ASTRI Mini-Array

Telescope Mechanical Structure Assembly Requirements Specifications

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DOCUMENT HISTORY		
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1.1	14/12/2020	Include comments from SE Team.
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1 Introduction

The **ASTRI** (Astrofisica con Specchi a Tecnologia Replicante Italiana) **Mini-Array** is an INAF project aimed consisting of nine identical dual-mirrors Cherenkov gamma-ray telescopes that will be installed at the site of the Teide Observatory in Tenerife (Spain) to study astronomical sources emitting at very high-energy in the TeV spectral band.

Besides gamma-ray scientific program, the ASTRI Mini-Array will perform optical intensity interferometric observations of bright stars.

1.1 Purpose

This document gives the requirement specifications for the Telescope Mechanical Structure Assembly (MSA). **These requirements are an updated version of the requirements used to build and test the ASTRI-Horn end-to-end telescope prototype.** They consider the lessons learnt during construction, assembly, integration and operation of ASTRI-Horn at the INAF Astronomical Station of Serra La Nave on Mount Etna.

1.2 Scope

The scope of the document is to provide the Supplier with the requirement specifications of the ASTRI Telescope Mechanical Structure Assembly and all the background information needed to correctly understand the specifications.

1.3 Content

The sections of this document present the requirement specifications that shall be used by the supplier for building, assembly, test and delivery the ASTRI Telescope Mechanical Structure Assembly.

1.4 Definitions and Conventions

1.4.1 Abbreviations and acronyms

The following abbreviations and acronyms are used in this document:

AIT	Assembly Integration and Testing
AIV	Assembly Integration and Verification
ASIC	Application Specific Integrated Circuits
ASTRI	Astrofisica con Specchi a Tecnologia Replicante Italiana
AR	Camera Acceptance Review
ATRR	Acceptance Test Readiness Review
BEE	Back End Electronics
CDR	Critical Design Review
CFI	Customer Furnished Item
CITIROC	Cherenkov Image Telescope Integrated Read Out Chip

COTS	Commercial Off The Shelf
EMC	Electro Magnetic Compatibility
FEE	Front End Electronics
FEM	Finite Element Analysis
FPGA	Field Programmable Gate Array
FMECA	Failure Mode Effects and Criticality Analysis
HW	Hardware
IAC	Instituto de Astrofísica de Canarias
INAF	Istituto Nazionale di Astrofisica
IPC	Industrial Computer
ITW	Integration Time Window
KOM	Kick Off Meeting
LLI	Long Lead Item
LRU	Line Replacement Unit
MIUR	Ministero dell’Istruzione, dell’Università e della Ricerca
MSA	Mechanical Structure Assembly
PA	Product Assurance
PBS	Product Breakdown Structure
PCB	Printed Circuit Board
PDM	Photon Detection Module
PDR	Preliminary Design Review
PR	Cameras Production Review
OPC-UA	Open Platform Communications - Unified Architecture
QA	Quality Assurance
QR	Qualification Review
QTRR	Qualification Test Readiness Review
RAM	Reliability, Availability and Maintainability
RR	Camera Requirements Review
SCADA	Supervisory Control And Data Acquisition system
SE	System Engineering
SI^3	Stellar Intensity Interferometry Instrument.
SiPM	Silicon Photo-Multiplier
SLN	Serra La Nave
SMM	Structural Mathematical Model

SOW	Statement of Work
SU	Safety Unit
SW	Software
TCS	Telescope Control Software
TE	Test Equipment
TMM	Thermal Mathematical Model
UPS	Uninterruptible Power Supply
VCD	Verification Control Document
VDB	Voltage Distribution Box
VHE	Very High Energy
WR	White Rabbit

1.4.2 Definitions

1.4.2.1 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.

1.4.2.2 Customer and Contractor

Customer – In the context of this document the Customer is INAF

Contractor – In the context of this document the Contractor is the supplier of the Telescope Mechanical structure.

1.4.2.3 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 and performances.** These are all the requirements that define what the product shall perform, in order to conform to the needs statement or requirements of the user.
- **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.

- **Physical.** These are all the requirements that establish the boundary conditions to ensure physical compatibility and that are not defined by the interface requirements, design and construction requirements, or referenced drawings.
- **Interface.** These are all the requirements related to the interconnection or relationship characteristics between the product and other items.
- **Product assurance.** These are all the requirements related to the relevant activities covered by the product assurance to ensure that the hardware, software, electronic components, standards, materials, mechanical parts and the industrial fabrication and configuration control processes used to build the product fit the requirements over the entire operation lifetime.
- **Verification.** These are all the requirements related to the Verification methods requested by the project.
- **Packaging, Transportation and Handling.** These are all the requirements related to the relevant activities to the final delivery of the products.

1.4.2.4 Definition of the requirements verification methods

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

1. test (including demonstration);
2. analysis (including similarity);
3. review-of-design;
4. inspection.

a. All safety critical functions shall be verified by test.
b. Verification of software shall include testing in the target hardware environment.

1.4.2.4.1 Test

a. Verification by tests shall consist of a measure of the performance and functionality of the product under simulation conditions comparable to those of the destination environment.
b. The analysis of data derived from testing shall be an integral part of the test and the results shall be included in the test report.
c. When the test objectives include the demonstration of qualitative operational performance, the execution shall be observed, and results recorded.
d. A test programme shall be prepared for each product
e. The test programme shall be coordinated with the integration flow.
f. Tests performed as part of the integration flow to check quality and status of the in-progress configuration (including interfaces), having a formal verification purpose, shall be included in the test programme.
g. The test programme shall be defined in the Assembly, Integration and Test plan.

1.4.2.4.2 Analysis

a. Verification by analysis shall consist of performing theoretical or empirical evaluation using techniques agreed with the Customer.

> NOTE Techniques comprise systematic, statistical and qualitative design analysis, modelling and computational simulation.

b. Verification by similarity shall be part of the verification by analysis.
c. Similarity analysis shall provide evidence that an already qualified product fulfils the following criteria:

1. The already qualified product was not qualified by similarity.
2. The product to be verified is an off-the-shelf item without modifications already subjected to qualification.

d. Similarity analysis shall define differences that can dictate complementary verification activities.
e. An analysis programme shall be defined in the Verification Plan (VP).

1.4.2.4.3 Review-of-design (ROD)

a. Verification by Review-of design (ROD) shall consist of using approved records or evidence that unambiguously show that the requirement is met.

NOTE Examples of such approved records are design documents and reports, technical descriptions, and engineering drawings.

b. A review-of-design programme shall be defined in the Verification Plan (VP).

1.4.2.4.4 Inspection

a. Verification by inspection shall consist of visual determination of physical characteristics.

NOTE Physical characteristics include constructional features, hardware conformance to document drawing or workmanship requirements, physical conditions, software source code conformance with coding standards.

b. An inspection programme shall be defined in the Verification Plan (VP).

1.4.2.5 Definition of the codes of the requirements

The requirement code is defined as follow ASTRI-XXXX-YYYY.

- The XXXX digits refer to the identification code of the element the requirement refers to as defined in the product tree (see **Error! Reference source not found.**).
- The YYYY digits refers to the type of requirements and coding is reported in Table 1.

Table 1. Definition of code for type of requirement

Type of requirement	Code
Environmental	1000
Functional and performances	2000
Design	3000
Physical	4000
Interface	5000
Product Assurance	6000

Verification	7000
Package, Transportation and Handling	8000

For the requirements listed in this document the code will be ASTRI-7100-YYYY. In the tables that follows, only the code referring to the type of requirement is then shown.

1.4.2.6 Definitions of Mechanical Structure Assembly (MSA) States

State. A State represents a situation where some invariant condition holds; 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.

Substate. 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).

The states below are applicable to the Telescope MSA.

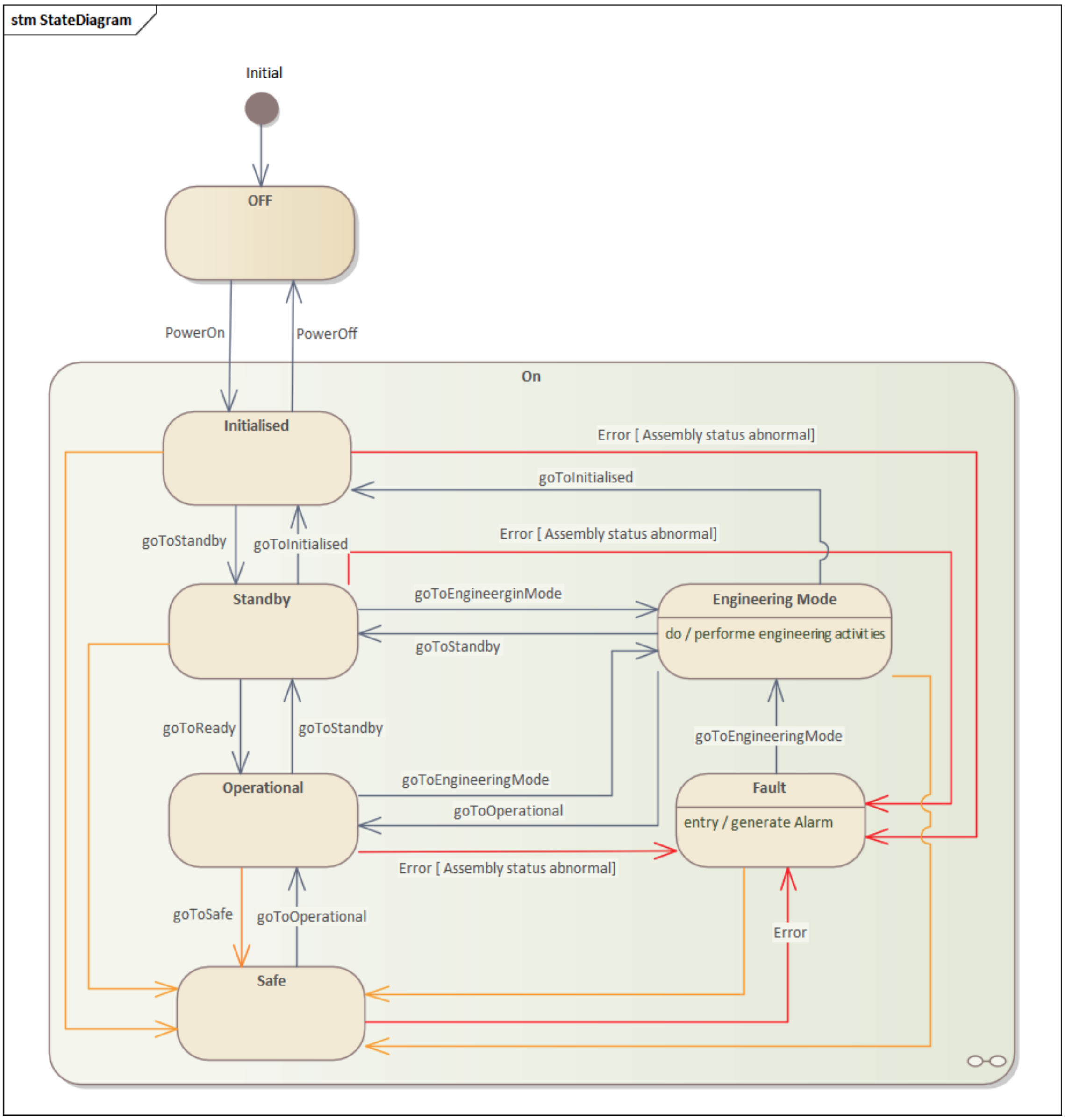

Figure 1-1. ASTRI Telescope Structure State Machine. . The read lines indicate the errors that can trigger a transition to Fault state. The orange lines indicate the transition to the Safe State. The On/Off states are triggered by the connection/disconnection of the MSA to the electrical power.

Off State: The MSA is entirely without electrical power.

On State: *The MSA* is powered-on, and available to operate under the sub-states described below:

- **Initialised State**: the state of the MSA after power on. All Local Control systems (LCSs) are powered-on. The LCS software is running, initialized and the communication with the MSA Local Supervisor is established. The MSA is in parking position, a configuration suitable for survival in extreme environmental conditions.

- **Standby State**: a state in which the MSA is still in safe configuration (but the MSA stow-pins are disengaged). All MSA LCSs are ready to receive commands. MSA Drive system is powered-on. The MSA is ready to perform a transition to the operation State.
- **Operational State**: the MSA state associated with operations (e.g. pointing and tracking a sky object), with configuration dictated by performance requirements. Two Operational sub-states (not represented in the figure) could be present:
  - **nominal:** the MSA can be operated with full performances;
  - **degraded:** the MSA can be operated with reduced performances.

- **Safe State**: if dangerous conditions are present, the MSA goes into a state where the MSA is considered exposed to “normal” risk for damage or loss. This is also the configuration designed for survival in extreme conditions, minimising the use of power. The MSA is in parking position and only some (TBC) MSA LCSs are still providing basic status and monitoring information to the MSA Local Supervisor.

- **Fault State**: the MSA has encountered a serious problem, which means it is currently unable to meet the requirements associated with one of the standard states. An alarm shall be generated by the MSA LCS before enter this state.

- **Engineering Mode State**: a logical state designed to facilitate MSA maintenance and engineering activities. This state is unavailable for routine operations and can be entered only upon request by MSA experts.

1.4.2.7 Definitions of Modes

- **Local Mode**: mode of operation of MSA activated and deactivated by a person physically present in the Telescope area acting on a local switch in the Telescope Control cabinet. Whilst in Local Mode all remote actions that could endanger the safety of a local person are prevented. Local Mode supports engineering and maintenance activities. In Local Mode, the MSA Local control system shall provide hierarchical safety levels to the user that can be bypassed using relaxed safety limits in order to test and maintain the systems. In Local Mode the MSA LCS may be used via a local User Interface provided by the LCS.

- **Remote Mode**: Mode of operation of the MSA to allow control by a person not present at Telescope Area, available when not disabled at the Interface Cabinet. Remote mode supports observatory science operation and system/array-level engineering activities. In Remote Mode the MSA operations are controlled by SCADA.

1.4.2.8 Systems of Coordinates

The location of any ASTRI Array telescopes, Lidar, Weather Stations, at the Teide site must be given as a WGS84 (X, Y, Z) position or a longitude, latitude and altitude above the geoid.

The WGS84 X, Y, Z coordinates or the latitude, longitude and altitude of a telescope must be derived for each telescope through accurate GPS measurements in the point along the Azimuth Axis of the telescope, that is at the centre of Azimuth bearing. This point corresponds to the “Telescope” position (P_{Tel}).

The telescope location P_{Tel} is the origin (observer) of the Celestial Horizon Coordinate system (used to point each telescope to a direction of the sky. This fixed coordinate system has the X-axis aligned with the West-East direction, the Y-axis aligned with the North-South direction and the Z-axis is given by the local vertical (opposed to local gravity). This and the other main Telescope Coordinate systems are summarized in the following table.

Table 2 – System of Coordinates definitions.

Coordinate	Origin	X axis	Y axis	Z axis	Rotation Angle Definition	Notes
Telescope Foundation Reference System (TFRS)	The center of the telescope foundation finished upper floor/plane.	Points to the East, in the plane of the foundation finished upper floor/plane.	Points to the North, in the plane of the foundation finished upper floor/plane.	Right hand complement to x and y axes. Parallel to local gravity.		
Telescope Horizon Reference System (THRS)	The center of the azimuth circle, in the plane of the azimuth bearing, at XXX m above the level of the TFRS.	Points to the East, in the plane of the azimuth circle.	Points to the North, in the plane of the azimuth circle.	Right hand complement to x and y axes.		
Azimuth Reference System (ARS)	Identical to THRS.	Aligned with THRS x-axis when the azimuth angle=0°.	Right hand complement to x and y axes.	Identical to THRS.	The azimth angle is the angle between the ARS x-axis and the THRS x-axis due to the rotation around the z-axis. Azimuth angle increase in clockwise direction when view from above.	
Elevation Reference System (ERS)	TBD	Parallel to the ARS x-axis and collinear with the Elevation axis of the telescope.	Rotated around the x-axis according with right-handed system by the elevation angle.	Parallel to the ARS z-axis when the zenith angle is 0°.	The zenith angle is the angle between the ERS z-axis and the ARS z-axis direction.	When azimuth angle=0° and zenth angle= 90°, the telescope is pointing North.

1.4.2.9 Definitions of Conditions and Limits

- **Observation Conditions**. Environmental conditions under which full operation of the ASTRI mini-array must be possible without incurring damage.
- **Normal Conditions**. Environmental conditions under which the ASTRI mini-array 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 ASTRI mini-array system transitions from any state to Safe state. The level of damage incurred under transition conditions must not exceed the Serviceability Limit State.
- **Survival Conditions**. Environmental conditions expected to occur with a probability of roughly 2% per annum at the Teide site. The level of damage incurred under survival conditions must not exceed the Serviceability Limit State.

- **Serviceability Limit State** (SL): The MSA is slightly damaged. Repair can be performed in-situ using spare parts and a normal level of on-site manpower.
- **Damage Control Limit State** (DCL): The MSA is significantly damaged. The telescope is not operational but does not pose a safety risk while in the Safe state. The MSA is repairable but requires additional resources beyond the normal maintenance of the facility.
- **Collapse Prevention Limit State** (CPL): The MSA is heavily damaged, with very limited residual strength and stiffness. Although MSA elements are still capable of sustaining loads, their resistance cannot be relied upon indefinitely.

1.4.2.10 Mechanical Structure Assembly Related Definitions

Actuator: physical device which converts commands from the controller into physical effects on the controlled physical system.

Camera: All of the hardware and software associated with an instrument used for image detection, digitisation, transmission and preprocessing. The Cherenkov Camera and the Stellar Intensity Interferometry Instrument (SI3) are Instruments and are parts of a Telescope System. The Optical Camera is used only for the alignment of the primary mirror segments. The CCD Camera used by the Pointing Monitor Camera is an auxiliary Instrument.

Control Unit(s): computing unit(s) in charge of executing the control and monitoring functions related to the associated item (e.g. drive systems, conditioning system, etc).

Controller: control component designed to give the controlled physical system a specified control performance. In its most general form, a controller can include hardware, software, and human operations.

EtherCAT: is a real-time Industrial Ethernet technology originally developed by Beckhoff Automation. The EtherCAT protocol which is disclosed in the IEC standard IEC61158 is suitable for hard and soft real-time requirements in automation technology.

Field/Plant: in hierarchical and distributed control system architecture, the term both refers to the bottom layer of the control chain, namely the set of equipment under control, as well as the area where the equipment under control are located (e.g. on-board the telescope).

Fieldbus: industrial communication network and protocol system that interface control and safety unit(s) to the field devices.

Field Devices: components of a control system that are attached or connected to the equipment under control, typically sensors (e.g. switches, encoders, etc.) and actuators (e.g. valves, circuit breakers, motors, etc.).

Control System: A Control System is integrated hardware and software that manages, commands, regulates and monitors the operation of a system and associated subsystems and devices (System under Control). In other words, it is a system that controls other systems by applying well defined relations between input and output of the system. Control system includes supervisory control and data acquisition (SCADA) systems, distributed control systems (DCS), and other control system configurations such as Programmable Logic Controllers (PLC).

Local Control System: control and safety units, control software, local communication infrastructure required to guarantee functional operation of the a given equipment and all the other support elements needed for integration, verification and maintenance activities. The conceptual architecture of any ASTRI Local Control Systems is given in figure:

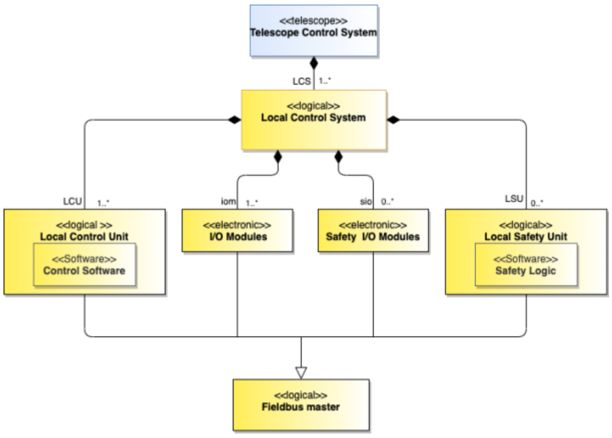

Figure 1-2 The logical Architecture the Telescope Local Control Systems

Monitor Data: data, which are regularly updated and published, providing complete status information about the associated item equipment, function and performance. . These data can also serve for the purposes of verification, maintenance, failure analysis, etc.

Interlock: mechanical, electrical or other type of device, the purpose of which is to prevent the operation of hazardous machine functions under specified conditions.

Programmable Logic Controller (PLC): a special computer device used for industrial control systems.

Safety Unit(s): computing nodes in charge of executing the safety-related functions of the associated item.

Safety Integrity Level: measures of the safety risk of a given process. Safety Integrity Level (SIL) shows to what extent can a process be expected to perform safely and, in the event of a failure, to what extent can the process be expected to fail safely.

Table 3 - SIL definition extracted from the standard ISO/IEC/IEEE 61508

	PROBABILITY OF FAILURE	
Safety Integrity Level (SIL)	**Mode of operation: on demand** (average probability of failure to perform its design function upon demand)	**Mode of operation: continuous** (probability of dangerous failure per hour)
4	$\geq 10^{-5}$ to $< 10^{-4}$	$\geq 10^{-9}$ to $< 10^{-8}$
3	$\geq 10^{-4}$ to $< 10^{-3}$	$\geq 10^{-8}$ to $< 10^{-7}$
2	$\geq 10^{-3}$ to $< 10^{-2}$	$\geq 10^{-7}$ to $< 10^{-6}$
1	$\geq 10^{-2}$ to $< 10^{-1}$	$\geq 10^{-6}$ to $< 10^{-5}$

SCADA (Supervisory Control and Data Acquisition): The software system controlling all the operations carried out at the ASTRI Mini-Array site at Teide. SCADA is the central control system which interfaces and communicates with all systems (e.g. Telescopes, Environmental Monitoring system, etc.) installed at the ASTRI Mini-Array site.

Sensors: are devices that produce a signal as output with respect to a physical quantity given as input.

Telescope: A system composed of an Instrument (Cherenkov Camera and Intensity interferometry Unit) a Mechanical Structure Assembly and Optics, which is used to collect sky images due to astronomical objects or Cherenkov light from Air Showers.

Telescope Optical axis: In an ideal telescope the optical axis (a telescope without mechanical defects, misalignments, etc.), is the axis perpendicular to the centre of curvature of the telescope focal plane.

Telescope Park position: Safe parking position during daytime and bad meteorological conditions. (pointing to north at the Teide Site). In park position the axes stow-pin, motor brakes, clumps or other locking devices are inserted/activated.

Telescope Home position: The initial position that the telescope must reach, after any axes locking device is deactivated, before to be available, the telescope axes position encoders are initialized. The home position for the ASTRI Telescopes at Teide corresponds to pointing to the Horizon in the North direction.

Telescope Pointing: the selection of the two mechanical angles (for the ASTRI Telescope azimuth, *Az* and elevation, *El*) that brings the telescope optical axis into alignment with a specified celestial target direction specified in Right Ascension (R.A) and Declination (Dec).

Requested Telescope Pointing direction: the direction on the sky of the telescope optical axis specified by the azimuth and elevation angles of rotation of an ideal telescope. The value of the telescope Azimuth and Elevation are calculated from the sky target coordinates applying the standard Astrometric Transformation Chain and the pointing model.

Actual Telescope Pointing direction: the effective direction on the sky of the telescope optical axis specified by the azimuth and elevation angles of rotation of the telescope.

This is calculated from the telescope rotated angles as measured by the axis encoders removing the contribution of the pointing model.

Telescope Pointing error: is the angular separation between the requested telescope pointing direction and the actual telescope pointing direction.

Telescope Slewing/Repositioning: is the rotation of the telescope structure around the azimuth and elevation axes to move the telescope optical axis from any telescope pointing direction to another requested telescope pointing direction.

Telescope Tracking: is the continuous rotation of the telescope around the azimuth and elevation axes needed to compensate the apparent motion of the celestial objects caused by the rotation of the Earth. Tracking is performed in blind mode, without the aid of any guiding system (e.g. a CCD camera monitoring the celestial target and providing feedback). It is a special sequence of pointing positions based on a pre-calculated tracking trajectory.

Tracking trajectory: An ordinated sequence of telescope azimuth and elevation coordinates and time at which that coordinates shall be reached by the telescope. The azimuth and elevation coordinates are calculated from the sky R.A. and Dec. coordinates of the target considering the pointing model corrections.

Telescope Structure tracking error: It is the angular separation between the theoretical target trajectory (expressed as a time ordered sequence of azimuth and elevation angles) and the actual trajectory followed by the telescope derived from the telescope structure encoder values, removing the pointing model corrections.

Telescope Offsetting (**also known as Wobble**): the rotation of the telescope azimuth and elevation axes to move from one requested telescope pointing direction to another over a small (<1°) angular distance.

Telescope Pointing Model: the pointing model includes corrections for repeatable pointing errors due to misalignment of the telescope mechanical axes and other relevant imperfections of the telescope mechanical structure and its control systems due to environmental and operating conditions (e.g. temperature and elevation angle). It does not include atmospheric refraction corrections and errors due to the imperfect smoothness of the required motion due to mechanical and wind disturbances or any other non-repetitive error. The pointing model can be expressed as a look-up-table or in an analytical form. The Telescope pointing model shall be derived through a calibration procedure that will be periodically scheduled (months).

2 Related Documents

2.1 Applicable Documents

[AD1] ASTRI Product Assurance Plan ASTRI-INAF-PLA-3000-001
[AD2] ASTRI Mini Array Environmental Conditions: ASTRI-INAF-SPE-2000-002
[AD3] Directive 2006/42/EC on machinery, and amending directive 95/16/EC. European directive, The European parliament and the council of the European union.
[AD4] ASTRI Mini Array Product Tree - ASTRI-INAF-DES-2000-001
[AD5] ASTRI Mini-Array MAC Requirements - ASTRI-REQ-UNIPG-3000-008
[AD6] ASTRI Mini-Array THCU and SAFETY Requirements - ASTRI-REQ-UNIPG-3000-009
[AD7] ASTRI Mini Array Optical design description - ASTRI-INAF-DES-7200-001
[AD8] ICD for UVSiPM - ASTRI-INAF-ICD-10210-001
[AD9] ICD for PMC - ASTRI-INAF-ICD-7510-001
[AD10] ICD for M2 - ASTRI-INAF-ICD-7220-001
[AD11] ICD for Communication - ASTRI-INAF-ICD-7132-001
[AD12] ICD for M1 - ASTRI-INAF-ICD-7210-001
[AD13] ICD for Cherenkov camera - ASTRI-INAF-ICD-7300-001
[AD14] ASTRI Mini-Array Technical Standards - ASTRI-INAF-SPE-2000-003
[AD15] ASTRI Mini-Array Interface Management Plan - ASTRI-INAF-PLA-2400-0001

2.2 Reference Documents

[RD1] ASTRI-Horn “Heritage”: Telescope Control System ASTRI-INAF-REP-9100-001
[RD2] ASTRI Mini Array Top Level architecture - ASTRI-INAF-DES-2100-001
[RD3] TELESCOPE CONTROL UNIT SOFTWARE DESCRIPTION - ASTRI-IR-INAF-3700-093
[RD4] TELESCOPE HEALTH CONTROL UNIT SOFTWARE DESCRIPTION - ASTRI-IR-INAF-3700-094

3 Overview of the System and General Requirements

3.1 The ASTRI Mini Array Telescopes

The ASTRI Mini Array shall include nine ASTRI telescopes representing an updated version of the ASTRI-Horn prototype Telescope operating at Serra La Nave (Catania, Italy) on Mount Etna. The ASTRI-Horn prototype is shown in Figure 3-1.

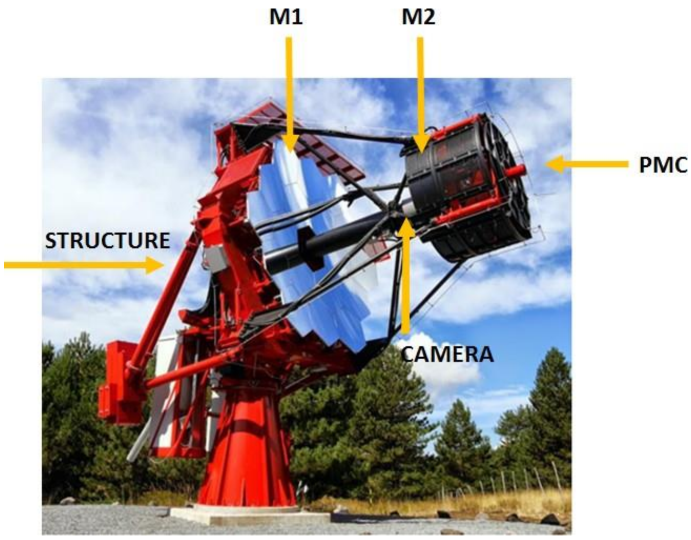

Figure 3-1 The ASTRI-Horn Telescope

Each ASTRI telescope shall have an optical system based on a dual-mirror Schwarzschild-Couder design.

Each ASTRI telescope optical system shall be mounted on an altitude–azimuth Telescope Mechanical Assembly Structure (MSA).

The scientific instruments, the Cherenkov Camera, the Stellar Intensity Interferometry Instrument, and the Optical Camera (that shall be used for the Alignment of the optical system), shall be located on the focal plane via an appropriate structure that is part of the Mechanical Structure Assembly.

The Telescopes shall be mounted on concrete foundations.

The Optical design of each ASTRI telescope is described in [AD7]. The main characteristics of the optical elements are summarized in the following Tables (4,5,6):

Table 4 - Telescope Mechanical Structure and Optical Design

Item or Parameter	Value ASTRI mini-array telescopes	Notes
Mount	Alt-Az	

Optical design	Schwarschild-Couder	
Distance M1-M2	3108.4 mm	Measured along the optical axis between the M1 and M2 centres
Distance M2-CAM	0.519 mm	Measured along the optical axis between the M2 and Focal Plane centres.
Equivalent focal length	2.15 m	
F-number, f/#	0.5	
Plate scale	37.5 mm/deg	
Average effective collecting area	5 m^2	
Point Spread Function, PSF, evaluated as D80 param.	< 0.19°	D80 parameter: diameter of the circle corresponding to an encircled energy of 80%.

Table 5 - M1 Principal Characteristics

Item or Parameter	Value ASTRI mini-array telescopes	Notes
Diameter	4.3 m	
Radius of Curvature, RoC	8.2 m	
Number of facets	18	distributed in 3 coronas
Number of facets coronas	3	
Radius of Curvature for each corona from the inner (1) to the outer (3)	(1) 8.52 m (2) 9.87 m (3) 12.54 m	
Facet type	hexagonal	
Facet side-by-side	0.85 m	
Coating	$Al+SiO_2+ZrO_2$	

Table 6 - M2 Principal Characteristics

Item or Parameter	Value ASTRI mini-array telescopes	Notes
Diameter	1.8 m	

Radius of Curvature	2.18 m	
Number of facets	1	
Facet type	Monolithic hemispherical	
Coating	$Al+SiO_2+ZrO_2$	

3.1.1 The ASTRI Min-Array Site Layout and Geographical Locations

The ASTRI Mini-Array shall meet all science, technical, operational and safety requirements at the Array Site location within the IAC Teide Observatory property.

The ASTRI Mini-Array deployment at the Teide Observatory is illustrated in the following figure:

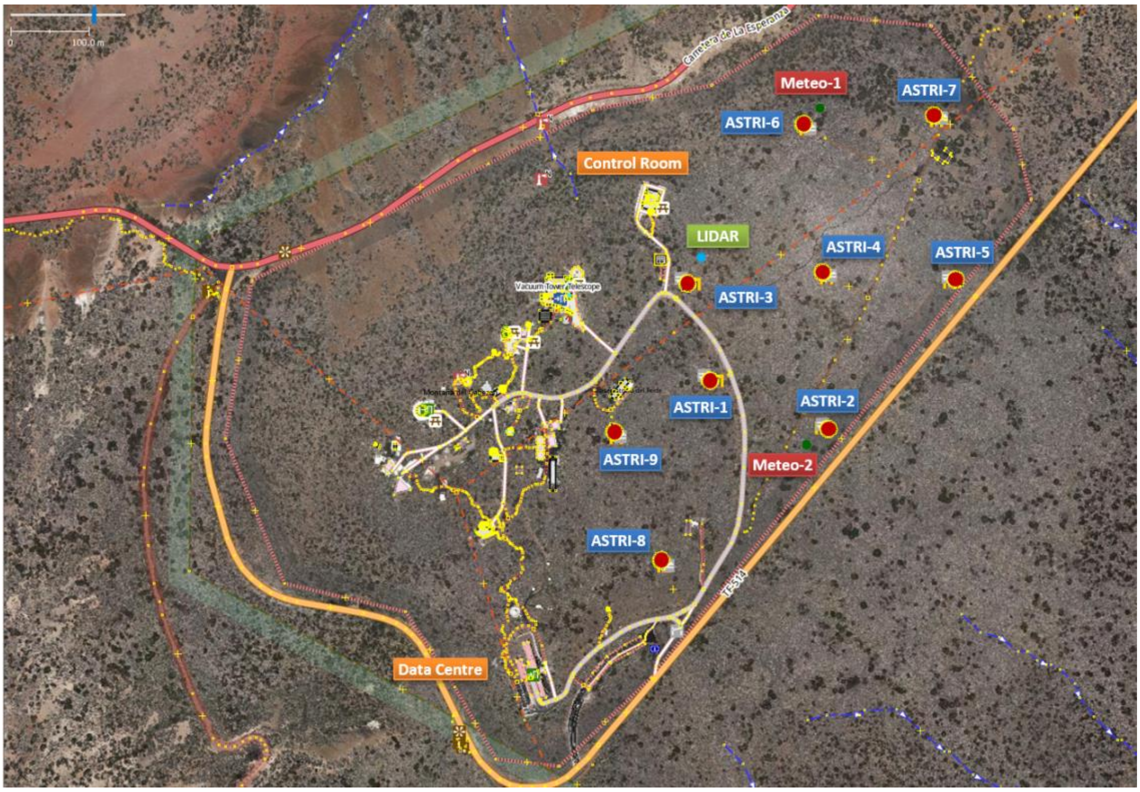

Figure 3-2 - The ASTRI Mini Array Layout at Teide Observatory. The big red dots indicate the positions of the ASTRI telescopes (ASTRI-1 to ASTRI-9).

The nine ASTRI telescopes denominations and geographical latitudes, longitudes and altitudes are reported in Table 6.

Table 7 - Geographical locations of the ASTRI Telescope Array at Teide

Telescope	Latitude	Longitude	Altitude (m)
ASTRI-1	28°18´3.69" N	16°30´28.69" W	2359.00
ASTRI-2	28°18´2.43" N	16°30´23.78" W	2348.00
ASTRI-3	28°18´8.53" N	16°30´29.82" W	2364.00
ASTRI-4	28°18´8.31" N	16°30´23.90" W	2356.00
ASTRI-5	28°18´8.73" N	16°30´17.63" W	2358.00
ASTRI-6	28°18´14.91" N	16°30´24.88" W	2351.00
ASTRI-7	28°18´15.56" N	16°30´18.56" W	2342.00
ASTRI-8	28°17´57.45" N	16°30´31.34" W	2376.15
ASTRI-9	28°18´2.75" N	16°30´33.98" W	2359.00

3.1.2 Array Power Distribution System

In order to fully operate the Telescope shall be connected to the Array site power distribution system provided by the Array infrastructure and shall be able to manage the distribution of the electric power to its sub-systems and supervise the electrical power status of each device. The design of the ASTRI Mini Array Electrical distribution system is shown in **Error! Reference source not found.**. It includes an emergency power generator that is able to provide power to the Array to safely park all telescopes in case of a grid power outage.

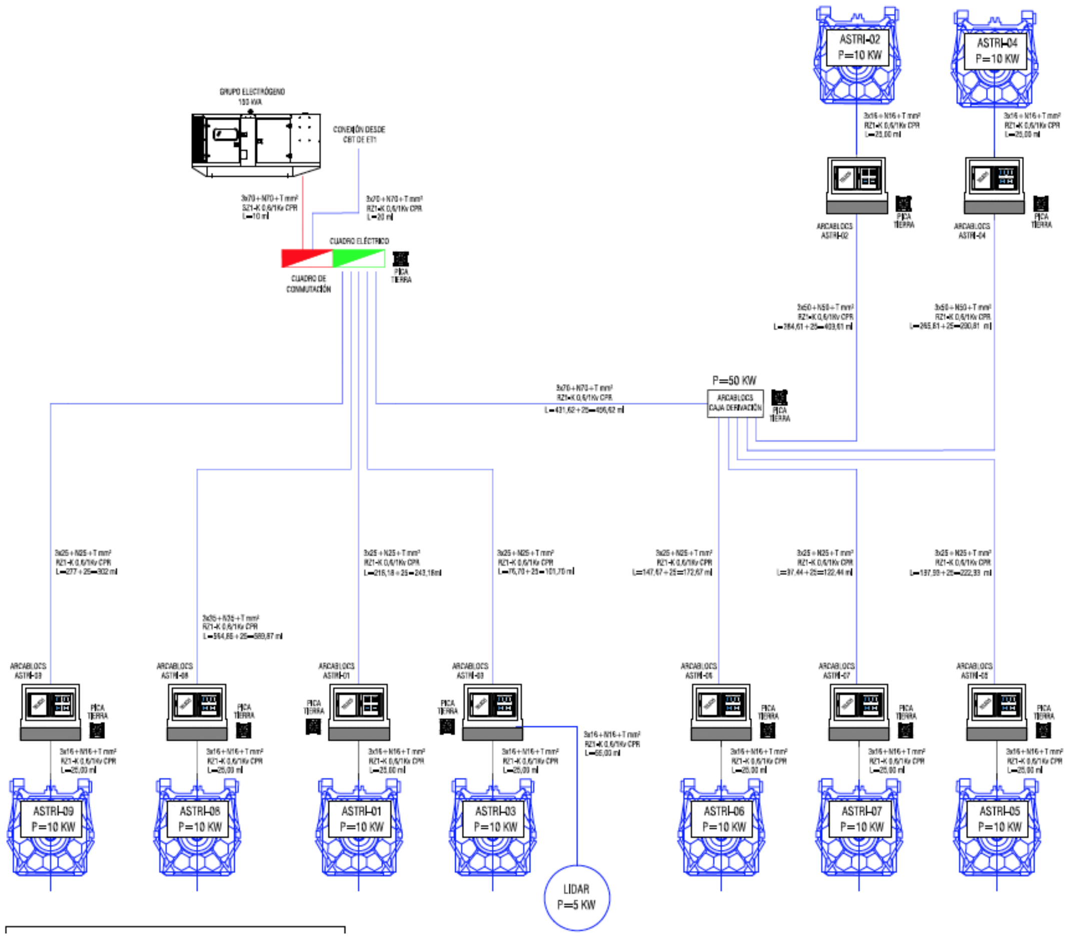

Figure 3-3 ASTRI Mini-Array Electrical distribution system at Teide

Each telescope shall be connected to the power lines provided by the Service Cabinet that are:

- 400 V (3P+N, 50 Hz) for Normal power.
- 230 V (P+N, 50 Hz) for UPS power.

3.1.3 Site Telescope Area

The logical deployment of the Telescope at the Teide site is given in Figure 3-4 (the figure elements are just for illustration). The Service Cabinet represents the place where the Telescope shall be connected to the Site power, network and time distribution systems. The Local Security and Environmental Monitoring devices are the Local Camera of the Mini-Array Site CCTV system and local weather sensors (e.g. rain sensors).

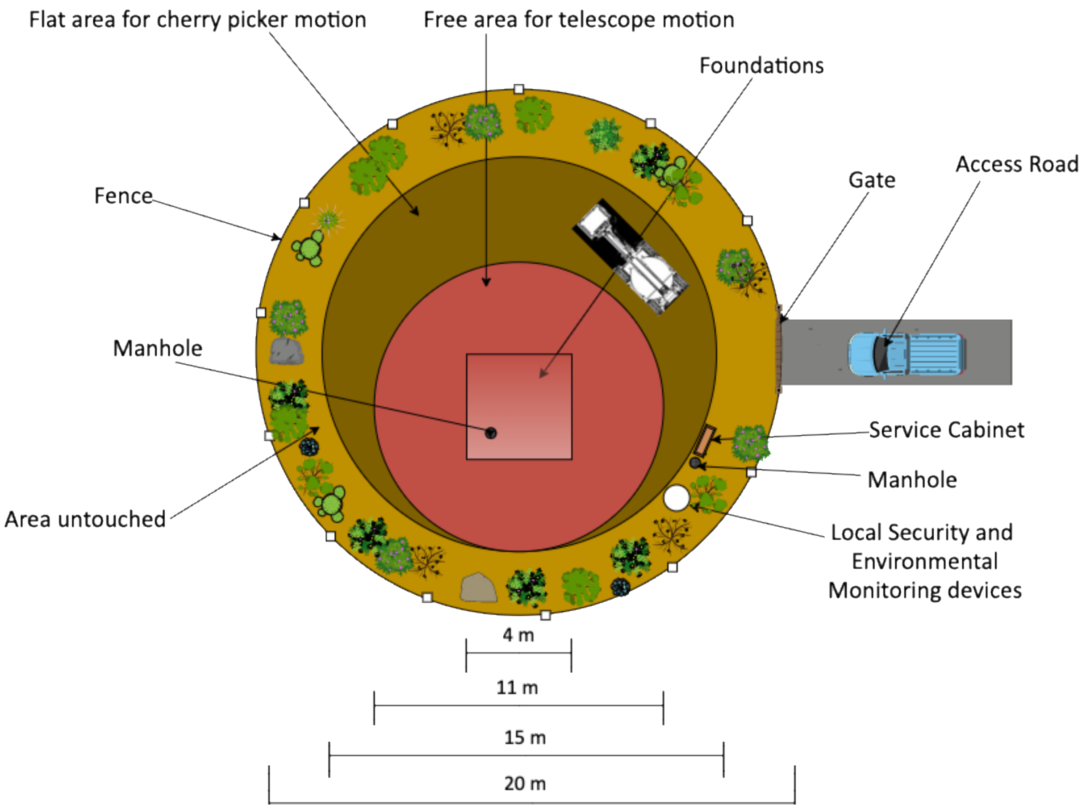

Figure 3-4 A sketchy representation of each Telescope area at the Teide Telescope.

The connection between the Telescopes and the Service cabinet is schematically illustrated in Figure 3-5.

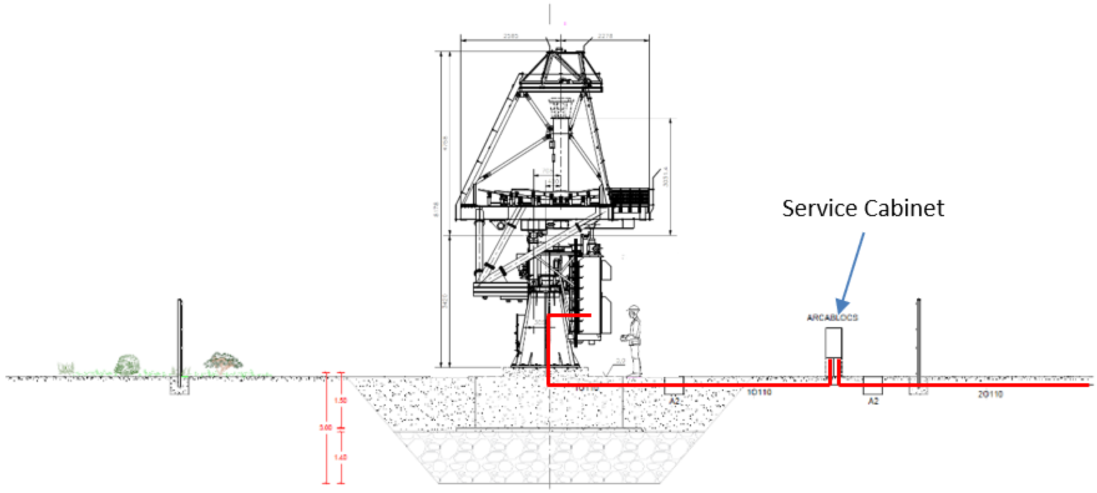

Figure 3-5 Details of the how each Telescope will be installed at the Teide site.

3.2 The ASTRI Telescope Logical Architecture

The context diagram of the telescope is illustrated in Figure 3-6:

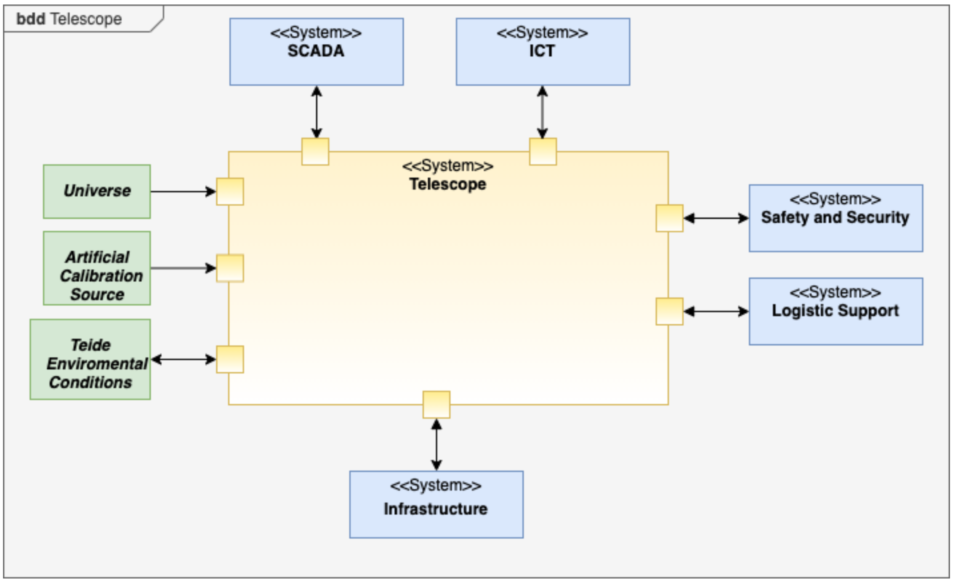

Figure 3-6 Telescope Context diagram

The telescope has the following high-level functionalities: move automatically to any position in the sky as requested by SCADA; collect light (Cherenkov emitted by air shower, stars, and artificial light from the calibration instrument); focus the light onto the focal plane photodetector (Cerenkov Camera or Stellar Intensity Interferometry Instrument and Optical Camera); acquire scientific and calibration images (i.e. to convert light into an electric signal, and amplify, condition, digitize and add a timestamp to each event); deliver the raw images to SCADA for local temporary storage and transmission to the ASTRI Data Centre in Italy.

The Telescope is a stand-alone machine as defined by the Machinery Directive [AD3]. It shall be controlled remotely by the SCADA system and a Telescope Engineering GUI and locally by the Local Engineering GUI provided with each Local Control system. In this context the Telescope Control System shall implement the following functionalities: control of the telescope subsystems remotely or via local control console; handling of human errors, hardware failures, and operational and environmental stresses to protect human, devices, and environment from unacceptable health risk of injury or damage. A safety fence shall be installed around the telescope area to keep persons and equipment safe.

In order to assign a timestamp to each detected light event, the telescope shall be connected to the Array network and Time Synchronization System provided by the ASTRI Mini Array Information and Computing Technology (ICT) system.

3.3 The ASTRI Telescope Decomposition

The ASTRI telescope decomposition is given in Figure 3-7 :

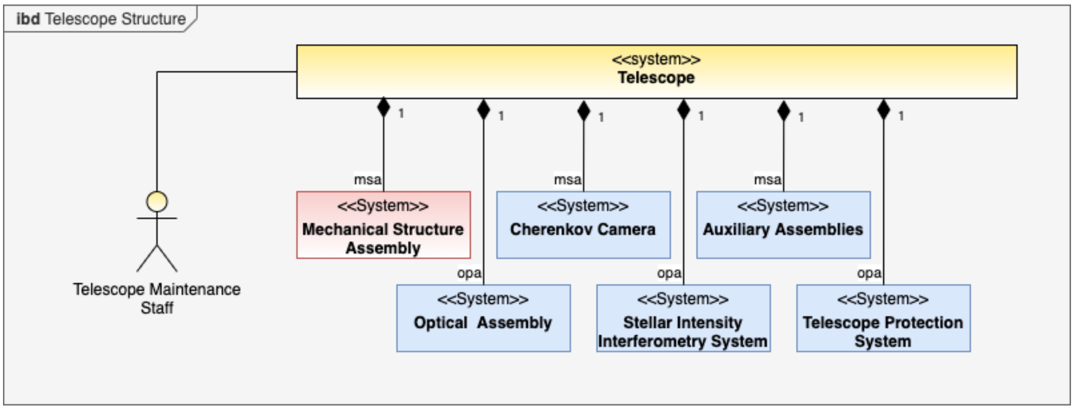

Figure 3-7 Telescope system decomposition.

The description of the Mechanical Structure Assembly is given in section 3.4., while the other components of the Telescope are briefly described in the following subsections.

3.3.1 Optical Assembly

All the hardware needed to collect light. It includes the primary and secondary mirror and their control hardware.

3.3.2 Auxiliary Assemblies

The auxiliary assemblies are those items that support the main function of the telescope during operations and maintenance. Not all those items are permanently present on the telescope but can be installed when needed. The Auxiliary assemblies include:

- The Pointing Monitoring Camera (see [ÅD9])
- The Telescope Conditioning Monitoring System

- The Mirror Alignment system and Optical Camera
- The UVSiPM Instrument for measurement of the Night Sky Background (see [AD8]. There are only three of these instruments mounted on three of the nine Telescopes.

3.3.3 Telescope Protection System

All the hardware necessary to guarantee the safety of the telescope and of the people working on it during operations or maintenance activities. It includes the Telescope Safety and Fire protection systems.

3.3.4 Cherenkov Camera

All the hardware and software associated with Cherenkov image detection, digitisation, transmission and preprocessing. The Cherenkov camera of the ASTRI telescope (see [AD13]), catch and record the ultra-fast Cherenkov light flashes, in the wavelength interval of 300-600 nm, produced by the charged particles in the Air Shower cascade process initiated and sustained by the primary particles crossing the Earth atmosphere.

3.3.5 Stellar Intensity Interferometry Instrument

The Stellar Intensity Interferometry Instrument (SI^3) is a dedicated optical photon detection unit for intensity interferometry observations with the ASTRI telescopes of the mini-array. This module is mounted in front of the Cherenkov Camera through the use of a swing arm (TBC) and it is completely independent from it.

3.3.6 Telescope Control System

The TCS is functionally part of the Telescope but it is a product that will be delivered by the ASTRI Mini-Array SCADA Work Package. The TCS shall be responsible for coordinating any activities of the telescope. It includes the Local Supervisors of the Telescope Local Control systems (LCSs). The TCS does not include direct control of any telescope mechanism, and is not responsible for any time-critical operations. All real-time functions are performed by the Telescope LCSs.

3.4 The Telescope Mechanical Structure Assembly decomposition

The Telescope Mechanical Structure Assembly (MSA) shall include all the hardware and software that shall allow the telescope to point different parts of the sky with the required performances. All mechanical parts needed to support the telescope optics for collecting light shall be part of the MSA.

The MSA of the Telescope shall provide the motion capabilities that allow the Telescope to point and track over its specified range. All the electromechanical part of the MSA are provided with power and communication via dedicated supply lines on the MSA.

The MSA shall be connected to the concrete foundation supporting the Telescope. The Foundations will contain a Telescope anti-seismic system if it may be considered necessary.

The MSA decomposition is given in Figure 3-8 ASTRI Mechanical Structure Assembly :

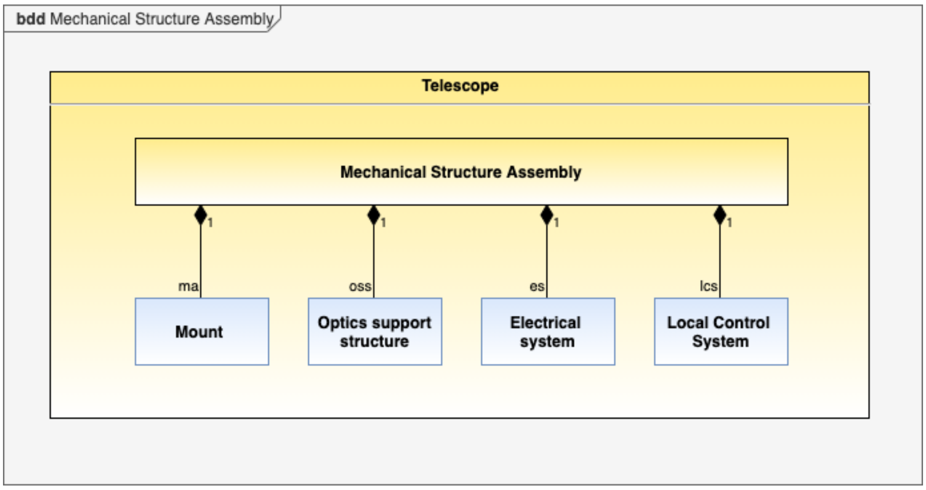

Figure 3-8 ASTRI Mechanical Structure Assembly decomposition

3.4.1 The MSA Mount

The Telescope MSA Mount shall include the main mechanical structure and all the interfaces needed to install the telescope auxiliary systems as well as the interfaces with the Instruments (Cherenkov Camera, SI^3 and Optical Camera). The Mount shall include all the motors, encoders, drives, bearings, and electronics for the control of the main telescope axes. The Mount shall include all the equipment needed to anchor the MSA to the concrete foundations. It shall also include all the access equipment and handling tools needed to maintain the telescope and sub-systems.

The Mount decomposition is given in the following Figure 3-9.

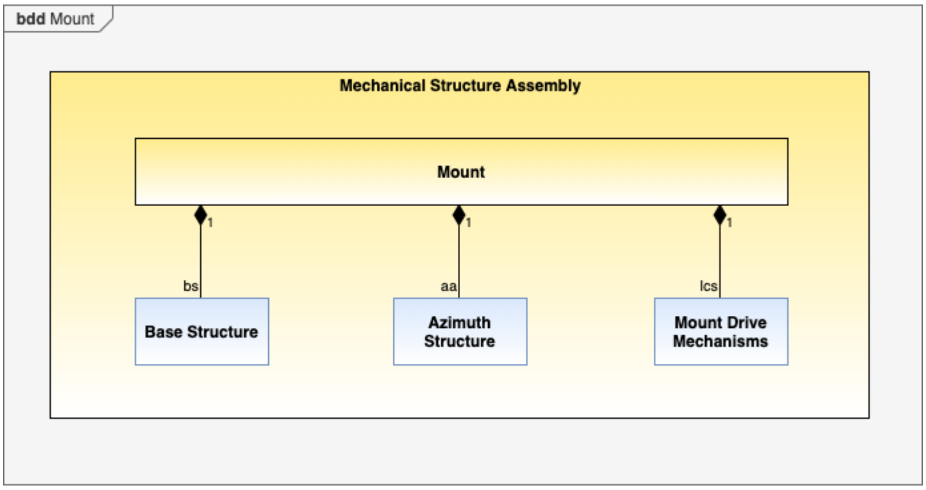

Figure 3-9 Mount subsystem decomposition.

3.4.1.1 Base structure

This term shall indicate the fixed part of the Mount supporting the entire telescope and its connection to the concrete foundations. It includes the support Structure of the Azimuth encoder and the azimuth cable wrap.

The Base structure shall be provided with a door to allow inspection of the Azimuth Encoder and of the Azimuth Cable wrap system.

3.4.1.2 Azimuth Structure

This term shall indicate the structure that rotates about the azimuth axis. It connects the elevation assembly to the base structure. The main part of the Azimuth structure is the Azimuth fork which includes:

- the azimuth bearing;
- the support structure of the Telescope electrical and control cabinets;
- the support structure of the elevation drive system and encoder;
- the support structure of the azimuth drive system;
- the support structure of the azimuth and elevation stow pins;
- the Elevation cable wrap.

3.4.1.3 Mount Drive mechanisms

The mount drive mechanisms shall include:

- Azimuth and Elevation drives (motors and their brakes, and associated electronics and controls)
- Encoders
- Limit switches (the devices detecting and preventing the MSA motion outside of the safety range)
- Stow pins (the devices used to lock the MSA into the parking position).

3.4.2 The MSA Optical Support Structure

The MSA Optical Support Structure is the structural elements on which M1 segments and M2 are mounted and includes

- The M1 dish, the structure to which are anchored the M1 mirror segment supports.
- The M2 support structure. It also includes the Pointing Monitoring Camera support and the Intensity Interferometry Module support structure (TBC).
- The structure connecting the M1 dish and the M2 support structure;
- The Instrument support structure on which the Cherenkov Camera and the Optical Camera used for the alignment of the mirrors can be mounted;
- The counterweights to balance the elevation structure around its axis of rotation;

These elements shall be anchored to Mount Structure.

3.4.3 The MSA Electrical System

The MSA Electrical system shall include all the means (cables, switchboards, cable trays, etc) for the distribution of electrical power inside the MSA.

3.5 The ASTRI Mini Array Control System Overview

The Software logical architecture of the ASTRI Mini-Array Control system at the Teide Site is illustrated in Figure 3-10. The full description of the ASTRI Mini-Array Software Architecture is given in [RD2].

As part of the ASTRI Mini-Array each telescope cooperates to obtain stereoscopic air shower and intensity interferometric observations and to the safety operation of the Array under supervision of SCADA. Therefore, the Telescope shall be able to receive commands from SCADA and from the Safety and Security System; communicate to SCADA and to the Safety and Security System its status, monitoring data or alarm conditions.

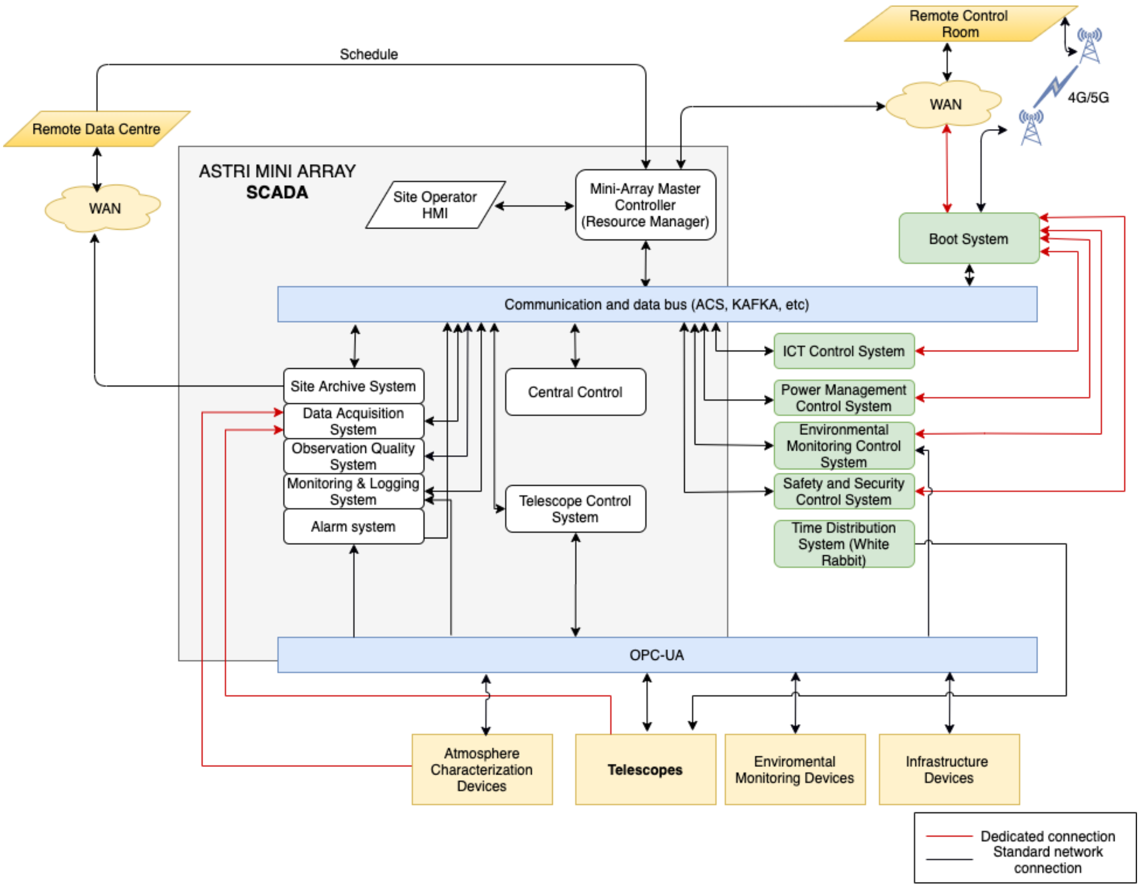

Figure 3-10 Logical Control Software Architecture of the ASTRI Mini-Array at the Teide site.

The Telescope Control System (TCS) is designed and implemented by the Customer. It is deployed at the Site data Centre and implements the high-level functionalities of the telescope. Figure 3-11 show the first level decomposition of the TCS.

The Telescope Manager provides the interface used by the SCADA Central Control to coordinate the operations of all nine ASTRI telescopes of the Mini Array.

The TCS implement Local Supervisors dedicated to coordinate the Telescope Local Control Systems. The TCS include: the Local Control System (LCS), the supervisors of the LCS and the Telescope Manager.

The state of the MSA (given in 1.4.2.7) and the states of the local control systems are separated, and the TCS manage the association between the states. As a consequence, the MSA LCSs identify the states to be controlled.

A LCS takes care of one complete subsystem (like the mount), implements all the local feedback loops, and provides a command interface and a monitor interface to the higher level control system (the supervisor), which orchestrates all the LCS. The LCSs have enough intelligence to control its domain specific actuators and sensors.

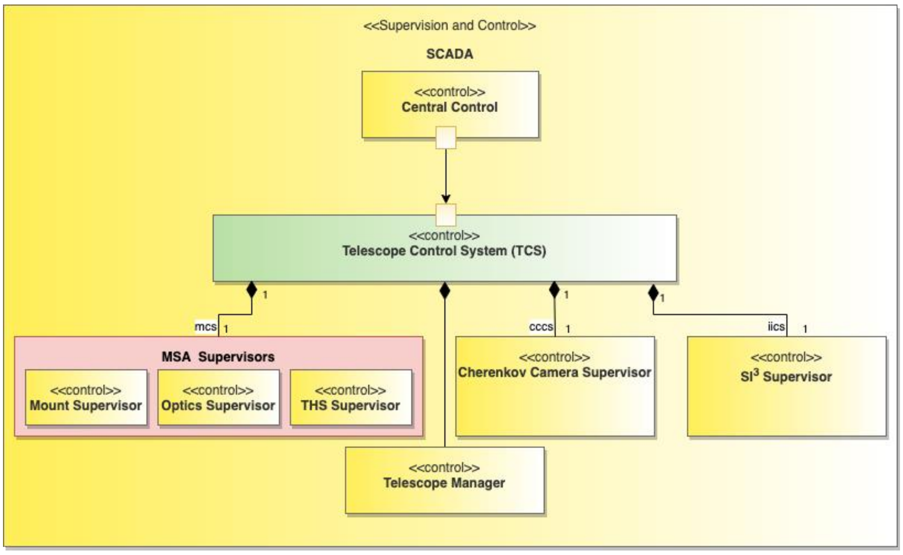

Figure 3-11 Telescope Control System main components.

3.5.1 The Telescope Control Architecture

This section gives a description of the ASTRI Telescope Local Control Systems to provide the needed background to the MSA Contractor.

Figure 3-12 shows an overview of the Local control architecture of the Telescope. It is an update of the architecture implemented in the ASTRI-Horn [RD1].

3.5.1.1 Azimuth Drive subsystem

The Azimuth axis motion shall be powered by two servomotors located at 180 to each other. Each motor shall be provided with two reduction stages and transmits motion to the mechanical axis through a pinion mounted on the second reduction gearbox that is coupled to the Azimuth slewing-bearing.

The two motors shall be coupled together in a master-slave configuration, controlled in differential torque mode in order to eliminate backlash and hence guarantee good motion accuracy under all operational conditions.

The master motors shall be equipped with a brake and a back shaft. In case of power failure or when the azimuth emergency switches are reached, the motor brake shall be able to be released manually to allow to move the azimuth axis with a battery powered emergency motor (e.g. a drill) coupled to the back-motor shaft.

The Azimuth axis encoder shall be the Heidenhain incremental tape encoder ERA7400C and four ERA7480 scanning heads, providing a resolution of 1.6”.

3.5.1.2 Elevation Drive subsystem

The Elevation axis motion shall be powered by a servomotor equipped with a brake to provide safe operations and avoid accidents to people and hardware.

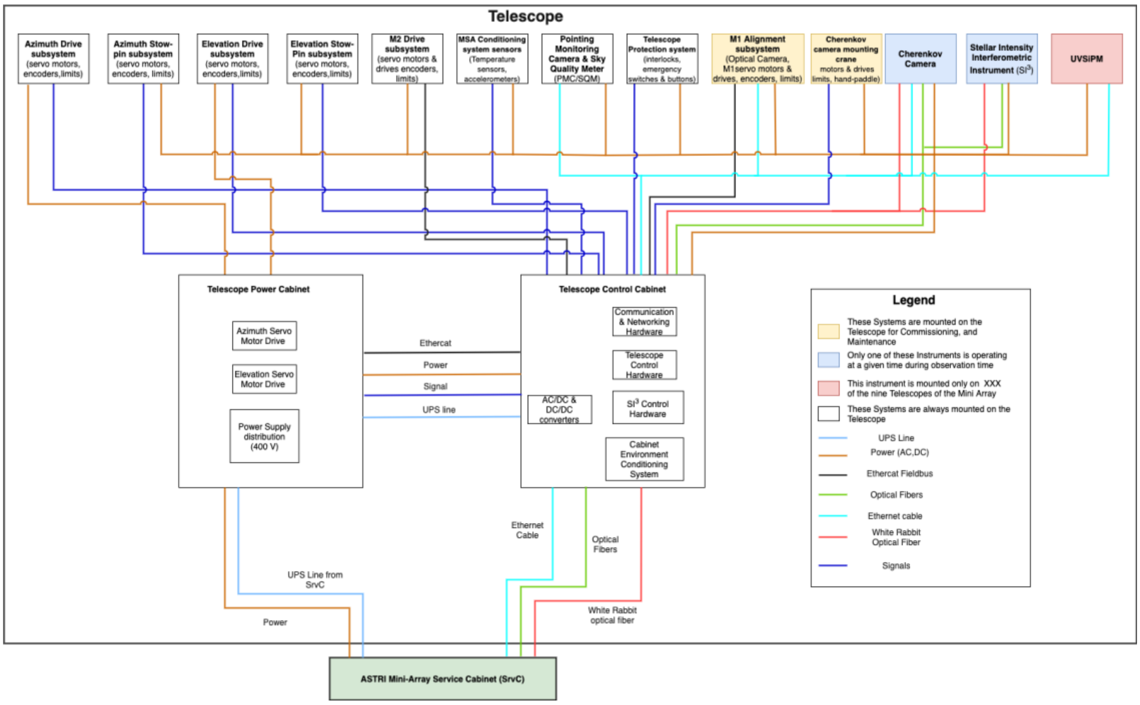

Figure 3-12 Telescope Local Control Architecture

In case of power failure or when the elevation emergency switches are reached, the motor brake shall be able to be released manually to allow to move the elevation axis with a battery powered emergency motor (e.g. a drill) coupled to the back-motor shaft.

The Elevation axis encoder shall be the Heidenhain RCN2580 absolute encoder, providing a resolution of ± 2.5”.

The telescope control hardware and electrical communication components are grouped following their functionality and they are contained in two electrical cabinets, supported by the Azimuth Fork: Telescope Power Cabinet (TPC, HPC in ASTRI-Horn) and the Telescope Control Cabinet (TCC, LPC in ASTRI-Horn).

3.6 The MSA Local Control Systems

The MSA Local Control Systems (LCSs) include control software, control units, devices and local communication infrastructure (cabling, trays, patch panels, network equipment etc) needed to monitor and safely command the MSA and its sub-systems. It does not include the actuators and sensors of the MSA.

The main MSA LCSs are:

- The **Mount LCS**, is the main control system of the telescope. It controls all the Telescope functionalities like pointing to and tracking any celestial object accessible fron the Teide site.

- The **Telescope Health and Safety LCSs**, is in charge to monitor the health and safety of the MSA and of the entire Telescope. It is in charge of the power monitor an distribution management (switch-on/off) of all telescope subsystems, including the Science Instruments and the Commissioning and Maintenance mechanisms that will be temporary mounted on the MSA.

- **The Optics LCS**, is in charge of the control of the M2 (focusing) and of the special mechanism that will be used to Align the M1 segment during the Telescope Commissioning and Maintenance.

3.6.1 The MSA Local Control and safety System Units

Figure 3-13 shows the main components of the MSA Control Hardware. It includes all the electronics and hardware parts needed to drive the telescope to any accessible sky position during the commissioning, testing and observing phases.

The main MSA Control Hardware components are:

- The Telescope Control Unit (TCU) is the IPC running the software which is in charge of the monitoring and control of the Elevation and Azimuth axes motion.
- The Telescope Health (THCU) and Safety Units (SU) runs the software and safety logic which are in charge of the interlock chain and power management of the telescope and of the monitoring of the health of all the Telescope subsystems.
- The Optics Control Unit (OCU, named AMCU in the ASTRI-Horn prototype) run the software which is in charge of the control and monitoring of the M2 positioning system and of the control and monitoring of the of M1 segment alignment system used during commissioning and maintenance.
- The Azimuth and Elevation Servo Drivers, which include the high-power electronics stage that deliver power to the and provide the main motor velocity and torque control loops.

The TCU, THCU and OSU shall be Beckhoff industrial PCs (IPCs) integrated in the TCC. These IPCs demonstrated their high reliability and reduced maintenance need during the last seven years of use in the ASTRI-Horn prototype.

TCU, THCU and OSU will run the Beckhoff TwinCAT software system which turn any MSA IPC into a real-time controller with a multi-PLC system.

The Safety Unit shall be a Beckhoff safety PLC (IEC 61508 SIL 3). It shall be connected to the THCU via the Beckhoff E-Bus so it is considered as part of the THCU.

The Azimuth and Elevation servo drives shall be connected to the Local Control Units using EtherCAT (IEC 61158) fieldbus.

All digital and analog Beckhoff I/O modules used in the MSA Local Control Systems shall be connected to the Local control units using the EtherCAT (IEC 61158) fieldbus. The wiring of the Beckhoff I/O modules shall be performed making use of the special connectors provided by BECKHOFF, avoiding when is possible the direct wires connections into the front clamps.

The TCU, THCU and OSU shall be connected to the electrical line under UPS provided by the ASTRI Mini Array site Infrastructure.

All Industrial PCs shall be equipped with a 24 V power supply unit and an integrated UPS. The UPS supplies the PC with power if the mains power fails. This allows data to be saved after which the PC can be shut down properly.

The THCU, the SU and the communication devices of the MSA shall be always powered-on also during the day.

The TCU, THCU and OSU TwinCAT PLCs shall share internal variables through the Real-Time Ethernet protocol provided by Beckhoff and already available in the TwinCAT tool.

The Contractor shall procure, install and test all the hardware components of the MSA Control and Safety Units.

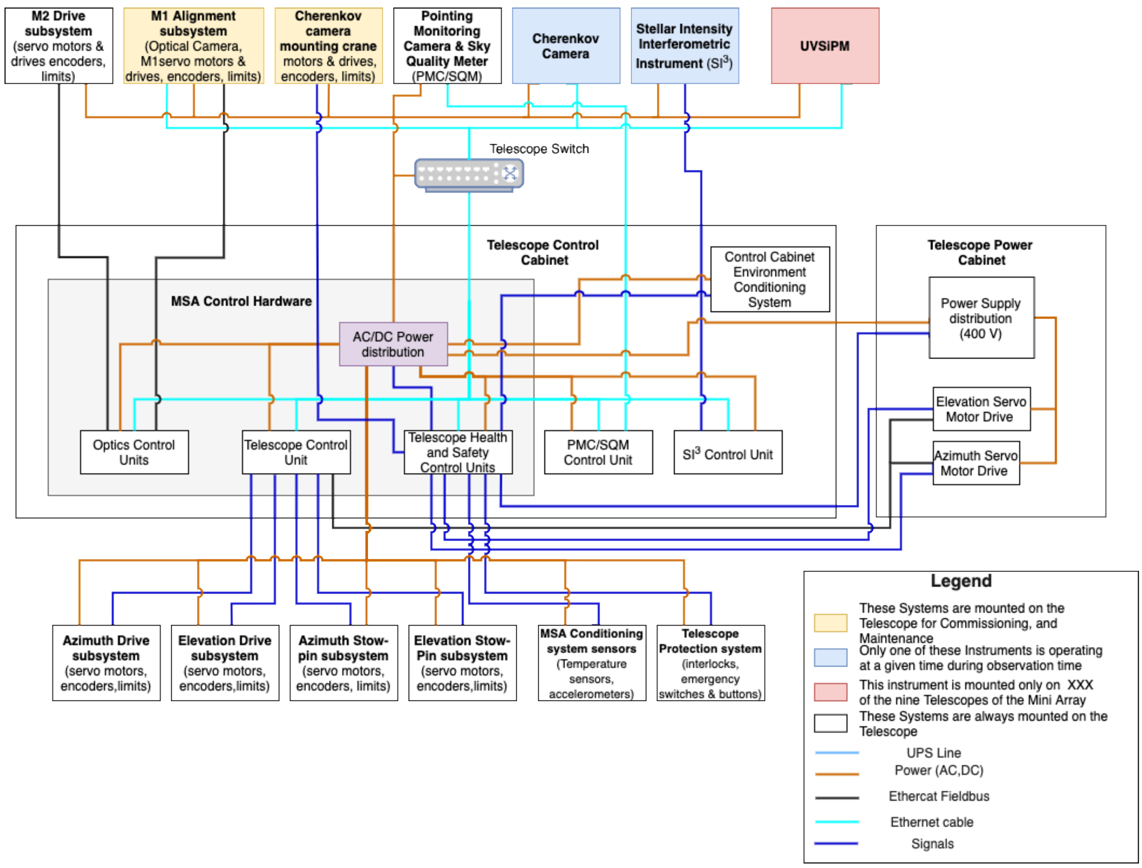

Figure 3-13 The MSA Control Hardware conceptual design

3.6.2 The MSA Local Control software

The MSA Local Control Software shall be developed by the Contractor. The component provided by the Costumer or by other suppliers are highlighted in the text.

The MSA Local Control Software is running on the Local Control Units (TCU, THCU, OCU) and Safety Unit (SU).

The MSA Local Control Software shall run as PLC programs under the Beckhoff TwinCAT software system which turn any MSA IPC into a real-time controller with a multi-PLC system.

The software running on the PLC created by TwinCAT shall be written using the IEC61131-3 PLC programming languages.

Each MSA Local control system shall use the OPC-UA communication protocol (IEC 62541) to exchange information with the TCS on the basis of a dedicated Interface Control Document.

Each MSA Local control software shall implement a TwinCAT OPC-UA Server.

The MSA Local Control Software main components are: (see Figure 3-14)

- The Mount Local Control Software that shall run on the TCU, includes:
    - The Mount Axes Controller (MAC) running on a dedicated TwinCAT PLC (MAC PLC). The MAC shall use the PLCopen Motion Control Library,

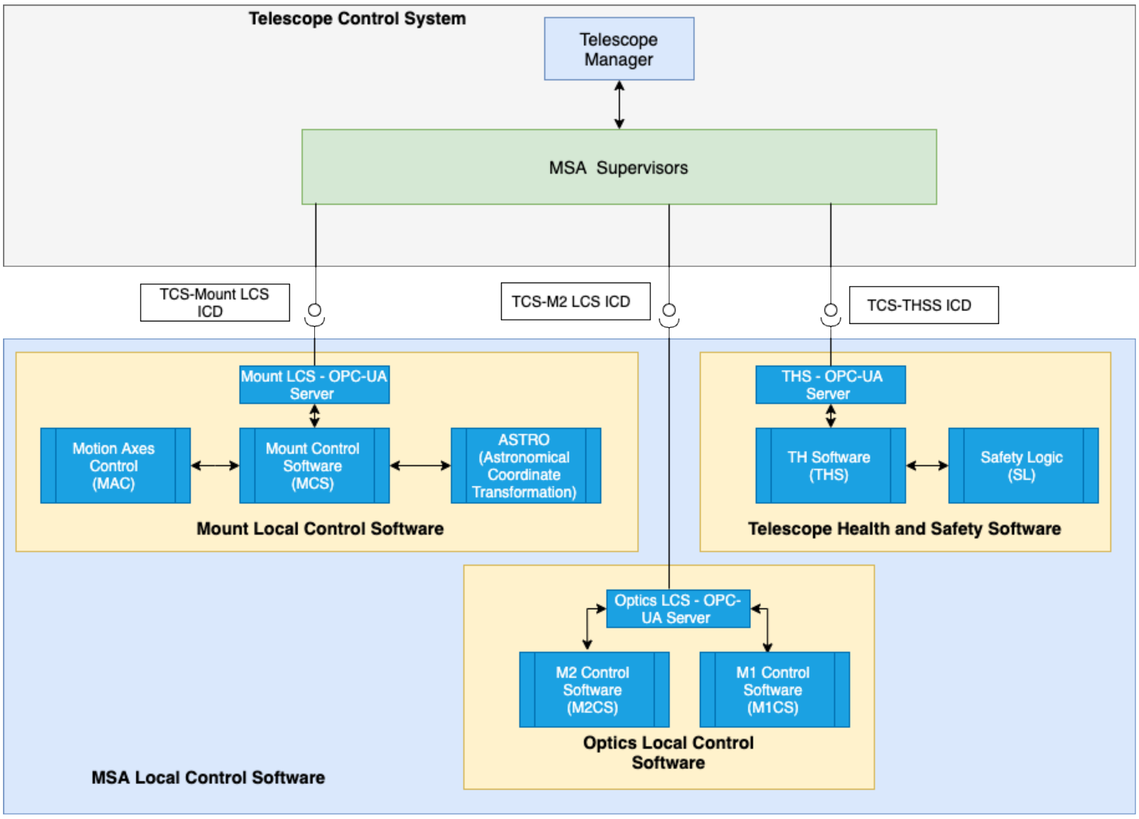

Figure 3-14 The MSA Local Control Software and their interfaces with the TCS

available in TwinCAT, for implementing all servo control software necessary to safely operate the Azimuth and Elevation Drive subsystems. The Motor Axis Control shall be able to control the movement of the MSA locally via a hand-paddle for diagnostic and maintenance purpose.

    - The Mount Control Software (MCS) running on a dedicated TwinCAT PLC (MC PLC). It provides the interface with the TCS and coordinate all functionalities needed to the science, calibration and maintenance operation of the MSA.
    - The Astronomical Coordinate Transformation (ASTRO) running on a dedicated TwinCAT PLC (ASTRO PLC). It provides the needed Astronomical transformation and sky trajectory generation needed to point and track a celestial source.
      The ASTRO software is provided by the Customer as a TwinCAT PLC program written in IEC61131-3 Structured Text language.
    - A local Human Machine Interfaces should be provided to use locally the MCS functionalities.
- The Telescope Health Software (THS) that shall run in a dedicated TwinCAT PLC (THS PLC) of the THCU.
- The Safety Logic running on the Safety PLC.
- The Optics Local Control System running on the OSU, include
    - The M2 Control software (M2CS) running on a dedicated TwinCAT PLC (M2C PLC). The M2C shall use the PLCopen Motion Control Library provided by TwinCAT for implementing all servo control software necessary to safely operate the Focusing system of M2.
    - The M1 Control software (M1CS) running on a dedicated TwinCAT PLC (M1C PLC). **This component shall be used only for the Alignment of the M1 segments during Commissioning or Maintenance activities**.
      The M1CS is provided by the Customer as a TwinCAT PLC program written in IEC61131-3 Structured Text language.
    - A local Human Machine Interfaces should be provided to use locally the OSU functionalities.

During tracking of a celestial source, the MAC shall handle position, velocity and time commands sent by the TCS to the MCS, with accuracy needed to meet the motion requirements. The TCS system will provide positioning update sent to the MAC with frequency in the range [1-10] Hz.

The MCS shall be able to generate position, velocity and time sequence to track celestial source to command the MAC with frequency in the range [1-10] Hz.

When slewing is done not under MCS control, the MAC shall use a standard S-shaped motion profile. This motion profile shall conform to both the fixed and software limits. These requirements shall be met for both axis and for accelerating, decelerating and braking.

[RD1] is the reference document that shall be used by the Contractor for the design and implementation of the hardware and software components of the Mount and Telescope Health and Safety Local Control System.

The Mount and Telescope Health and Safety Local Control Software developed and used by the ASTRI-Horn prototype is described in detail in [RD3] and [RD4] and the source code may be provided by the Customer to the Contractor.

4 Environmental Conditions

The Environmental conditions of the Teide site where shall be operated the ASTRI Mini Array are reported in [AD2]. A summary is given in the following table.

Table 8 - Environmental Conditions at Teide

Parameter	Normal	Observation	Transition	Survival
Air pressure	750±50 mbar			
Air temperature	-5°C to +25 °C		For T<-5°C or T>25°C to Safe State	-10°C to +30°C without power; -15°C to +35°C in Safe State
Temperature gradient	N/A	7.5°C/h	> 7.5°C/h	0.5°C/min for 20 mins
Relative humidity	2% to 90%		>90%	2% to 100%
Rain	none		≤2mm in 1h	≤70mm in 1h; ≤200mm in 24h;
Snow	none		none	≤200 kg/m2 on horizontal surface <50cm
Hailstone	none		none	∅ =5 mm, E = 0.2 J
Wind	≤50km/h for 10mins	≤36km/h for 10 mins	≤50 km/h for 10mins; serviceability limit state: <60km/h for 10mins	≤100km/h for 10mins; serviceability limit state: ≤120km/h for 10 mins in safe state; serviceability limit state: ≤120km/h for 10 mins in safe state; serviceability limit state: ≤248km/h for 1s (gust); serviceability limit state: ≤90km/h for 10 mins (precipitations hail / snow/ rain);
Solar radiation	1200 W/m^2 (averaged over 1 hour) T≤ 35ºC in the safe state			
Dust and sand	none		none	2.9 x 10^5 particles of ≥5μm size per m^3 of air for 90% of the time at 2m above ground
Illumination	none		none	≤10^6 photons ns^{-1} cm^{-2}

Earthquakes	none	horizontal ground acceleration ≤0.06g; peak vertical ground acceleration < 0.06g

5 MSA Functional Requirements and performances

5.1 Azimuth and Elevation Motion Requirements

The MSA shall be able to point at the different field positions on the sky. The requirements below define the pointing range and accuracy. The requirements are for simultaneous motions in both axes.

Code	Name	Description	M
2010	Functional Azimuth Motion range	During operation the MSA must be able to rotate, in a controlled manner, both clockwise and counter-clockwise, in the range from -270° to +270° starting from the East geographical direction.	T
2020	Functional Elevation Motion range	During operation the MSA must be able to rotate, in a controlled manner, both clockwise and counter-clockwise, in the Elevation range from 0° to +90°.	T
2030	Observation Elevation range	The elevation range of the MSA during observations shall be at least 20-91 degrees.	T
2040	Observation Azimuth range	The azimuth range of the MSA during observations shall be 360° degrees.	T
2050	Repositioning time	During observations the MSA shall be able to rotate to any point in the sky above 30° in elevation within 70s.	T
2060	Azimuth speed and acceleration	The MSA azimuth axis shall move with a speed > 4.7 °/s and an acceleration of at least 1 $°/s^2$.	T
2070	Elevation speed and acceleration	The MSA elevation axis shall move with a speed > 1.1 °/s and an acceleration of at least 0.8 $°/s^2$.	T
2080	Tracking error	The MSA shall be able to track any sky target in the positioning range for observations with an error in each axis of <0.1 degrees (<6 arcmin) over a period of 600 sec. The tracking error shall be evaluated as the r.m.s of difference between the commanded positions and the MSA positions as determined by the Encoder system.	T
2090	Pointing error	The MSA pointing error during observations shall be < 35 arcsec. The pointing error shall be evaluated as the difference between the commanded positions and the MSA positions as determined by the Encoder system.	T
2100	Pointing Astrometric error	The astrometric pointing accuracy of the MSA on the sky shall be 7 arsec r.m.s. This shall be obtained after installation of the optical systems and after applying the pointing model corrections.	T

5.1.1 Definition of the operational Azimuth and Elevation motion paths

The Azimuth and Elevation axes paths are illustrated in the following figures.

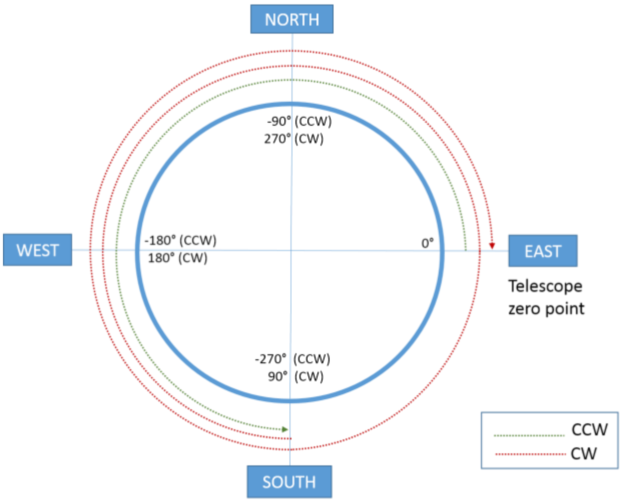

Figure 5-1 The allowed Azimuth path of the Telescope.

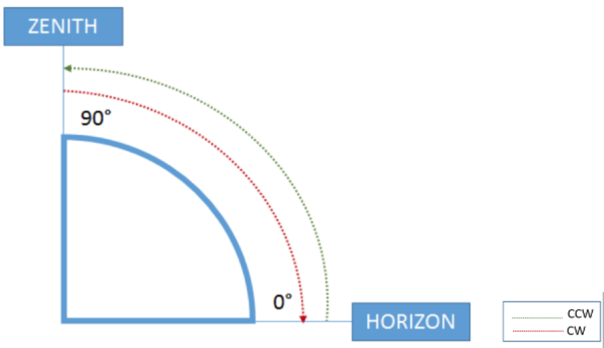

Figure 5-2 The allowed Elevation path of the Telescope.

For the Azimuth (AZ) axis we should consider Three coordinate systems, based on different contests: MSA (STR), MSA Encoder (ENC) and Sky (SKY).

The MSA Clock Wise (CW) and Counter Clock Wise (CCW) motion range of the AZ axis are given in [**ASTRI-7100-2010**]. In order to check if the AZ axis has reached its position from the CW or CCW direction a dedicate devices shall be mounted inside the base of the telescope at the East geographical direction.

The mechanical zero point of the STR reference frame, is defined as the position at which the optical axis of the telescope faces at East. This is the position at which the cables wrap inside the MSA base is completely unwound.

The encoder (ENC) coordinate system is the reference frame used by the MSA Local Control Software to control and monitors the AZ positions. This shall be implemented in the MSA LCS Software. In the ASTRI-Horn implementation if the MSA LCS the origin of the ENC system was set at South geographical direction. In this way the values of the AZ in ENC coordinate increase going in CW direction up to 540, where the limit is reached (see the red dotted line in figure 5-1).

For the pointing and tracking purpose, the Azimuth and Elevation of the Telescope correspond to the standard Astronomical Horizontal coordinate. The Azimuth origin of this system is at North and the values increase if the rotation of the axis takes place in CW direction between 0-360°. The Elevation shall be 0° at the horizon and increase up to 90° at the zenith.

5.2 MSA Servo control loop

The Contractor shall design the MSA servo loop (including the encoder and motor drive system) considering velocity control at low tracking velocities and minimizing the possible induced control noise to the mechanical structure and optical system.

The Contractor shall perform and provide Servo Control Analysis and simulations for the Azimuth and Elevation Axes. In this analysis the following requirements shall be considered:

Code	Name	Description	M
2110	Control loop gain margin	The gain margin for both MSA axes control loops shall be not less than 6 dB over all conditions.	A,T
2120	Control loop phase margin	The phase margin for both MSA axes control loops shall be not less than 30 degrees over all conditions.	A,T
2130	Position closed loop bandwidth	The MSA Azimuth and Elevation position close loop bandwidth shall be greater than 1Hz.	A,T

5.3 Operational Requirements

The operation of the ASTRI Mini – Array during the night are under the supervision of a remote operator, there is not presence of personnel on the Array site during the night.

Code	Name	Description	
2140	Subsystem calibration	The MSA subsystems calibration activity that not necessarily need night sky conditions shall be performed during daytime.	T
2150	Transition state	The MSA shall transit from the initialized state to the operational state in less than 30 minutes.	T
2160	Power Control	The MSA LCS shall allow to control the power of each MSA subsystem both remotely and locally by a person present at the telescope area.	T
2170	Hand-paddle	The MSA LCS shall allow to safely control the MSA motion locally through a dedicated hand-paddle for diagnostic or maintenance purpose.	I,T

2180	Power on	In remote mode the MSA LCS shall automatically transit from the Off state to the Initialized state when power is provided.	T
2190	Sudden Loss of Power	In the exceptional cases of a sudden loss of power all MSA subsystems shall not suffer any damage.	I,T
2200	Local Errors	The MSA LCS shall monitor all parameters needed to assess the health and status of MSA and its subsystems.	D,T
2210	Error reporting to upper leve	The MSA LCS shall notify to the TCS any detected error.	D,T
2220	Automatic recovery procedure	The MSA LCS, when possible, shall implement automatic error recovery procedures.	D,T
2230	Recovery reporting to upper level	The MSA LCS shall notify to the TCS the results of the error recovery procedure on the basis of the MSA to TCS Interface Control Document.	D,T
2240	Error Recovery procedure failure	In case an error recovery procedure for any MSA subsystem fails, the MSA LCS shall automatically transit to Fault state that prevents damage. The MSA LCS shall notify the fault State to the TCS on the basis of the MSA to TCS Interface Control Document.	D,T
2250	Alarm Generation	If an error recovery procedure for any MSA subsystem fails the MSA LCS shall send an alarm to the TCS on the basis of the MSA to TCS Interface Control Document.	D,T
2260	State Change Notification	The MSA LCS shall notify to the TCS the change of state of the MSA on the basis of the MSA to TCS Interface Control Document.	D,T
2270	Performance monitoring	The MSA LCS shall monitor the performances of any MSA subsystem and notify an alarm if they are not met to the TCS.	D,T
2280	Support for troubleshooting activities	The MSA LCS shall provide the support to all troubleshooting activities down to the level of LRUs of each MSA Subsystem.	D,T
2290	Configuration Settings	The MSA LCS shall be able to receive all configuration data delivered by the TCS in order to prepare for transition among states on the basis of the MSA to TCS Interface Control Document.	D,T
2300	Transition Interruption	The MSA LCS shall allow to interrupt transitions between states upon request by the TCS. The MSA LCS shall return to the previous state within the corresponding transition time.	D,T

2310	Time Synchronization	The MSA LCS internal time shall be synchronized to the ASTRI Site NPT Time provided by the ASTRI Mini Array Time synchronization system.	D,T
2320	Monitoring Data	The MSA LCS shall provide monitoring information to the TCS on the basis of the MSA to TCS Interface Control Document.	D,T
2330	Logging	The MSA LCS shall provide logging information to the TCS on the basis of the MSA to TCS Interface Control Document.	D,T
2340	Configuration	The MSA LCS shall receive configuration from the TCS on the basis of the MSA to TCS Interface Control Document.	D,T
2350	Command	The MSA LCS shall receive commands from the TCS on the basis of the MSA to TCS Interface Control Document.	D,T

6 Design Requirements

6.1 Materials, Parts and Processes

For the selection of materials, parts and processes, the localization and the remoteness of the Teide observatory site shall be considered.

Code	Name	Description	M
3000	Environmental Condition of the Site	The design of the MSA shall consider the environmental condition listed in Table 8.	D
3010	Altitude of the Site	The design of the MSA shall consider the specific conditions related to high altitude of the site (>2300 m a.s.l.). This may result in derating of components and selection of specific materials.	D
3020	Environmental, equipment and occupational safety and health	For environmental, equipment and occupational safety and health: the European Union (EU) law shall be applied, e.g. RoHS 2 Directive 2011/65/EU (https://eur-lex.europa.eu/legal-content/IT/TXT/?uri=CELEX%3A32011L0065)	D
3030	Electrical Cables	Only cables that do not generate toxic gases in case of a fire shall be used, the EU Regulation No 305/2011 (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32011R0305) is applicable.	D

6.2 Electromagnetic Compatibility

Code	Name	Description	M
3040	Electromagnetic Compatibility	The MSA shall be electromagnetically compatible, with noise generated by each subsystem having an acceptable level of impact on the performance of the other. The subsystems should also be designed to tolerate EM noise associated with local maintenance and engineering activities.	D

6.3 Workmanship

Code	Name	Description	M
3040	Workmanship	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 shall be used by the Contractor for the design, construction and test of the MSA. 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 >2000m above sea level.	D

6.4 Interchangeability

Code	Name	Description	M
3040	Interchangeability	In the design of MSA the Contractor shall consider interchangeability requirements related to the long lifetime of the instrument. In particular the probable non-availability	D

		/-pourability of electronic components over the long instrument lifetime shall be considered.	

7 Physical Requirements

Code	Name	Description	M
4000	Total Moving Mass	The total moving mass of the MSA shall not exceed 18 metric tons. The MSA moving mass includes all payloads.	D,A
4010	Optical elements locations	The MSA 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.	D,T
4020	M2 - Focal Plane distance	The MSA 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.	D,T
4030	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: ±4 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	D,T
4040	M1 Segment Alignment tool	The MSA Contractor shall develop a tool that will allow to properly align the M1 segments. This tool shall allow to calibrate the position of each segment at regular intervals with tip-tilt accuracy of 10arcmin and piston accuracy of 0.05mm.	I,D,T
4050	M2 Displacement tolerances	The displacement of M2 shall be: 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: ±4 mm along Z_{ERS} Axial error with respect to Cherenkov camera: ±1 mm along Z_{ERS} The maximum allowed rotation with respect to its nominal position shall be within 10 arcmin along all axes.	D,T
4060	M2 Positioning system	The secondary mirror position shall be adjusted with tip-tilt accuracy of 10arcmin and piston accuracy of 0.02mm.	D,T
4070	Parallelism between gravitational vector and Azimuth axis	The MSA azimuth axis shall remain parallel to the gravitational vector to within 30 arcsec over the entire azimuth axis operational range.	D,T
4080	Perpendicular condition between Elevation and Azimuth axes	The elevation and azimuth axes shall remain perpendicular to within 60 arcsec over the entire operational range of both axes.	D,T
4090	Perpendicular condition between Elevation and Optical Axes	The MSA elevation and optical axes shall be perpendicular to within 60 arcsec.	D,T
4100	Balancing system	The MSA 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	D,T

		axis and perpendicular to both the optical axis and the elevation axis.	

8 Interface Requirements

Code	Name	Description	M
5000	ASTRI Mini-Array Interfaces	All Interfaces between the MSA and the external elements of the ASTRI Mini-Array shall be defined as per the ASTRI Mini-Array Interface Management Plan [AD15]	I,D,T
5010	Telescope Foundation Interface	The MSA interface with the Concrete foundation provided by the Customer shall be as described in a dedicated Interface control document	I,D,T
5020	Site Power interface	The MSA interface with the ASTRI Mini Array Power distribution system shall be as described in a dedicated Interface Control document.	I,D,T
5030	Site ICT Interface	The MSA interface with the ASTRI Mini Array ICT system shall be as described in the dedicated Interface control document [AD11]	I,D,T
5040	Telescope Control System interface	The MSA Local Control Systems interface with the Telescope Control System provided by the Customer shall be as described in a dedicated Interface control document.	I,D,T
5050	Safety & Security System interface	The MSA Safety System interface with the ASTRI Mini-Array Safety & Security System shall be as described in a dedicated Interface control document.	I,D,T
5060	Cherenkov Camera Interface	The MSA interface with the Cerenkov Camera provided by the Customer shall be as described in the dedicated Interface control document [AD13]	I,D,T
5070	Intensity Interferometry Instrument Interface	The MSA interface with the Intensity Interferometry Instrument shall be as described in the dedicated Interface control document.	I,D,T
5080	Pointing Monitoring Camera Assembly Interface	The MSA interface with the Pointing Monitoring Camera assembly provided by the Customer shall be as described in the dedicated Interface control document [AD9]	I,D,T
5080	UVSiPM Interface	The MSA interface with the UVSiPM provided by the customer shall be as described in the dedicated Interface control document [AD8]	I,D,T
5090	M1 mirror segments Interface	The MSA interface with the M1 mirror segments provided by the Customer shall be as described in the dedicated Interface control document [AD12]	I,D,T
5100	M2 mirror Interface	The MSA interface with the M2 mirror provided by the Customer shall be as described in the dedicated Interface control document [AD10]	I,D,T
5110	Emergency drive Interface	The MSA shall provide Interfaces for connection of an emergency drive in both Azimuth and Elevation axes to move the telescope in safe position in case of maintenance or power failure.	I,D,T

9 Product Assurance (PA) induced requirements

9.1 Quality plan

Code	Name	Description	M
6010	Quality Plan	The MSA supplier shall produce a specific quality plan compliant to the ASTRI Product Assurance Plan [AD1] that shall be implemented for all activities relates to MSA production.	I

9.2 Lifetime

Definition: Lifetime is defined as the period over which a ASTRI Mini Array element shall be compliant with the applicable requirements applicable to that element and at the same time, the cumulative capital investment costs of repairs or replacements, taking into account the normal maintenance program, is below 20% of the initial capital investment cost for that element.

Code	Name	Description	M
6020	System Lifetime	The MSA and all its subsystems shall be designed for an operational Lifetime of 30 years.	A
6030	Drive System lifetime	The lifetime of MSA telescope drive motors, servos and gears must be ≥ 15 years.	A
6040	Duty Cycle	The MSA shall be designed to be able to operate, on average, during 280 nights/years for the design lifetime. A typical MSA nightly operation cycle consists of: • Approximately 5 sources observations. • Each source observation is performed with 20 minutes of tracking followed by a 0.5° slew. • These operations are repeated typically 4 times before the source change. The source change may consist in the large pointing movement. • On average, the MSA will operate 8 hours a night, every night. In general, the MSA duty cycle during daytime maintenance can be considered negligible.	A

9.3 RAMS Analysis

Code	Name	Description	M
6010	RAMS Analysis	The MSA Contractor shall perform and provide the RAMS (including FMEA/FMECA) analysis of the MSA.	I

9.3.1 Reliability

Code	Name	Description	M
6030	Fatigue and wear	Unless otherwise approved by the Customer, all assemblies, subassemblies, components, parts, and mechanical systems	A

		shall be designed to exceed the MSA lifetime. Contractor shall identify any and all items not likely to exceed the design lifetime, and their application and use shall be subject to approval by the Customer.	
6040	Spare parts	Friction and wear components not expected to provide reliable performance over the design lifetime shall be easily replaceable, and the appropriate number of spares supplied by the Contractor.	I
6050	Common Components	To the extent possible, components and subsystems that are common off the shelf (COTS) or previously designed, built, and tested by Contractor or by Customer shall be used to minimize cost and to optimize the ability to maintain and procure consumable parts	I
6060	Venting	All components of the MSA shall be vented as needed so that changes in atmospheric pressure when transporting from sea level to the observatory site shall not cause damage or failure.	I
6070	Light contamination	No equipment shall be allowed anywhere on the MSA that emits UV or optical (300 nm to 550 nm) light. Any unavoidable sources shall incorporate appropriate metallic shielding. LEDs will only be allowed where they are an integral part of a necessary piece of equipment (as such any light emitted shall be contained).	I

9.3.2 Availability

Code	Name	Description	M
6080	MSA Availability	The availability of the MSA during observation time must be > 98.5%.	A

9.3.3 Maintainability

The MSA maintenance shall consist primarily of the following set of on-site activities **to be carried out only during daytime:**

- Preventive maintenance;
- Predictive maintenance;
- Corrective maintenance.

The MSA Maintenance manual, in the preventive maintenance section, shall define all “check point activities” on items that, if disabled, would interfere with essential operations, endanger safety, or involved high cost or long lead times for repair or replacement (in case of failures). Examples of preventive maintenance are:

- Visual inspection;
- Adjustments and specific tests;
- Cleaning;
- Lubrication;
- Consumable parts replacements (e.g. filters, etc.);

- Removal and replacement of limited lifetime items (components that by technical limitations must be replaced after a certain period as in the case of failure may trigger hazards);
- Removal and replacement of components subject to restoration to as-new condition (overhaul or restauration);
- Replacement of obsolete items (items embedding new technology with proven reliability and performance, not produced or missing from aftermarket).

The MSA Contractor shall identify and define the assemblies or components qualified for predictive maintenance based on fault coverage (percentage of some type of fault that can be detected during the test of any engineered system).

The MSA corrective maintenance shall be based on the principle that the system functionality downtime shall be minimized by limiting necessary corrective action to fast and easy replacement of LRUs.

Code	Name	Description	M
6090	Maintenance and Repair Times	The MSA Contractor shall consider that that only daytime maintenance and repair are allowed.	I
6090	User and Maintenance manuals	The MSA Contractor shall provide the user and maintenance manuals.	I
6100	Conditioning Monitoring	The condition of key MSA structure elements must be continuously monitored, to allow early identification of problems and increased availability due to replacement of parts prior to failure.	I,T
6100	Bill of materials	The MSA Contractor shall provide a complete Bill Of Materials.	I
6100	Maintenance tools	Only standard tools available at the Mini-Array Site shall be used for maintenance and repair activities. In case special tools are needed, they shall be provided by the MSA Contractor. (Special tools as well as diagnostic and test equipment are defined as those tools that are not commercially available).	I
6110	Spare parts	The spare parts analysis shall be performed by the MSA Contractor to determine the recommended spare parts, modules, assemblies required to maintain full operation of the MSA, to maximize the availability of spares while minimizing the number of spare parts to be held for maintenance. The analysis shall be based on the MTBF of items, lead- and turn-around times, and the period required for provisioning with spares. The MSA Contractor shall provide a tabular form with a minimum level of spare parts recommended for one MSA.	I
6120	Drawings	The MSA Contractor shall provide the complete set of mechanical, electrical and electronics drawings in electronic form using the DWG and the ISO 10303 (STEP) standard formant.	I
6140	ID Card	If applicable, MSA components shall be delivered with a specific card that summarizes main parameters and characteristics of the system.	I
6100	ID Code	An unique ID code shall be assigned to each MSA Component listed in the Bill of Material down to the level of LRU.	I
6110	Preventive maintenance	The on-site preventive maintenance of the system shall require on average < 2 person-hours / week.	D
6120	Corrective maintenance	The on-site corrective maintenance of a single system shall require on average < 2 person-hours / week.	D

6140	Loading and unloading procedures	All loading and unloading procedures of any MSA element must be clearly documented, specifying the levels of personnel and equipment needed for the procedure to be safely completed within one working day.	D
6150	Software manuals and source codes	The MSA Contractor shall provide all manuals and documentation needed to support safe operation and maintenance of the MSA control system. The source code shall be delivered with the control system software including all tools to recompile, debug and test the software.	I

9.3.4 Safety

Code	Name	Description	M
6160	Standards	The MSA mechanisms shall be compliant with Machinery Safety Directive 2006/42/EC. Specifications for the design of safety-related parts of control systems are given in standards EN ISO 13849-1, standard EN 62061 and IEC 61508 for functional safety.	I,D
6170	ISO 12100 Standard compliance	In the MSA design of the system inherently safety measures shall be taken as per standard ISO 12100:2010 (clause 4)	D
6180	Operations	System operations shall be compliant with norm ISO 12100:2010 (clause 5).	D
6190	EN60204 Standard compliance	The MSA shall be equipped with systems that guarantee protection from permanent damage against electrostatic discharges, voltage fluctuations, electromagnetic disturbances and incorrect connection of cables in compliance with the EN 60204/1 directive.	D
6200	Safety devices	The MSA shall include brakes, dampened hard stops, Azimuth and Elevation stow pins, emergency stops, safety interlocks, limit switches and any other mechanisms necessary to ensure protection of personnel and components during normal operation and maintenance.	I,T
6210	Interlocks	The MSA shall be equipped with a interlock system in order to guarantee the compliance to all safety requirements. The local interlock and safety system of the Telescope shall be connected to ASTRI Array site safety interlock system as defined in a dedicated Interface Control Document.	A,T
6220	Interlocks monitoring	Each interlock source shall provide a pair of potential-free contacts and its status shall be monitored, but not controlled, by the MSA SU.	I,T
6230	Interlocks chain	All the interlock source contacts shall be series connected to form an interlock chain controlling the power supply to the interlocked subsystem and the brakes (if any) associated to that subsystem.	I,T
6240	Emergency Stop	Emergency stop pushbuttons shall be Connected to the SU and shall be located in positions where the operator access is not prevented by the presence of physical obstacles. The setting of an emergency stop switch shall halt all significant motions of all structural elements with the fastest controllable deceleration, up to a maximum deceleration time of 1 s. and then completely	I,T

		remove power from all the motor drives and cause the brakes to be engaged.	
6250	Lock-out /Tag-out function	For personnel safety during maintenance operations, a Lock-out /Tag-out function shall be provided that cuts the power to all the moving parts. It shall be a separate section of the interlock system, having an independent energy isolating device, or circuit breaker, which can be padlocked in safe (power off) position for Lock-out/Tag-out.	I,T
6260	Acoustic and luminous signalling of movement	When in local operation mode, the MSA a sound and luminous signal shall be activated sound for at least 10 seconds, before the MSA moves.	I,T
6270	Hazardous areas	Hazardous areas, or areas where damage to humans or critical components could result, must be properly signalled and access to them shall be controlled (e.g. via a badge) and restricted to workers with adequate skills and certificates.	I
6280	Skill and certificates	Operators of potentially hazardous equipment, as well as those in charge of abnormally dangerous activities, must be in possession of the appropriate skills and certificates.	I
6290	Electrical Safety	Electrical installations, equipment and components must be provided with safety mechanisms and signalling to avoid any kind of human injury to personnel during installation, maintenance, regular use, inadvertent operation, human error or any kind of system failure.	I,T

9.4 Manufacturing, Assembly, Integration and Verification (AIV) Phase

Code	Name	Description	M
6300	Standards	Manufacturing of the mechanical structure shall be complaint with [AD14] and [AD1].	I
6310	Factory Preliminary Acceptance	After manufacturing and successful assembly, integration and test (AIT) at the Contractor premise the MSA shall undergo Factory Preliminary Acceptance (FPA). The purpose of the FPA is to demonstrate to the Customer that the MSA meets all requirements and is ready for shipment to the Teide observatory site.	I,T
6320	Site Final Acceptance	Alter reintegration and successful assembly, integration and verification (AIV) at the Teide site, the MSA is subject of the Final Acceptance. The MSA Contractor shall demonstrate that the MSA is ready for regular use at the site	I,T

9.5 Erection at the Site

Code	Name	Description	M
6330	Site Assembly, integration and Verification Plan	The MSA Contractor shall produce a detailed MSA site Assembly, Integration and Verification plan that shall be approved by the Customer.	I
6340	Temporary structure for MSA erection	The Contractor shall design and supply all temporary structures, bracings and restraints required to provide stability to individual	I,D

		components or structure of the MSA during assembly. All temporary structures and restraints shall be removed after erection completion.	
6350	Measurements and tests	Effects of temperature on the MSA structure, on tapes and instruments shall be properly considered when measurements are made for setting out, during erection, and for subsequent dimensional checks. The reference temperature shall be 20°C. All measures have to be compensated to the reference temperature.	I,D,T
6360	On Site Test Report	The Contractor shall produce a final report summarizing all measurements carried out to demonstrate the achievements of the Customer requirements.	I
6370	Optional Customer test	The Customer reserves the right to arrange additional independent tests and measures, The Contractor shall provide assistance and the necessary facilities when already available.	I

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10 Verification Requirements

Code	Name	Description	M
7000	Verification Plan	The MSA Contractor shall produce the MSA Verification procedure plan that shall be approved by the Customer	
7000	Test Plan	The MSA Contractor shall produce the MSA Test plan that shall be approved by the Customer.	I
7010	Test Report	the MSA Contractor shall report the results of each test in a test report that shall be delivered to the Customer.	I
7020	VCD Matrix	The MSA Contractor shall produce a document with the verification matrix (VCD) showing total compliance with the Customer requirements.	I
7030	FEM	Finite Element Analysis model of MSA (if applicable) shall be preferred whenever the required verification method is Analysis (A).	I

11 Handling, packaging, transportation requirements

The final destination of the MSA is the Observatory of Teide.

Code	Name	Description	M
8010	System Packaging	System packaging shall prevent damages during transportation.	I
8020	Electrical and electronic component packaging	Packaging box used for electric and electronic components shall be provided with shock and temperature sensors shall be applied in order to verify if damaging condition happened during transportation.	I
8030	Transportation and storage temperature	The MSA shall suffer no damage when the ambient temperature is in the range -20ºC to 80ºC and no power is available.	A, I
8040	ID Code	Each element used for the packaging of the system (box, barrier bag, etc.) shall have stamped the System's identification code (ID).	I
8050	ASTRI and INAF Logo	The INAF and ASTRI logo shall be present on the System	I
8060	Packaging of electrical and electronic equipment	Package of electrical/electronic equipment shall provide adequate de-humidifying agent or desiccant to prevent condensation-caused damage during transportation and storage.	I
8070	Packaging identification	All packaging shall be marked for a quick and clear identification by the Customer.	I
8090	Law-complying activities' organization	All transportation activities shall comply with all local applicable laws, statutes, rules and regulations in force. The Contractor shall obtain, at its sole expense, all permits and approvals required to transport the components, materials and equipment.	I
8100	Shipping documentation - 2	One copy of the shipping list shall be placed inside the cases or crate, in a waterproof fold.	I
8120	Shipping documentation - 3	One copy of the shipping list shall be placed outside the cases or crates, protected by a metal plate in stainless or galvanized steel.	I
8130	Shipping documentation - 4	Each structure, equipment, component or material shall be marked to assure its identification with the item or code assigned by the Contractor in the Shipping List as per Req. 8100.	I
8140	Shipping documentation - 5	Each component or material shipped disassembled or loose shall be marked by stamping or by indelible paint with the same "code that identifies it in the Shipping List as per Req. 8100.	I
8150	Shipping documentation - 6	The small sized parts that cannot be marked individually shall be grouped into suitable packages that shall contain only identical materials. The identification code shall be indicated at least on 3 sides of the package.	I

8160	Normal sizes package	Packages shall not exceed, if possible, the following sizes and weight: • sizes: 12.2m long, 2.4m wide, 2.5m high • gross weight: 25 tons	I
8170	Over sizes package	When packages overpass the size or weight shown at requirement 8170, the Customer shall be informed with an outline drawing of the package to be shipped, showing: • overall dimensions; • gross weight; • positioning of centre of gravity both in longitudinal and transversal directions; • slinging points. For the packages requiring special lifting devices or particular handling measures and/or precautions the Contractor shall analyse in advance the solutions with the Customer and subsequently shall submit drawing and handling schemes together with the indication of the slinging or supporting points.	I
8180	Cases and crates: materials	Cases' and crates' materials shall be compliant with: UNI EN 12246, UNI EN 12248.	I
8190	Cases and crates: characteristics	All cases and crates used for shipping shall be realized according with: UNI 9151-1-2-3, UNI EN 13626.	I
8200	Cases and crates: marking	Cases and crates shall be marked for slinging and handling according with UNI EN 780.	I
8210	Cases and crates: phytosanitary measures	All wooden cases shall be treated with fumigation according ISPM 15 rules and/or shipping site's country in force law.	I
8220	Pallets: materials	Pallets' materials shall be compliant with: UNI EN 12246, UNI EN 12248.	I
8230	Pallets: characteristics	Pallets shall be compliant with UNI EN ISO 8611-1.	I
8240	Pallets: allowed use	Pallets shall be used only if contained in successive cases or containers.	I
8250	Material and packing before departure inspection	Materials and equipment shall be inspected by a Contractor's representative before the departure; Customer shall be adequately informed in order to be present during this operation. Customer's inspection does not relieve the Contractor from the responsibility and contractual obligations.	I
8260	Material and packing post arrival inspection	Materials and equipment shall be inspected by the Contractor's representative after unloading from the trucks/ship; the inspection shall care about:	I

		• condition and external appearance of containers, checking for damages; • seals integrity on containers.	
8270	Restore of damaged steelwork component	Any steelwork, damaged during off-loading, transportation, storage or erection shall be restored by the Contractor to conform to the standards of manufacture given in [AD14]	
8280	Destination	All the materials object of the Contract shall be shipped to the destination chosen by the Customer, at the Teide Observatory.	I
8290	Ports of shipment	The port(s) of shipment shall be chosen by the Contractor and approved by the Customer.	I
8300	Air Transport	Use of air transport shall be possible only in the case of particular components.	I