be avoided. The mounting method of devices shall allow easy replacement (e.g. DIN-rails). The electrical cabinet shall guarantee the ergonomics for all the devices that are frequently operated (e.g. switches and circuit breakers)		R, I
D-SST-ELS-3008	Screw terminal protection	230/400 Vac screw terminals shall be protected by means of transparent plastic shields to avoid electrical shocks.		R, I
D-SST-ELS-3009	Reference standard for: connectors, plugs, sockets, and coupler	Connectors, plugs, socket-outlets and couplers installed for any purpose and application shall be qualified for industrial or military application.		R, I, C
D-SST-ELS-3010	Cables routing	230/400Vac cables (L1, L2, L3, N, PE) shall be routed separately w.r.t. the 24Vdc, 5Vdc cables.		R, I
D-SST-ELS-3011	Cables protection	All cables shall be protected against damage from abrasion, contact with sharp edges or protrusions. All cables running exteriorly to the SST-MEC shall be positioned inside cable glands to protect them from the external environment, especially from UV exposure. Cable glands shall feature proper terminations to avoid ingress of water. EMC requirements prevail over practical considerations, convenience of mounting and aesthetic aspects.		R, I

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
D-SST-ELS-3012	Static cables protection	Cables exiting from the two cabinets and reaching the cable box on top of the Fork shall be installed inside galvanized steel ducts to protect them.		R, I
D-SST-ELS-3020	Cables shielding	All cables shall be shielded.		R, C
D-SST-ELS-3030	Cabinets thermal design	SST-MEC Cabinets shall implement a thermal control system capable of heating and cooling the interior environment. Internal temperature and humidity of cabinets shall be monitored. Just external air may be used for cooling.		R, D
D-SST-ELS-3031	Cabinets IP rating	Electrical cabinets shall feature an IP rating 65 or better, according to IEC 60529. If fans are used for temperature control, then the IP rating shall be at least 54.		R, C
D-SST-ELS-3032	Cabinets EMI/EMC rating	The electrical cabinets shall be EMI/EMC compliant according to IEC 61000.		R, C
D-SST-ELS-3033	External power generator	Inside the base of the SST-MEC a dedicated socket shall be present to attach a portable power generator. It shall be possible to disconnect the telescope from the array power distribution and locally operate it for maintenance and emergency operations.		R, T
D-SST-ELS-3040	Array connection point	A dedicated box inside the SST-MEC base shall serve as power and data connection point with the array.		R
D-SST-ELS-3050	SST-MEC LCS control fieldbus	EtherCAT shall be uniquely adopted as the real-time communication bus for all SST-MEC servo drives (main axes, M2 and M1).		R
D-SST-ELS-3051	SST-MEC LCS Control units	Only Beckhoff Automation PLCs and control hardware shall be adopted.		R

11.4 Auxiliary Devices

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
D-SST-AUX-5000	M1 calibration actuators definition	A set of 54 removable actuators shall be provided to be installed on SST-MEC M1 Dish to optically align the M1 segments. This set shall be common for N (TBD) telescopes of the array.		R
D-SST-AUX-5001	Condition Monitoring system definition	A condition monitoring system based on accelerometers shall be implemented to monitor vibration level of rotating machinery, and possibly predict upcoming failures.		R
D-SST-AUX-5010	M1 calibration actuators range	The M1 calibration actuators operating range shall be of at least 15 mm.		R, T
D-SST-AUX-5011	M1 calibration actuators mechanical range	The M1 calibration actuators mechanical range shall be of at least 16 mm.		R
D-SST-AUX-5012	M1 calibration actuators limits	The M1 calibration actuators shall be provided with mechanical limit switches to define their operating range.		R
D-SST-AUX-5013	M1 calibration actuators accuracy	The accuracy of the M1 actuators shall be no more than 0.1 mm over the entire range of 15 mm, <= 0.03 mm over 1 mm.		R, T
D-SST-AUX-5014	M1 calibration actuators resolution	The resolution of the M1 calibration actuators shall be <= 0.005 mm.		R, T
D-SST-AUX-5015	M1 calibration actuators removal	The removal of M1 calibration actuators shall not induce unwanted motions over 0.01 mm of the M1 actuators.		R, T

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
D-SST-AUX-5016	M1 calibration storage boxes	Appropriate boxes shall be designed for the long-term storage of the M1 actuators. Each box shall not weight more than 50 kg.		R
D-SST-AUX-5100	Condition Monitoring items	The condition monitoring system shall include At least 6 IEPE accelerometers.		R
D-SST-AUX-5101	Monitored objects	The accelerometers shall be used to monitor, at least: The two azimuth motors, the two azimuth ratio gears, the elevation motor, the elevation ball screw reduction box.		R
D-SST-AUX-5102	Vibration data analysis	Vibration data during telescope operation shall be continuously monitored and logged. Data shall be available to the Mount LCS.		R

11.5 Mechanical structure maintenance tools

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
D-SST-TLS-7000	M1 segment extraction tool	A tool shall be designed to easily replace any of the M1 segment directly on the telescope in the parking position, without the need of removing any of the adjacent segments.		R, D
D-SST-TLS-7001	M2 Lateral fix point replacement tools	A tool shall be designed to easily replace any of the M2 Lateral fix points directly on the telescope in the parking position.		R, D
D-SST-TLS-7002	Stow pins replacement tool	A tool shall be designed to easily replace any of the Stow Pins directly on the telescope in the parking position, without the need of any external lifting device.		R, D

D-SST-TLS-7003	Azimuth ratio-gears replacement tool	A tool shall be designed to easily replace any of the azimuth ratio gears directly on the telescope in the parking position, without the need of any external lifting device.		R, D
D-SST-TLS-7004	M2 handling cart	A cart shall be designed to easily install the M2 mirror into the M2 support structure.		R, D
D-SST-TLS-7005	M2 handling cart safety	That M2 handling cart shall implement measures to eliminate or mitigate the possibility of damaging the M2 mirror during installation due to human mistakes.		R, D

11.6 Foundations

Requirement ID	Requirement Name	Requirement Statement	Requirement Source	Verification Requirement
D-SST-FOU-8000	SST-MEC interface	The foundations shall provide an adequate interface to the SST-MEC as per the applicable ICD [AD15].		R
D-SST-FOU-8001	Foundation stiffness	The minimum global stiffness, which the foundation shall exhibit is: • Vertical stiffness (Z) > $6.3\text{x}10^8$ N/m • In X/Y plane > $3.7\text{x}10^8$ N/m • Tilting stiffness: $8.8\text{x}10^8$ Nm/rad This stiffness shall include the effect of the embedded rods, the concrete slab and the soil. The assumed soil modulus of subgrade reaction shall be 50 MN/m3.		A

End of the document