GARA EUROPEA A PROCEDURA TELEMATICA APERTA PER L'AFFIDAMENTO DELLA FORNITURA DI 6 STRUTTURE ELETTROMECCANICHE DI TELESCOPI CHERENKOV ASTRI, DI ALTRI SOTTOSISTEMI E ATTIVITA' CORRELATE ALLA LORO INTEGRAZIONE E POSA IN OPERA, per il progetto ASTRI Mini Array

ASTRI Mini-Array
Statement of Work
(Capitolato tecnico)

TABLE OF CONTENTS

INDEX OF FIGURES & TABLES

1 Introduction

The ASTRI Mini-Array is an INAF project aimed to construct, deploy and operate a set of 9 Cherenkov telescopes of the 4 meters class at the Observatorio del Teide in Tenerife (Spain). The ASTRI Mini-Array will observe astronomical sources emitting at very high-energy in the TeV spectral band.

1.1 Scope

This Statement of Work (SOW) describes the activities and the deliverables necessary for the provision of the "ASTRI Mini-Array Telescope extension" required by INAF (referred to as "the Customer") in the context of ASTRI Mini-Array Project.

This SOW will serve as an applicable document throughout the execution of the work in charge of the company (referred to as "the Contractor") selected by INAF for the ASTRI Mini-Array Telescopes production, qualification and on-site follow up during guarantee period.

The scope of supply of ASTRI Mini-Array Telescope extension project will consist in:

- Production, test in factory, packing, shipping to site, of 6 ASTRI Mini-Array telescopes.
- Assembly, Integration and Verification on site of the 6 telescopes
- Production, test in factory, packing, shipping to site and integration on the telescopes, of 9 stellar intensity interferometry instrument mechanical arms.

In the following chapters will be detailed the deliveries and the activities to be performed within this project.

1.2 Definitions and Conventions

1.2.1 Abbreviations and acronyms

ASTRI	Astrofisica con Specchi a Tecnologia Replicante Italiana
ATRR	Acceptance Test Readiness Review
AZ	Azimuth
BOM	Bill of Materials
CFI	Customer Furnished Item
CITIROC	Cherenkov Image Telescope Integrated Readout Chip
COTS	Commercial Off The Shelf
CFI	Customer's Furnished Items
CTA	Cherenkov Telescope Array
CV	Curriculum Vitae
EL	Elevation
FAR	Final Acceptance Review
FOV	Field of View
GUI	Graphical User Interface

HPC	High Power Cabinet
Hz	Hertz
IAC	Instituto de Astrofísica de Canarias
ICD	Interface Control Document
IACT	Imaging Atmospheric Cherenkov Telescope (Technique)
ICT	Information and Communication Technology
INAF	Istituto Nazionale di Astrofisica
KOM	Kick Off Meeting
LPC	Low Power Cabinet
MAIT	Manufacturing Assembly Integration Test
MIUR	Ministero dell'Istruzione, dell'Università e della Ricerca
N	Neutral/Ground
OPC-UA	Open Platform Communications - Unified Architecture
P	Phase
PA	Product Assurance
PAR	Preliminary Acceptance Review
PDF	Portable Document Format
PLC	Programmable Logic Controller
PMC	Pointing Monitoring Camera
PRR	Production Readiness Review
QA	Quality Assurance
RR	Readiness Review
RUP	Responsabile Unico del Procedimento
SC	Schwarzschild-Couder
SCADA	Supervisory Control and Data Acquisition
SE	System Engineering
SiPM	Silicon Photo-Multiplier
SOW	Statement of Work
SQM	Sky Quality Monitor
SW	Software
TCS	Telescope Control Software
TE	Test Equipment
THCU	Telescope Health Control Unit
TTL	Transistor-Transistor Logic

TRR	Telescope Readiness Review
UPS	Uninterruptible Power Supply
VHE	Very High Energy

1.2.2 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 standard operation, engineering and maintenance activities may be undertaken, during day or night.
- **Transition Conditions**. Environmental conditions under which environmental parameters may exceed those of the observing state, whilst the system transitions into a safe state.
- **Survival Conditions**. Environmental conditions expected to occur with a probability of roughly 2% per annum at the array site. The level of damage incurred under survival conditions must not exceed the serviceability limit state.
- **Serviceability Limit**. Damage can be repaired in-situ using available spare parts and a normal level of on-site manpower.
- **Collapse Prevention Limit**. The structure is heavily damaged, with very limited residual strength and stiffness, yet retains structural integrity and resists collapse. Repairs may require additional resources beyond those usually available on-site.

2 Applicable and reference documents

2.1 Applicable Documents

[AD1] ASTRI Mini-Array Documentation & Data Management Plan
[AD2] ASTRI Mini-Array Product Assurance Plan
[AD3] ASTRI Mini-Array Software Product Assurance Plan
[AD4] ASTRI Mini-Array Environmental Conditions
[AD5] ASTRI Mini-Array Technical Common Standards
[AD6] ASTRI Mini-Array Mechanical Assembly Requirements Specifications
[AD7] ASTRI Mini-Array SI^3 Requirements Specification
[AD8] ASTRI Mini-Array Telescope - Internal Communication ICD
[AD9] ASTRI Mini-Array Telescope - M1 panels ICD
[AD10] ASTRI Mini-Array Telescope - M2 ICD
[AD11] ASTRI Mini-Array Telescope - Cherenkov Camera ICD
[AD12] ASTRI Mini-Array Telescope - PMC ICD
[AD13] ASTRI Mini-Array Telescope - UVSiPM ICD

2.2 Reference Documents

[RD1] ASTRI Mini-Array Telescope Design Description
[RD2] ASTRI Mini-Array top level architect software architecture
[RD3] ASTRI Mini-Array Infrastructure design description
[RD4] ASTRI Mini-Array SI^3 concept design

3 Introduction

The ASTRI project began as an Italian “Flagship Project” funded by the Ministry of Education University and Research (MIUR) and led by the Italian National Institute for Astrophysics (INAF) and now is going on with the support by MIUR with other funds and contributions by International partners. The initial aim of the project was the development of a technologically innovative solution for the Small-Size Telescopes (SSTs) class of the Cherenkov Telescope Array (CTA) devoted to cover the energy band up to 100 TeV and beyond.

The result of the first phase of the project was a prototype telescope in dual-mirror Schwarzschild-Couder (SC) configuration installed at Mt. Etna (Italy). The prototype, called the ASTRI-Horn telescope (in honour of the Italian-Jewish astronomer Horn d'Arturo, inventor of the segmented mirror solution for astronomical telescopes), has started its scientific operation in fall 2018 and has provided the first detection of very high-energy (VHE) gamma-ray emission from the Crab Nebula by a Cherenkov telescope in dual mirror configuration.

As a continuation of the project, a Mini-Array of 9 ASTRI dual-mirror telescopes is currently being implemented. It will be deployed at the Observatorio del Teide (Figure 1), in the Canary Island of Tenerife in collaboration with Instituto de Astrofísica de Canarias (IAC) and with other national and International partners.

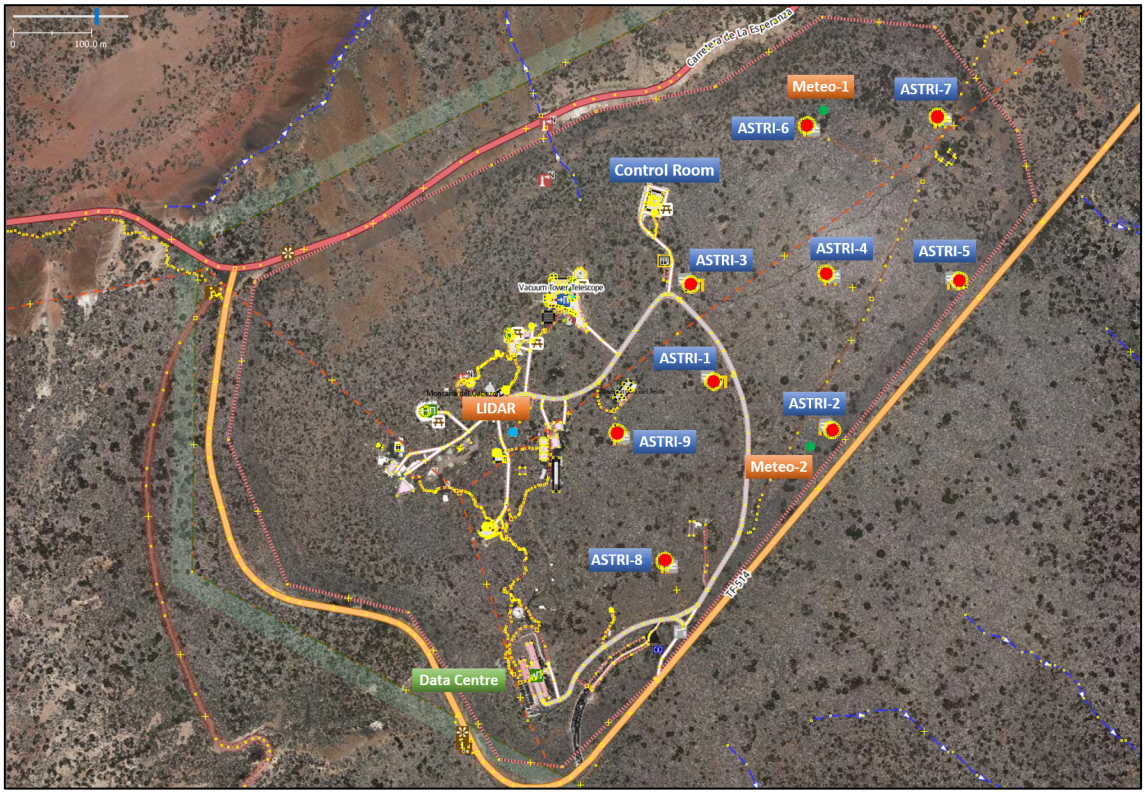

Figure 1. ASTRI Mini-Array general Layout at the Teide observatory. The figure shows the final positions for the 9 telescopes,

Thanks to its expected overall performance, better than current IACT arrays (like HESS, MAGIC and VERITAS) for energies above ~1 TeV and up to 100 TeV, and its

wide field of view, the ASTRI Mini-Array will be an important instrument to perform soon deep observations in gamma rays of the Galactic and extragalactic sky. Important synergy with already existing IACT and Water Cherenkov facilities in both the northern and southern hemispheres are also foreseen.

4 The ASTRI telescope

A detailed and full description of the ASTRI Mini-Array telescope is beyond the scope of this document moreover, is the subject of [RD1]. In this paragraph, we will give a brief overview of its characteristics.

The ASTRI telescope adopts an altitude-azimuth design in which the azimuth axis permits a rotation range of ±270°. The primary mirror dish, which supports the primary mirror, is mounted on the azimuth fork, which allows the telescope to rotate around the elevation axis from 0° to +91°. The mast structure, that supports the secondary mirror and the camera, is placed on the primary mirror dish.

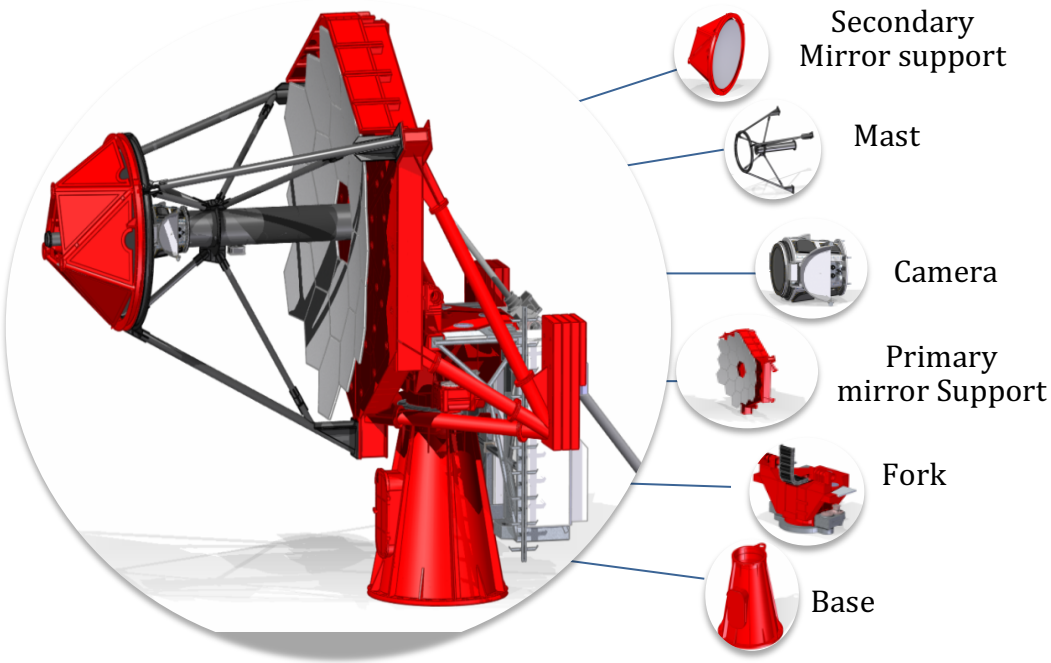

Figure 2. ASTRI telescope, pointing the horizon (0°)

The ASTRI telescope main elements are:

1. The mechanical structure assembly.
2. The optical assembly.
3. The Cherenkov camera.
4. The intensity interferometry module.
5. The auxiliary assemblies.
6. The telescope protection system.
7. The telescope control system

4.1 Mechanical Structure Assembly

The Mechanical Structure Assembly parts may be grouped in three subassemblies:

- Mount subassembly

- Elevation subassembly
- Electrical System

4.1.1 Mount Subassembly

The Mount Subassembly provides the support for the optical support structure. It includes 2 main structural elements:

1) The Base.
2) The Azimuth Structure (Fork).

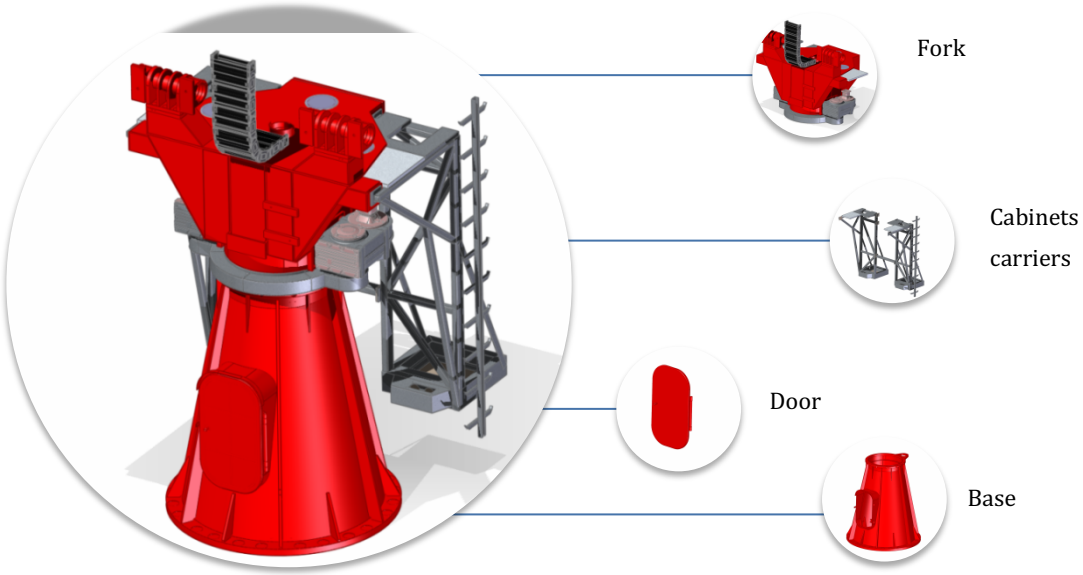

Figure 3. Mount subassembly

The base is fixed to foundation while the azimuth fork is installed on base top by means of azimuth bearing, to permit the relative rotation of the two elements. Material used is common S355J0 painted steel

The base main structure is a cone that links the foundation to the azimuth bearing. The shape is imposed by the interfaces of the foundation anchor bolts and the bolts required by azimuth bearing. The conical shape guarantees the best compromise between effective transmission of the telescope's loads to the plinth and the lowest mass. Furthermore, it provides access to the volume contained inside, that addresses items as azimuth encoder, cables, azimuth switches etc, sensitive to weather agents. Thanks to that, alignment and maintenance procedures may be carried out safely. The access door to the cone's internal volume is clearly visible in Figure 3.

The Azimuth Fork structure provides support and interface for the following essential elements:

- Azimuth bearing
- Elevation bearings

- Azimuth ratio-motor drive
- Elevation actuator drive
- Azimuth and Elevation Stow pins
- Azimuth and Elevation switches
- Azimuth and Elevation cable wraps
- Elevation Bumpers
- Support for Electrical Cabinets

These items grant the motion of the telescope mount as well as the safety during survival conditions for personnel and hardware; these 2 tasks make the fork a critical part of the entire telescope structure.

4.1.2 Elevation Structure Subassembly

The Elevation Structure subassembly includes four main parts:

1) Primary mirror support (M1 Dish).
2) Mast.
3) Secondary Mirror Support Structure (M2 Support Structure).
4) Counterweights.

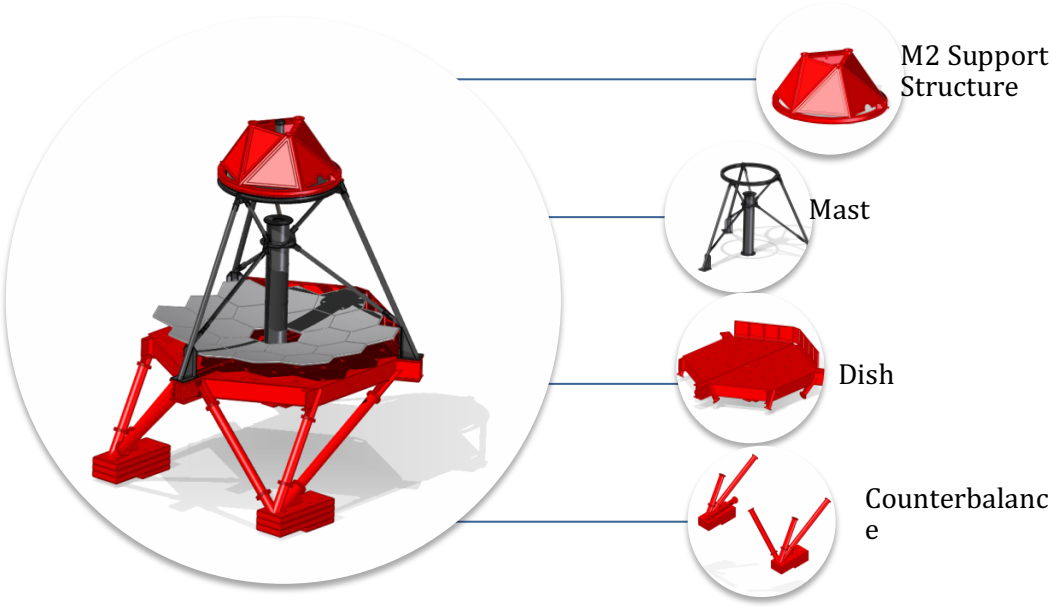

Figure 4. Optical Support Subassembly

The primary mirror support is a hexagonal dish, in two halves, (to grant the transportability within the standard sizes). It carries the supports for the segments of the primary mirror (18), the interfaces to elevation bearings and elevation actuator and the interfaces with the elevation stow pin. To provide protection to M1 segments from snow and ice when the telescope is in a parking position, a group of shields in perforated aluminium plates is located on the upper two sides of the hexagon, sloped in order to ease evacuation.

Counterweights support beams carrying balancing masses. Threaded rods allow you to install fine balancing plates.

The mast is provided with three pipes support systems, spread at 120° to each other. The top ring guarantees to have a single stiff structure that improves repeatability during M2 Support Structure removal/installation.

M2 support structure has a triangular layout made of welded pipes attached to a ring. The upper triangle keeps the interfaces with the actuators of the secondary mirror.

4.1.3 Electrical System

The division of the electrical sub systems follows the scheme shown in Figure 5.

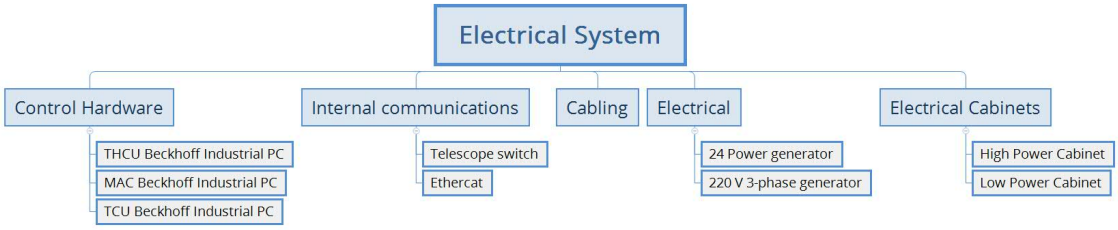

Figure 5. Electrical sub-system scheme

The main issues of the electrical design of the telescope are:

1) power dimensioning of the electrical cabinets and cables.
2) cable routings (in terms of cable wraps, conduits, trays);

The telescope receives power from an external double interface with the following characteristics:

- One 3P+N+PE, 400 Vac, 50 Hz, Normal Power Line;
- One P+N+PE, 230 Vac, 50 Hz, UPS Power Line;

The relevant earthing system is TN-S (PE and N are separate conductors, connected to the ground near the power source).

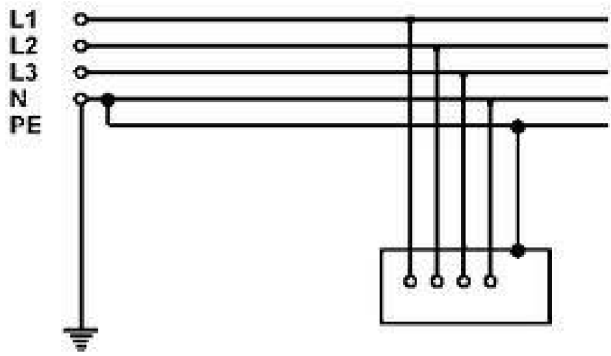

Figure 6. TN-S representative scheme

The design of the electrical distribution grid respects, for each feeder:

- the protection against overload;
- the protection against short circuits;
- the protection against indirect contacts;

4.1.3.1 Electrical installation

From the Telescope Interface Infrastructure, the power and communication incoming lines enter the telescope from the Base, pass through the azimuth cable wrap up the two electrical cabinets on the Fork.

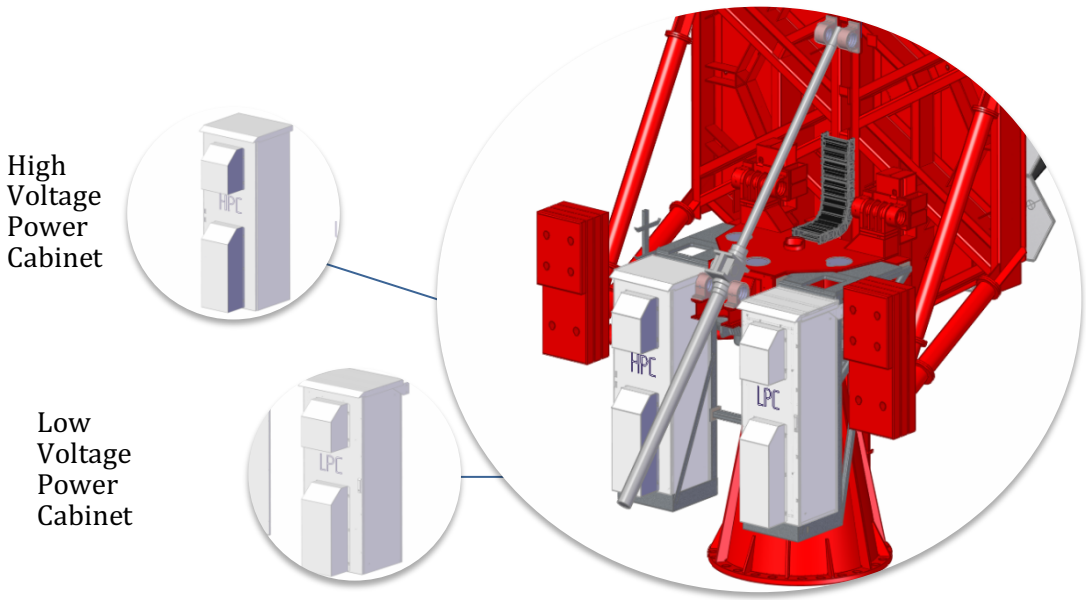

Figure 7. Electrical cabinets position on telescope

More in detail, the Telescope has four electrical interfaces incoming from the infrastructure:

- 400 V (3P+N, 50 Hz) for normal power;
- 230 V (P+N, 50 Hz) for UPS power;
- Fibre optic for control and data;
- Ethernet connection for diagnostic in local mode.

All these cables are routed through the AZ cable drape, considering also a spare length to allow the cables to follow the movement of the axis.

In the telescope's base are present these devices:

- AZ encoder heads;
- Base door limit switch.

At the top interface of the AZ cable drape there's a box (the "AZ fork cable box") which is the interface with the cable duct system: it allows the cables distribution towards the cabinets (LPC and HPC) and towards the EL cable wraps. Furthermore, the cables which serve the various devices/equipment installed in this area exit from the cable duct by means of dedicated cable glands.

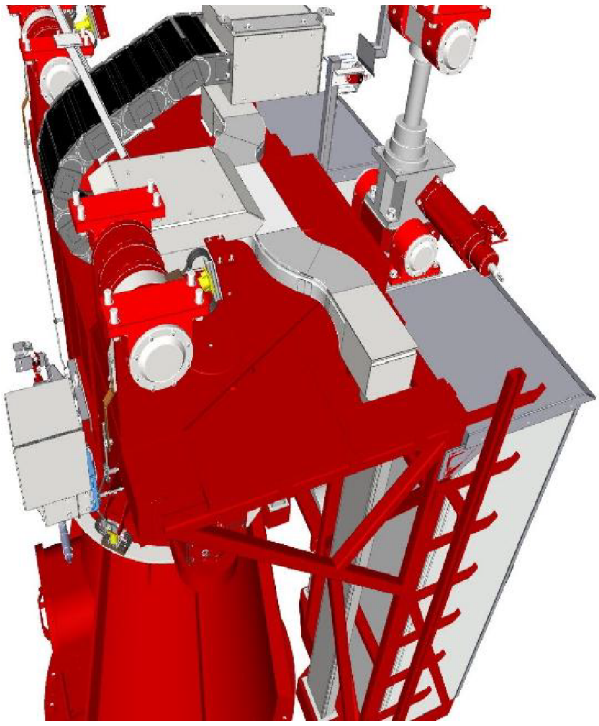

Figure 8. Cable wraps

In the telescope fork are present these devices:

- EL encoder;
- AZ and EL rotational limit switches;
- AZ and EL rotational motors;
- AZ and EL stow pins;
- Base light.

From the EL cable wrap, by means of opportune cable conduits (external to the masts) the cables are distributed along the mast path.

The central masts are used to distribute the cable towards the Cherenkov Camera while another set continues along the mast to reach the equipment of the M2 area. These last are:

- M2 actuators (with the relevant M2 box used as electrical interfaces and disconnection point);
- M2 actuators encoders;
- SQM/PCM equipment.

4.1.3.2 Telescope automation and safety

In the telescope, a single channel automation system is foreseen. It consists of:

- 31 inputs;
- 1 safe PLC;
- 2 outputs.

Further details in [AD6].

Figure 9. M2 Support Structure

4.1.3.3 Lightning protection system

In order to protect the telescope and its equipment from the effect of lightning a protection system (LPS) has been installed.

Even if the telescope is entirely metallic and could have been used as a unique natural protection system an additional external LPS has been foreseen.

The LPS is composed by:

- round wires of hot dip galvanized steel (Ø8mm) and all the relevant metallic supports, foreseen all around the upper part of the telescope up to the M1 dish, at the interface with the Fork;
- 2 brushes made of metal graphite as electrical interface between the M1 dish and the Fork;
- brushes made of metal graphite as electrical interface between the Fork and the Base.

4.2 Optical Assembly

The optical design is based on a dual-mirror Schwarzschild-Couder configuration. This configuration allows the telescope to obtain a better correction of aberrations at large incident angles even for small focal ratios and hence facilitates the construction of compact telescope systems. This optical system is an attractive solution for the Cherenkov telescopes of class “small-size” since it enables good angular resolution across the entire field of view and allows reducing the focal length and therefore the physical pixel and overall camera size. This optical configuration will be adopted for the first time on a Cherenkov telescope array.

The primary mirror is segmented while the secondary is monolithic. The primary is composed of a set of 18 hexagonal-shaped panels. The profiles of both mirrors are aspheric with substantial deviations from the main spherical component.

The resulting telescope is a compact system, with a primary mirror diameter of 4 m, a secondary mirror diameter of 1.8 m, a primary-to-secondary distance of 3 m and a secondary to camera distance of 0.52 m.

This optical setup delivers a plate scale of 37.5 mm/degree, an equivalent focal length of 2150 mm and an effective area of about 5m^2 almost constant across a field of view of 10^o in diameter. The angular resolution in terms of the radius where the 80% of the focused photons falls is almost constant, being 0.09^o on average across the entire FOV of 10^o.

4.3 The Cherenkov Camera

The ASTRI-Horn prototype telescope includes a Cherenkov Camera of novel design based on SiPM detectors. In the prototype version, the camera has 2368 distributed pixels on a curved focal plane (Figure 10).

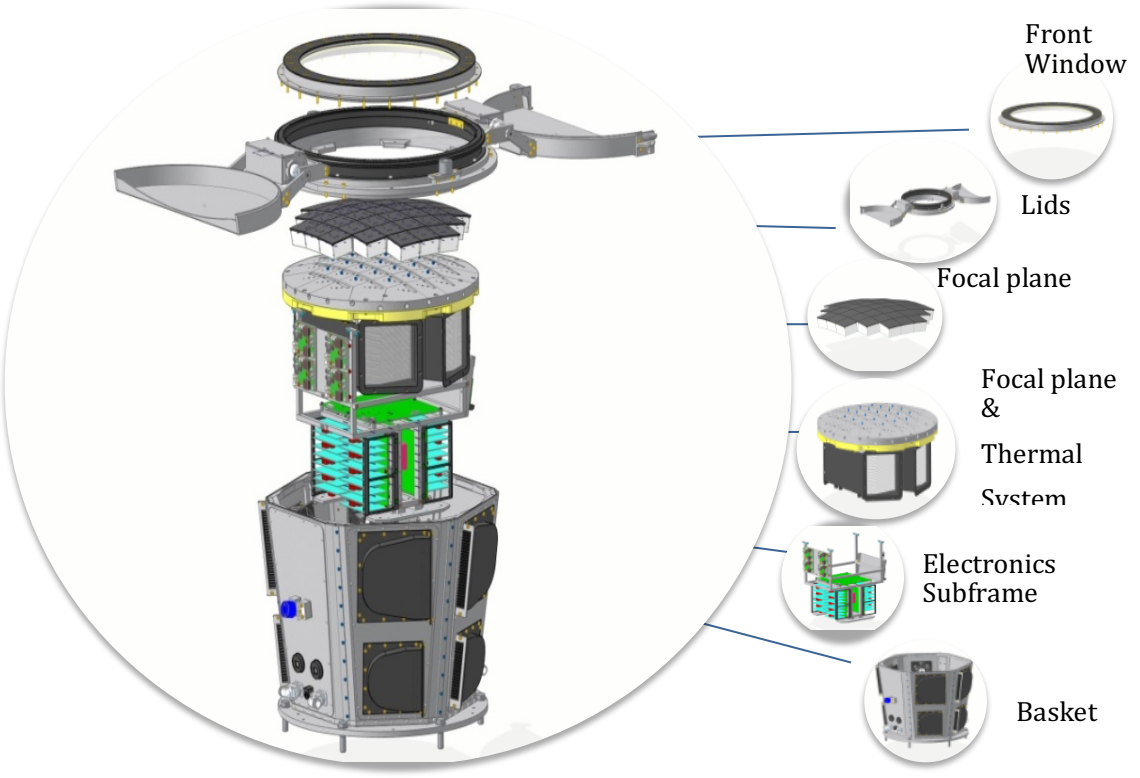

Figure 10. 3D rendering of the ASTRI camera prototype - Exploded view

The pixels have a linear dimension of 7x7 mm^2. Coupled with the characteristics of the optical system this corresponds to an angular pixel size of approximately 0.2 degree and a field of view (FOV) of about 8 degrees. Furthermore, more than 80% of the light emitted by a point source is collected within the dimensions of a pixel over the full field of view of the telescope.

The design of the electronics ensures a high efficiency detection of a Cherenkov event, with over 600 events per second, with a very high dynamic range (from 1 to 1500 photoelectrons per pixel).

4.4 The Stellar Intensity Interferometry Instrument

The telescopes of the Mini-Array, unlikely the prototype, will be equipped with an intensity interferometry instrument (SI^3). The instrument is dedicated optical photon detection module to perform intensity interferometry observations, mounted in front of the Cherenkov Camera using a swing arm and completely independent from it.

Observation with the SI^3 instrument will be used in alternative to the Cherenkov camera.

This instrument will consist of:

- Focal plane optics;
- Focal plane detectors based on a 4 cooled SiPM 3x3 mm^2, arranged in a 2x2 matrix;
- Front end for SiPM readout;
- Conversion board digital/TTL output;
- White Rabbit (time tagging board) system;
- Acquisition electronics;
- Mechanical carrier of optics and electronics;
- Swing arm for the carrier.

The swing arm (see Figure 11) is needed as the whole module shall be placed between the camera and the secondary mirror; when not in use the intensity interferometry module must be hidden out the optical train M1/M2/Camera.

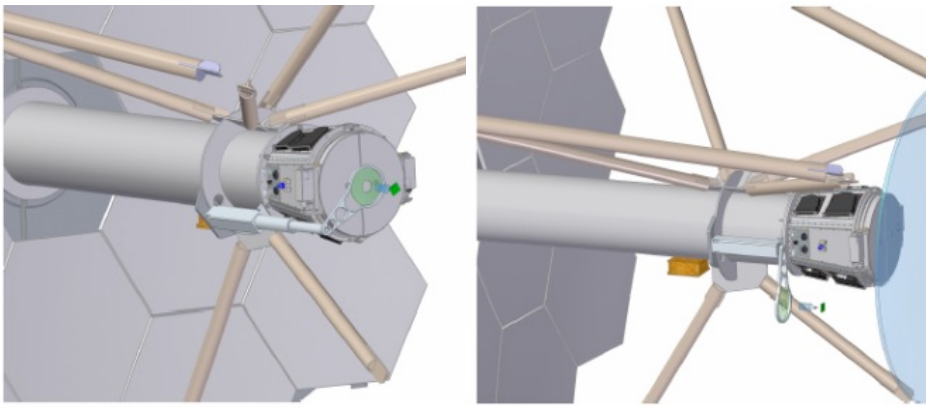

Figure 11. One of the concept designs for the swing arm described in [RD4]

4.5 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.

- Pointing monitoring camera
- UVSiPM instrument
- Mirror alignment system

- Telescope condition monitoring system

4.6 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.

- Telescope Fire Protection system
- Telescope Safety system

4.7 Telescope Local Control System

Figure 12 shows the conceptual architecture of any ASTRI Telescope Local Control System of the Mechanical Structure Assembly (MSA). It identifies the main hardware components of the telescope that software must control and operate together with their internal and external connections.

The term Local Control System (LCS) indicates the control and safety units, control software, local communication infrastructure required to guarantee functional operation of a given equipment and all the other support elements needed for integration, verification and maintenance activities.

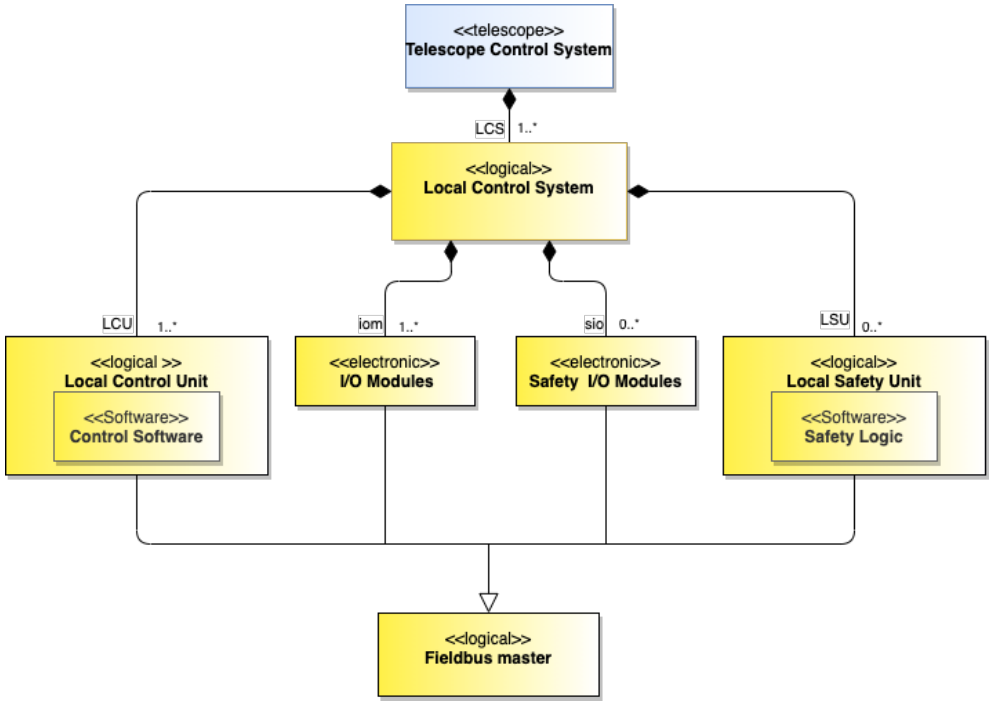

Figure 12. The logical Architecture of the Telescope Local Control Systems

The MSA Local Control Systems 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 subsystems. 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 from 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 a 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.

5 Scope of the supply

5.1 Telescopes for the ASTRI Mini-Array: supply of a batch of six

The ASTRI Telescope's elements (reference of this SOW) have requested a specific effort during the development of the prototype, because their performances are strictly correlated with the availability of a camera capable of achieving sensitivity goals and compatible with the telescope features.

The prototype's design has been revised after its intense use for validation, following a program of redesign foreseen in the contract of production of the prototype itself. Such re-design effort has led to a new version of the whole system (telescope + auxiliaries) that represented the model of the first batch of three telescopes (ASTRI-1, ASTRI-8, and ASTRI-9 of Figure 1) in the framework of the Mini-Array set of 9. **The first series of three telescopes of the array is then already being manufactured. The design of these telescopes satisfies all the requirements and guarantees the scientific performance of the ASTRI Mini-Array.**

In the call for tenders issued together with this SOW it is requested the construction of telescopes as similar as possible to the ones being manufactured except for the variants explicitly requested by INAF and described in the technical document package (e.g. swing harm to accommodate the Stellar Intensity Interferometry Instrument).

Moreover, it is possible to introduce in the current design minor variants (e.g. to facilitate telescope's maintenance) if they satisfy the requirements, do not reduce (or better improve) the performance of the telescope, and are cost effective. Those variants will be evaluated during the tender procedure.

5.2 Swing arm for the Stellar Intensity Interferometry Instrument

Finally, it is requested to design, produce, test and deliver for the entire array of nine telescopes a mechanical arm to insert the Stellar Intensity Interferometry Instrument (SI^3) described in section 4.4 to be integrated in the telescope mechanical structure. The supply shall include the software to control the mechanism. A concept design of the mechanism has been developed by INAF [RD4] and can be used as a reference.

5.3 AIV on site

The contractor will be responsible for packing, shipping, and installing the six structures at the ASTRI Mini-Array observational site.

6 Activities and planning

The ASTRI Telescopes production activities and deliverables shall be compliant with the specifications of requirements and interfaces and with the ASTRI product assurance plans.

For the production and AIV activities at the company integration site and at the observational site, some items will be Customer Furnished Items (CFI), under INAF responsibility for the procurement.

These items are:

1. Telescope Control Software
2. Pointing Monitoring Camera assemblies;
3. Primary mirror (M1) segments;
4. Secondary mirrors (M2);
5. Ethernet switches;
6. Stellar Intensity Interferometry Instrument;
7. Cherenkov Camera;
8. Mirror Alignment System;
9. UVSiPM instrument.

Items number 6, 7, and 9 will be delivered to test mechanical, electrical and software interfaces, then dismounted and returned back to INAF. Item number 8 will be available at the observational site.

6.1 Applicable and Reference Documents

For the telescopes' production the following applicable and reference documents shall be adopted

6.1.1 Applicable Documents

- Documentation management plan [AD1]
- Product assurance plan [AD2]
- Software product assurance plan [AD3]
- Environmental requirements [AD4]
- Technical Standard [AD5]
- Telescope Requirements Specifications [AD6]
- SI^3 Requirements Specification [AD7]
- Interface Control Documents for interfaces to the CFIs, [AD8], [AD9], [AD10], [AD11], [AD12], [AD13]
- As Built series of mechanical and electrical drawings in pdf format

The as-built drawings and electrical schemes are available at the following web site: http://www.brera.inaf.it/disegni-e-schemi-as-built/. The list of the drawings is given in section 12. This documentation is considered adequate to submit the offer.

The complete set of executive drawings in PDF format, schemes, reports, ICDs and all necessary documentation including local control software will be delivered after the contract.

6.1.2 Reference Documents

- ASTRI Mini-Array Telescope Design Report (mechanical, electrical and software) [RD1]

- ASTRI Mini-Array top level software architecture [RD2]
- ASTRI Mini-Array Infrastructure design description [RD3]
- ASTRI Mini-Array SI^3 Concept Design [RD4]

6.2 Parallel activities

INAF is running, in parallel to the present contractual activity, the following activities of relevance:

- Procurement of the ASTRI Mini-Array Cherenkov cameras
- Development of the ASTRI Mini-Array Control Software
- Design and production of the Stellar Intensity Interferometry Instrument

6.3 ASTRI Telescopes production overall objectives

The Contractor shall be responsible for the manufacturing of the ASTRI Mini-Array Telescopes and the provision of the ASTRI Mini-Array telescopes production batch. As part of the ASTRI Mini-Array Telescopes production, the Contractor activities shall include, but not be limited to, the following list of activities:

1. Provide a project plan including management and development activities:
    a. organization layout,
    b. key personnel with related CVs,
    c. provide the point of contact with whom exchange technical, managerial and administrative aspects,
    d. Management of sub-Suppliers,
    e. Product tree,
    f. Work Breakdown Structure,
    g. Work package description (including description of activities, inputs and outputs, type of resources, etc.),
    h. Schedule;
2. To provide a Risk Assessment Plan, describing the process to detect project risks, manage them and the strategies to mitigate their impacts;
3. Provide a Product Assurance Plan outlining:
    a. Documentation management
    b. Configuration management
    c. Quality provisions
4. Keep tracking of actions through an Action item list.
5. Liaise with the Customer bi-weekly in order to keep traceability of the development of the work unless differently specified by the Customer. These will be followed by a mutually agreed minute, reporting the contents and the actions arose from the discussion.
6. Close formally the milestones through review processes.
7. To produce the set of ASTRI Telescopes (#1-6) and perform acceptance test;
8. To pack, ship and install the set of ASTRI Telescopes (#1-6) at the ASTRI Mini-Array site at the Teide Observatory in Tenerife (Spain);

6.4 Workflow

To complete the project, a series of logical work steps shall be executed. Figure 13 summarised the expected workflow.

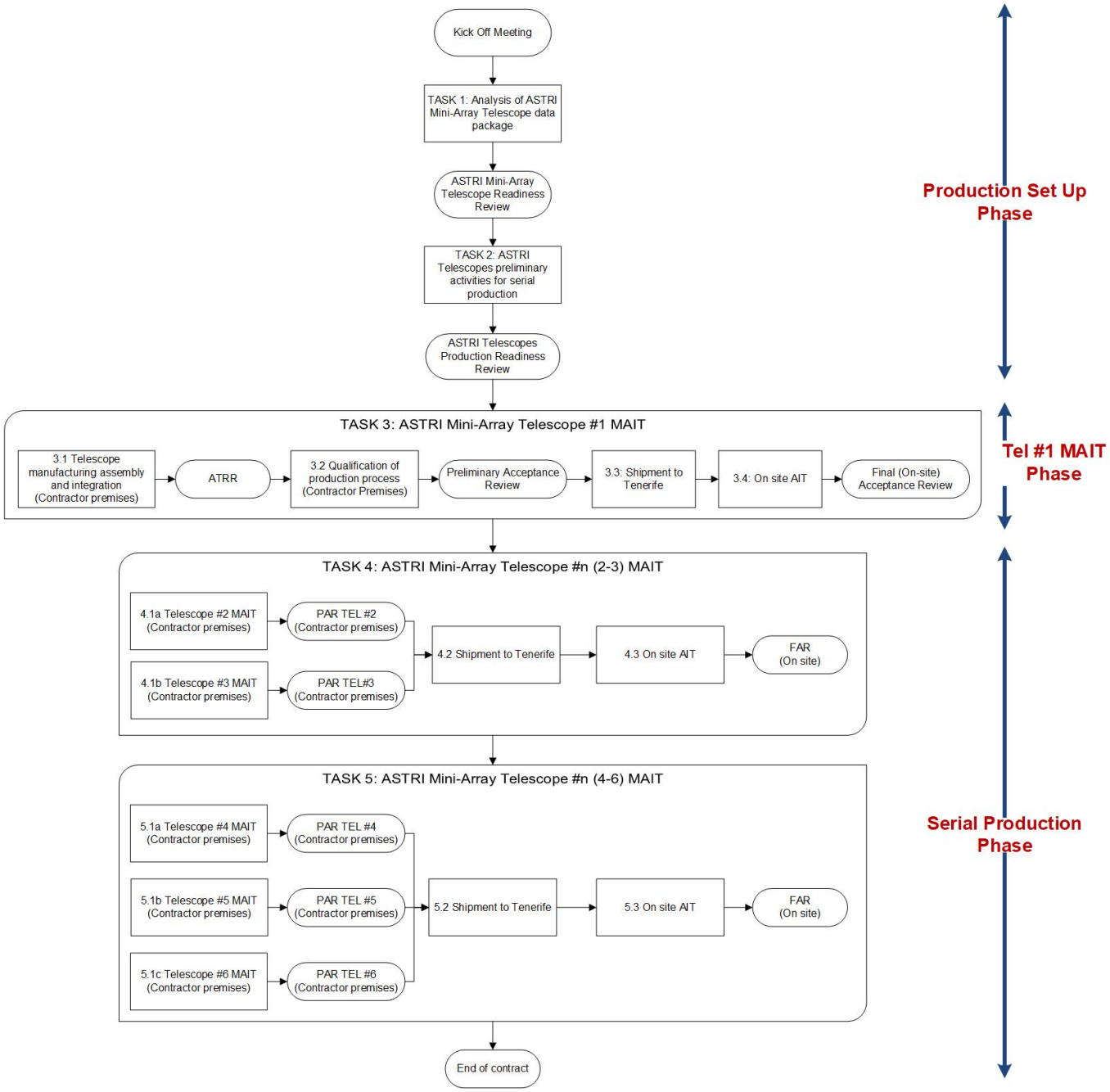

Figure 13. Workflow: Phases Descriptions

The details are formulated in the work descriptions of the phases given in section 7.

The work flow of ASTRI Mini-Array Telescopes production shall be structured along three phases:

- **Production set up phase**: Analysis of document package provided by INAF (reports, drawings, requirements, heritage of the ASTRI-Horn prototype and the re-design of the first batch of three, concept design of the SI^3 instrument), and activities to setup the serial production. During this phase variants requested by

INAF or proposed by the Contractor shall be deeply analysed to be formally approved for implementation. Finally, during this phase, the design of the SI^3 swing arm will be produced.

- **Telescope #1 MAIT phase**: Manufacturing, assembly, integration, test and acceptance on site of the telescope #1 (ASTRI-2 of Figure 1), the first telescope of this batch. Production, integration and test in factory of the first SI^3 swing arm.
- **Serial Production phase**: Production and acceptance on site of the telescopes #2-6. Production and site delivery of the remaining 8 SI^3 swing arms and end of the contract

Each phase shall be organised in tasks and sub-tasks as shown in Figure 13 and the details are formulated in the work descriptions of the phases given in section 7.

The ASTRI Telescopes production provision shall respect the ASTRI Mini-Array implementation program whose proposed master schedule is reported in section 10.

7 Phases Description

7.1 Production Set Up Phase

The outcomes of the Production Set Up Phase shall be the industrial organization necessary to initiate the construction of the Telescope #1, the first of the batch of 6, object of the tender. The above mentioned arrangement shall be the basis for the production process qualification (see Task 3, subtask 3.2).

The work to be performed within the Production Set Up Phase consists of 2 tasks as per Table 1.

Table 1. Production Set Up Phase

Production Set Up Phase	Activities description
Task 1	Assessment of ASTRI Mini-Array Telescope data Package
Task 2	Telescopes preliminary activities for serial production

The work to be performed, as a minimum, in each Production Set Up phase tasks and sub-tasks is described in the following sections.

7.1.1 Task 1: Assessment of ASTRI Mini-Array Telescopes Data Package

The Contractor shall critically review the ASTRI Mini-Array Data Package delivered during the tender and at KOM. This data package contains the detailed design of the telescopes of the first ASTRI Mini-Array batch of 3 telescopes, the requirements, the interfaces towards the CFI and the site infrastructure as described in section 6.1, and the concept design and requirements for the SI^3 swing arm.

The Contractor shall analyse the documentation and identify possible critical areas that will be discussed with the Customer at the Telescope Readiness Review (TRR).

With the aim to speed-up the Contractor learning process and transfer the specific know-how acquired by the first ASTRI Mini-Array batch of 3 telescopes development, ASTRI team members will assist directly the Contractor in this task.

Variants requested by INAF or proposed by the Contractor and approved in the tender process shall be developed and analysed in this phase. The design of the SI^3 swing arm shall be developed during this phase. The Contractor shall deliver all the necessary documentation to allow INAF to verify the compliance of the variants with the requirements and approve them.

The task will end with a review during which the Contractor will accept the data package and the Customer will approve the design variants. This will allow the Contractor to proceed to the next phase.

The duration of Task 1 shall not exceed 6 months.

Input:

- Tender Customer Documentation package;
- Complementary package (to be delivered at KOM);
- KOM agreements;
- ASTRI team coaching.

Output:

- Acceptance by the Contractor of the full data package delivered by the Customer
- Acceptance by the Customer of the design variants
- **PM-01**: Project Management Plan
- **PM-02**: Configuration Control Plan
- **PM-03:** Risk Management Plan
- **PA-01:** Quality Plan
- **SE-02:** FEM Analysis Report (in case significative variants are introduced)
- **SE-05:** Design report of the variants
- **DDF-01**: Design report of the SI^3 swing arm
- **DDF-02:** SI^3 swing arm ICD

7.1.2 Task 2: Preliminary Activities for Serial Production

Once finished the critical assessment of the data package and based on the TRR, the Contractor shall perform the procurement of the raw materials, tools and COTS components, the equipment of workshops areas, the agreements with sub-contractors and suppliers, the engagement of specialised workmanship, the writing of a detailed production workflows and schedules to ensure that the construction phases of the telescope #1 shall be compliant with the Customer's expectations resulting from task 1 of this phase.

The duration of Task 2 shall not exceed 2 months.

Input:

- Successful Telescope Readiness Review.

Documents Outputs: The output of this task shall be a documentation package composed by the following documents:

- Update of **PM-03, DDF-01**
- **PM-04**: Telescope Industrial Production Plan, including SI^3 swing arm;
- **SE-01:** AIT/AIV Plan

All the output of this task shall be presented for Customer approval at the Production Readiness Review (PRR).

7.2 Telescope #1 (ASTRI-2) MAIT Phase (Task 3)

Based on the Customer authorization (outcome of PRR) and task 2 outputs, the Contractor shall build and assemble the telescope #1, and the swing arm.

The outcomes of this phase shall be the acceptance, on site, of the first telescope of the batch. The SI^3 swing arm will be tested at the contractor premises on telescope #1 (functional, performance and interfaces tests) and appropriate debug activities shall be undertaken to correct non-conformities. These activities will be concluded at the end of task 4.1a.

The work to be performed within the ASTRI Mini-Array Telescope #1 MAIT Phase consists of one task, organised in four specific sub-tasks, as per Table 2.

The duration of Task 3 shall not exceed 5,5 months.

Table 2. Telescope #1 MAIT Phase

Telescope #1 MAIT Phase	Activities description
Task 3	Subtask 3.1: Manufacturing, assembly and integration (telescope, SI^3 swing arm)
	Subtask 3.2: Qualification of telescope production process Qualification of SI^3 swing arm
	Subtask 3.3: Shipment to Tenerife Site (telescope)
	Subtask 3.4: On site AIT (telescope)

7.2.1 Subtask 3.1 Manufacturing, Assembly and Integration of telescope #1

The production of Telescope #1 can start. In conformance with results of the Acceptance Test Readiness Review (ATRR) the telescope and the swing arm shall be subjected to the acceptance test, to be performed at Contractor premises.

The production shall be performed in a controlled environment and the integration operations and environment shall be tracked. The integration shall include but not limited to:

1. The electrical and mechanical integration of all the parts in conformance with the integration flux and integration test logic;
2. Applying the PA/QA control criteria;
3. Perform the hardware and software integration.

At the end of this subtask there shall be the Acceptance Test Readiness Review

Input:

- Authorization from Customer;
- CFI from Customer;
- Results from previous tasks.

Document Outputs

- **SE-01**: Update of AIV/AIT plan (including test procedures)
- **PA-02:** FMEA and RAMS analysis (telescope and swing arm)

7.2.2 Subtask 3.2 Qualification of Production Process

This subtask applies to telescope and SI^3 swing arm.

At the completion of the integration the Contractor shall execute the test plan for the functional/performance verification and calibration, in conformance with results of the Acceptance Test Readiness Review. The functional/performance test and calibration shall be performed at the Contractor site and at other facilities (if any) provided by the Contractor. All tests and results shall be documented. The Telescope #1 and SI^3 swing arm production functional/performance test and calibration shall include, but not be limited to:

- verification of mechanisms;
- verification of functions and performance;

- verification of software functions (control, OPC-UA interfaces, data telemetry, management of critical conditions etc.);
- verification of performance and mechanism at the environmental acceptance conditions;
- verify the critical operations;
- submit to Customer any discrepancies with respect to the expected performances/functionality.

At the completion of the pre-acceptance test campaign the contractor shall:

- compare test results to the requirements and evaluate the effective performance;
- address the non-compliances;
- implement (if necessary) feedback to the production flow;

The Preliminary Acceptance Review (**PAR**) at the Contractor premises will end this subtask.

Document Inputs:

- Successful outcome of **ATRR**;

Document Outputs (PAR#1):

- **MRD-01**: Telescope Manufacturing dossier;
- **MRD-02:** Telescope test reports**;**
- **MRD-03**: Telescope Inventory List (BOM);
- **MRD-05**: SI^3 swing arm test report
- **MRD-06**: SI^3 swing arm Inventory List (BOM);
- **SE-04**: Telescope User Manual
- **PA-03**: Verification Matrix
- **PA-04**: Telescope Non Conformances Reports
- **PA-05**: SI^3 swing arm Non Conformances Reports

Product Outputs (PAR#1):

- Telescope #1 ready for shipment to Tenerife;

7.2.3 Task 3.3: Shipment to Tenerife Site of telescope #1

The Contractor shall provide appropriate packaging materials and devices required for safe transport of the Telescope #1 from the manufacturer's facility to the installation site, located close to Mount Teide Observatory facilities, Tenerife (Canary Islands, Spain).

The Contractor shall be responsible of unloading activities and unpacking of Telescope #1 on site.

Documents Input:

- Authorization to shipment from the Customer (according a successfully outcome of the **PAR #1**);

Document output:

- Shipping documents;

7.2.4 Task 3.4: On Site AIT of telescope #1

At the delivery at Tenerife site, the Contractor shall perform:

1. Site preparation which comprises all the preliminary tasks needed to start site activities, such as the procurement of consumables and small tools, the organization of the site layout, the planning of the activities and preliminary training of the team in each activity.
2. Mechanical and electrical integration of the telescope, comprising the integration of CFI as well.
3. Verification of each single mechanical, electrical, electronical, and software subsystem of the telescope, and of the telescope system as a whole. Verification the compliance of telescope interfaces towards other subsystems (e.g. Cherenkov Camera) and towards the site infrastructure.
4. Assist the ASTRI Team during the acceptance of the Telescope #1 through the execution of the customer/contractor agreed operative test sequence necessary. This comprises the final verifications and tuning of the telescope as a whole, along with on-sky tests, calibration of M1 through the removable active optics, and astrometric calibration of the telescope; it ends with the final performance of the acceptance tests, and the FAR of the telescope.

The On-site AIT activities of all Telescopes shall then include, but not be limited to:

- Site inspection and preparation
- Arrival and unloading of the containers containing the parts of the telescope
- Site preparation
- Telescope base grouting
- Assembly and integration of the telescope
- Verification of communications
- Verification of telescope motions
- Verification of active optics
- Verification of safety devices
- Software debugging (if new software has been developed)
- Subsystems tuning
- Support to telescope commissioning performed by INAF

After the installation of the telescope #1 and the positive verification of the telescope performances, functions and interfaces the Final Acceptance Review shall be considered completed and the guarantee period shall start.

Document Input:

- Shipping documents.

Document Outputs (FAR#1):

- Update of Telescope #1 test reports **MRD-02**
- Update of **MRD-03.**
- Update of **PA-03.**
- Update of **PA-04**.
- Update of **SE-04.**
- **MRD-04**: Software database
- **SE-03**: Telescope Maintenance Plan

- **ML-01**: Telescope CAD model
- **ML-02**: Telescope As Built Drawings (including variants)
- **ML-03**: Telescope electrical scheme and drawings (including variants)

Product Outputs (FAR#1):

- Telescope #1 (ASTRI-2).

7.3 Serial production Phase

The Serial Production Phase consists of two tasks, each organized in 3 specific sub-tasks as per Table 3. During this phase, the telescopes #2-6 shall be realized, tested, shipped and accepted on site.

Furthermore, the debugged version of the SI^3 swing arm (if any) will be tested on telescope #2 and cleared for production.

Table 3. Serial Production Phase

Serial Production Phase	Activities description
Task 4	Subtask 4.1a: Manufacturing, assembly and integration tel. #2 Qualification of debugged SI^3 swing arm
	Subtask 4.1b: Manufacturing, assembly and integration tel. #3 Production of SI^3 swing arms
	Subtask 4.2: Shipment to Tenerife Site telescopes #2 and #3
	Subtask 4.3: On site AIT telescopes #2 and #3
Task 5	Subtask 5.1a: Manufacturing, assembly and integration tel. #4
	Subtask 5.1b: Manufacturing, assembly and integration tel. #5
	Subtask 5.1c: Manufacturing, assembly and integration tel. #6
	Subtask 5.2: Shipment to Tenerife Site On site AIT tel. #4, #5, #6
	Subtask 5.3: On site AIT Telescopes #4, #5, #6

7.3.1 Task 4: Telescopes #2-3 (ASTRI-3 and ASTRI-4) Production

The production of Telescopes #2-3 (ASTRI-3 and ASTRI-4 of Figure 1) can start after the positive ending of the Final on Site Acceptance Review (FAR) of telescope #1. The telescopes shall be subjected to the acceptance review (PAR) to be performed at Contractor premises. The duration of Task 4 shall not exceed 6,5 months.

7.3.1.1 Task 4.1a and Task 4.1b: Telescopes #2-3 MAIT

The production shall be performed in a controlled environment and the integration operations and environment shall be tracked.

The manufacturing and the procurements of the parts of the two telescopes shall happen in parallel to speed up the process.

AIT activities can happen in parallel in case the Contractor has multiple integration sites, but this is not requested. Therefore, the assembly of Telescope #3 can start after the successful PAR of telescope #2.

Following the acceptance tests of telescope #2 the debugged version of the SI^3 swing arm will be also tested.

The Telescopes #2-3 production functional/performance test and calibration shall include, but not be limited to:

- verification of mechanisms;
- verification of functions and performance;
- verification of software functions (control, OPC-UA interfaces, data telemetry, management of critical conditions etc.);
- verification of performance and mechanism at the environmental acceptance conditions;
- verify the critical operations;
- submit to Customer any discrepancies with respect to the expected performances/functionality.

At the completion of the pre-acceptance test campaign the contractor shall:

- compare test results to the requirements and evaluate the effective performance;
- address the non-compliances;
- implement (if necessary) feed-back to the production flow;

The integration shall include but not limited to:

- The electrical and mechanical integration of all the parts in conformance with the integration flux and integration test logic;
- Applying the PA/QA control criteria;
- Perform the hardware and software integration.

Input:

- Positive outcome of the Final on Site Acceptance Review for telescope #1;
- CFI from Customer;

Document output:

- **MRD-01**: Telescopes #2-3 Manufacturing dossier;
- **MRD-02:** Telescopes #2-3 test reports**;**
- **PA-03**: Telescopes #2-3 Verification Matrix
- **PA-04**: Telescopes #2-3 Non Conformances Reports
- Update of **DDF-01, DDF-02**
- Update of **PA-05**
- Update of **MRD-03**, **MRD-04**, **MRD-05, MRD-06**
- **ML-04**: SI^3 swing arm CAD model
- **ML-05**: SI^3 swing arm As Built Drawings
- **ML-06**: SI^3 swing arm electrical scheme and drawings

Product Outputs:

Successful completion of acceptance tests for the SI^3 swing arm will start mass production.

7.3.1.2 Subtask 4.2: Shipment to Tenerife of telescopes #2-3

The Contractor shall provide appropriate packaging materials and devices required for safe transport of the Telescopes #2-3 from the manufacturer's facility to the installation site, located close to Mount Teide Observatory facilities, Tenerife (Canary Islands, Spain).

The Contractor shall be responsible of unloading activities and unpacking of Telescope #2 and #3 on site.

Documents Input:

- Authorization to shipment from the Customer (according a successfully outcome of the **PAR #2-3**);

Document output:

- Shipping documents;

7.3.1.3 Subtask 4.3: on site AIT telescopes #2-3

The activities and their sequence will be as described in section 7.2.4.

Document Input:

- Shipping documents.

Document Outputs (AR):

- Update of Telescopes #2-3 test reports **MRD-02** and **MRD-05**
- Update of **PA-03, PA-04**.

Product Outputs (FAR#2-3):

- Telescopes #2 and #3 (ASTRI-3 & ASTRI-4).

7.3.2 Task 5: Telescopes #4-6 (ASTRI-5, ASTRI 6 and ASTRI-7) Production

The production of Telescopes #4-6 (ASTRI-5, ASTRI 6 and ASTRI-7 of Figure 1) can start after the positive ending of the Preliminary Acceptance Review (PAR) of telescopes #3. The telescopes shall be subjected to the acceptance review (PAR) to be performed at Contractor premises. The duration of Task 5 shall not exceed 9 months.

7.3.2.1 Task 5.1a, Task 5.1b and Task 5.1c: Telescopes #4-6 MAIT

The activities and their sequence will be as described in section 7.3.1.1

Input:

- Positive outcome of the Preliminary Acceptance Review for telescope #3;
- CFI from Customer;

Document output:

- **MRD-01**: Telescopes #4-6 Manufacturing dossier;
- **MRD-02:** Telescope #4-6 test reports**;**
- **PA-03**: Telescopes #4-6 Verification Matrix
- **PA-04**: Telescopes #4-6 Non Conformances Reports
- **MRD-05**: SI^3 swing arms test reports

7.3.2.2 Subtask 4.2: Shipment to Tenerife of telescopes #4-6

Activities as described in section 7.2.4.

Documents Input:

- Authorization to shipment from the Customer (according a successfully outcome of the **PAR #4-6**);

Document output:

- Shipping documents.

7.3.2.3 Subtask 4.3: on site AIT telescopes #4-6

Activities as described in section 7.3.1.3.

Document Input:

- Shipping documents

Document Outputs (AR):

- Update of Telescope #4-6 test reports **MRD-02** and **MRD-05**
- Update of **PA-02.**
- Update of **PA-03.**
- Update of **PA-04**.
- Update of **SE-03.**

Product Outputs (FAR#4-6):

- Telescopes #4, #5 and #6 (ASTRI-5, ASTRI-6, and ASTRI-7).
- Spare parts.
- 9 SI^3 swing arms.

The set of spare/attrition parts for the entire batch of telescopes shall be delivered at Tenerife site in the occurrence of the delivery of this last batch of telescopes.

8 Management, reporting, meeting and deliverables

The Management, Reporting, Meetings and Deliverables shall take into account the following specific requirements and the deliverable documentation requirements defined in [AD1].

8.1 Management and reporting

All documentation shall be provided in electronic version (Word and unlocked and searchable Acrobat pdf, or PowerPoint for presentations), and, if requested, on CD-ROMs, USB sticks and paper copies.

8.1.1 Minutes of Meeting

Minutes of Meeting shall be distributed within five days of the relevant meeting in Word format to all participants for comments.

8.1.2 Progress Reports

Progress Reports shall be sent by e-mail to the ASTRI Mini-Array Project Manager and to the RUP of the contract every month.

8.1.3 Technical Documentation

The Contractor shall deliver the entire supporting documentation developed for this activity, including also technical drawings in all produced formats (including the STEP files). Moreover, all mathematical models developed (in computer-readable form in a format and means to be agreed with INAF before submission) have also to be delivered.

- CAD models and drawings, including STEP files
- Structural and Thermal Mathematical Models (FEM)
- Electrical Layout and Printed Circuits drawings (schematics)

At the end of the contract, the ownership of all the technical documentation will become property of INAF.

8.2 Presentation Handouts

The Contractor shall provide handouts in electronic format for all meetings, reviews and presentations specified in this Statement of Work. All electronic presentations shall be delivered to the Customer by email not less than 5 working days prior to the respective meeting.

8.3 Meetings

As a minimum, the meetings, and reviews to be held are indicated in Table 4. The details of the reviews are given in the following sections.

8.3.1 ASTRI Mini-Array Kick Off Meeting (KOM)

- **Input**: Tender ASTRI Mini-Array Telescopes data package.
- **Description**: Complementary design documentation will be delivered or made available to Contractor. Project team will be presented.
- **Output:**

8.3.2 ASTRI Mini-Array Telescope Readiness Review (TRR)

- **Input**: KOM outcome & Customer Data Package.
- **Description:** on the basis of the data package review and of the confrontation with the ASTRI technical team during the KOM, the Contractor present the design variants for approval, and proposes an industrial baseline which shall be refined further during Task 2.
- **Output:** Full understating and acceptance of the Customer data package relative to the first batch of three telescopes. Approval by the Customer of the design variants requested by INAF or proposed by Contractor. Approval by the Customer of the SI^3 swing arm design.

Table 4. Mini-Array major reviews and events

Event/Milestones	Occurrence	Date	Location
Kick Off Meeting	**Beginning of activities**	**T0**	**Customer**
Telescope Readiness Review (TRR)	**End of task 1**	**T0+6**	**Customer/Contractor**
Production Readiness Review (PRR)	**End of task 2 (Production Set Up Phase)**	**T0+8**	**Contractor**
Acceptance Test Readiness Review (ATRR)	**End of sub-task 3.1**	**T0+11**	**Contractor**
Preliminary Acceptance Review #1 (PAR#1)	**End of sub-task 3.3**	**T0+12**	**Contractor**
Final Acceptance Review #1 (FAR#1)	**End of task 3 (Telescope #1 MAIT Phase)**	**T0+13,5**	**ASTRI Mini-Array Site**
Preliminary Acceptance Review #2 (PAR#2)	**End of subtask 4.1a**	**T0+16**	**Contractor**
Preliminary Acceptance Review #3 (PAR#3)	**End of subtask 4.1b**	**T0+18**	**Contractor**
Final Acceptance Review #2-3 (FAR#2-3)	**End of task 4**	**T0+20**	**ASTRI Mini-Array Site**
Preliminary Acceptance Review #4 (PAR#4)	**End of subtask 5.1a**	**T0+20**	**Contractor**
Preliminary Acceptance Review #5 (PAR#5)	**End of subtask 5.1b**	**T0+22**	**Contractor**
Preliminary Acceptance Review #6 (PAR#6)	**End of subtask 5.1c**	**T0+24**	**Contractor**
Final Acceptance Review #4-6 (FAR#4-6)	**End of task 5 (Production Phase)**	**T0+27**	**ASTRI Mini-Array Site**

8.3.3 ASTRI Mini-Array Production Readiness Review (PRR)

- **Input**: PM-01, PM-02, PM-03, PA-01, SE-02, SE-05, DDF-01, DDF-02
- **Description**: The industrial baseline proposed during TRR is discussed and its compliance with the Customer's expectations is cross checked.
- **Output**: INAF approval of Production Plan of telescopes and SI^3 swing arm.

8.3.4 ASTRI Mini-Array Acceptance Test Readiness Review #1 (ATRR)

- **Input**: PM-03, PM-04, SE-01, DDF-02
- **Description**: Examination of the telescope #1 production state and test plans and procedures.
- **Output**: Green light for tests in the factory of telescope #1 and SI^3 swing arm.

8.3.5 ASTRI Mini-Array Preliminary Acceptance Review #1 (PAR#1)

- **Input**: SE-01, PA-02.
- **Description**: Analysis of the results of the on factory tests for telescope #1 and SI[3] swing arm;
- **Output**: Preliminary acceptance of telescope #1, approval for its shipment to Tenerife and qualification of the production process. Debug activities for correcting SI[3] swing arm non conformities.

8.3.6 ASTRI Mini-Array Final Acceptance Review #1 (FAR#1)

- **Input**: MRD-01 MRD-02, MRD-03, MRD-04, MRD-05, MRD-06, SE-04, PA-03, PA-04, PA-05.
- **Description**: on site telescope #1 test results analysis;
- **Output**: Acceptance of Telescope #1 and green light to serial production.

8.3.7 ASTRI Mini-Array Preliminary Acceptance Review #2-3 (PAR#2-3)

- **Input**: SE-01, PA-02.;
- **Description**: on factory telescopes #2-3 test results analysis; analysis of the results of the on factory tests for SI[3] swing arm
- **Output**: Preliminary acceptance of telescopes #2-3 and approval for their shipment to Tenerife Site. Green light to serial production of SI[3] swing arm.

8.3.8 ASTRI Mini-Array Final Acceptance Review #2-3 (FAR#2-3)

- **Input**: MRD-01 MRD-02, MRD-03, MRD-04, MRD-05, SE-04, PA-03, PA-04, PA-05, DDF-01, DDF-02, ML-04, ML-05, ML-06;
- **Description**: on site telescope #2-3 test results analysis;
- **Output**: Acceptance of Telescopes #2-3.

8.3.9 ASTRI Mini-Array Preliminary Acceptance Review #4-6 (PAR#4-6)

- **Input**: SE-01, PA-02.;
- **Description**: on factory telescope #4-6 test results analysis;
- **Output**: Preliminary acceptance of telescopes #4-6 and approval for their shipment to Tenerife Site.

8.3.10 ASTRI Mini-Array Final Acceptance Review #4-6 (FAR#4-6)

- **Input**: MRD-01 MRD-02, MRD-03, MRD-04, MRD-06, SE-04, PA-03, PA-04;
- **Description**: on site telescope #4-6 test results analysis;
- **Output**: Acceptance of telescopes #4-6. Acceptance of the SI[3] swing arms. End of the contract.

8.4 Deliverables

8.4.1 Documents, and models

The documents package of each review, including all approved Technical Notes, presentation handouts, summaries and other technical documents produced under this contract, shall be delivered in electronic form.

Table 5. Documents to be delivered

Documents, models and to be delivered	
Project Management	
PM-01	Project Management Plan
PM-02	Configuration Control Plan
PM-03	Risk Management Plan (including risk registry)
PM-04	Telescopes Industrial Production Plan including SI^3 swing arm
System Engineering	
SE-01	AIT/AIV Plan (including test procedures)
SE-02	FEM Analysis (if necessary)
SE-03	Telescope Maintenance Plan (including SI^3 swing arm)
SE-04	Telescope User Manuals (including SI^3 swing arm)
SE-05	Variant Design Report
Product Reference File	
MRD-01	Telescopes Manufacturing Dossier
MRD-02	Telescopes Test reports
MRD-03	Telescopes Inventory List (BOM)
MRD-04	Software Database
MRD-05	SI^3 swing arm Test Report
MRD-06	SI^3 swing arm Inventory List (BOM)
Design Definition File	
DDF-01	SI^3 swing arm design description report (including software)
DDF-02	SI^3 swing arm ICD
Product/Quality Assurance	
PA-01	Telescopes Quality Plan
PA-02	Telescopes FMEA and RAMS analysis report (including SI^3 swing arm)
PA-03	Telescopes Verification Control Document (including verification matrix)
PA-04	Telescopes Non Conformances Reports

PA-05	**SI^3 swing arm Non Conformances Reports**
Models and drawings	
ML-01	**Telescope CAD Model (including variants)**
ML-02	**Telescope as Built full series of drawings (including variants)**
ML-03	**Telescope electrical layout and drawings (including variants)**
ML-04	**SI^3 swing arm CAD model**
ML-05	**SI^3 swing arm as Built full series of drawings (including variants)**
ML-06	**SI^3 swing arm electrical layout and drawings (including variants)**

Table 5 summarizes the documents, models to be delivered during the contract

8.4.2 Products

The main products to be delivered are listed in Table 6.

Table 6. Main products to be delivered

Item	Description	Milestone
Telescope #1	Telescope for production adjustment	FAR #1
Telescopes #2-6	Serial production telescopes	FAR #2-6
Spare set	Spare parts to be available at ASTRI Mini-Array site (Teide Observatory in Tenerife, Spain) according to the results of the RAM analysis	FAR #4-6
Test Equipment set	Set of TE deliverable to the ASTRI Mini-Array site (Teide Observatory in Tenerife, Spain) in support of the telescopes' integration, testing and transportation.	FAR #1
SI^3 swing arms	9 swing arms to insert the SI^3 instrument in the optical path	FAR #6

9 Contracting Institution undertakings

9.1 Customer Furnished Items

9.1.1 CFIs for company integration site activities

The furnished Customer Furnished items (CFI) for activities to be done at the company integration site are listed in Table 7.

Table 7. Customer Furnished Equipment List for company integration site activities

Item	Description	No.
Telescope Control Software	All the software necessary to control and monitor the telescope	1
PMC/SQM+SW	It's an optical camera, mounted in the M2 Support Structure looking at the sky. It's used for telescope's pointing and calibration purposes.	6
Ethernet Switch	The ethernet switch used for telescope internal communications	6
Primary mirror (M1) segments	The M1 hexagonal tiles form the primary mirror of the telescope: collect the light produced by the Cherenkov atmospheric events and re-direct it towards the secondary mirror.	108
Secondary mirror (M2)	It collects light from M1 focusing it on the Cherenkov Camera's focal plane	6
Stellar Intensity Interferometry Instrument + SW (if available)	The Intensity Interferometry Module is a dedicated optical photon detection module for performing intensity interferometry observations. It is mounted in front of the Cherenkov Camera through the use of a swing arm and it is completely independent from it.	1
UVSiPM + SW (if available)	This instrument is used to measure the night sky background. It uses SiPM as detector in single photon counting mode.	1
Cherenkov Camera (if available)	The main focal plane instrument	1
Set of M1 actuators	Set of removable actuators used to align the panels of the primary mirrors to test mechanical and software interfaces	3
AZ motors and stow pins handling device	AZ motors and stow pins handling device	1
M2 handling cart	M2 handling cart	1
M2 flexure maintenance device	M2 flexure maintenance device	3
M2 flexures	M2 flexures sacrificial pins	9

sacrificial pins		

SI[3] instrument, UVSiPM, and Cherenkov camera will be delivered to test mechanical, electrical and software interfaces, then dismounted and returned back to INAF.

9.1.2 CFIs for onsite AIV activities

Table 8 lists the furnished Customer Furnished items (CFI) for activities to be performed at the observational site in Tenerife.

Table 8. Customer Furnished Equipment List for onsite activities

Item	Description	No.
Mirror Alignment System + SW	The set of removable actuators used to align the panels of the primary mirrors	1
Cherenkov Camera (if available)	The main focal plane instrument	1
Crane	Crane used to assemble the various parts of the telescope	1
Crane manbasket		1
Articulated boom lift (Cherry picker)	To support AIV activities	1
Forklift	-	1
Portable power generator	-	1
Grout pump	-	1
Anti-shrinkage grout	-	~100kg
Portable air compressor	-	1

9.2 Coaching stage

With the aim to speed-up the Contractor learning process and transfer the specific know-how acquired during the development and manufacturing of the ASTRI telescopes, the ASTRI team members shall assist directly the Contractor at its own premises in the early period of the project until the PRR completion.

9.3 ASTRI Mini-Array site access

The Customer will make available the ASTRI Mini-Array site to the Contractor all activities related to the AIT on site of the telescopes.

The Contractor shall be responsible for execution of surveys, tests, measurements on site.

9.4 Personnel provided by INAF during onsite AIV activities

During onsite AIV activities INAF will be responsible for providing manpower to perform several tasks. Table 9 lists the role of that manpower.

Table 9. Manpower provided by INAF

Role	Number of people
Crane operator	1
Safety officer	1
Grout pump operators	2
Unskilled workers	2

10 Schedule and milestones

The proposed ASTRI Mini-Array Telescopes #1-6 production master schedule with the milestones, reviews and major events is shown in Figure 14.

Considering the KOM as T0, the supply of the 6 telescopes shall happen within 27 months from T0. In particular:

- The available data package shall be analysed and discussed within 6 months from the KOM.
- The preliminary activities for the serial production of the telescopes #1-6 shall be reviewed within 8 months from the KOM.
- The MAIT of the telescope #1 and the qualification of the serial production of the whole batch of 6 shall be completed within 12 months from the KOM.
- The AIT on site of the telescope #1 shall be completed within 13,5 months from the KOM.
- The MAIT of telescopes #2-6, their AIT on site and the FAR shall be completed within 27 months from the KOM.

The Contractor can present and justify alternative schedules (in compliance with the task flow reported in this SoW) considering a project organization with optimization of time.

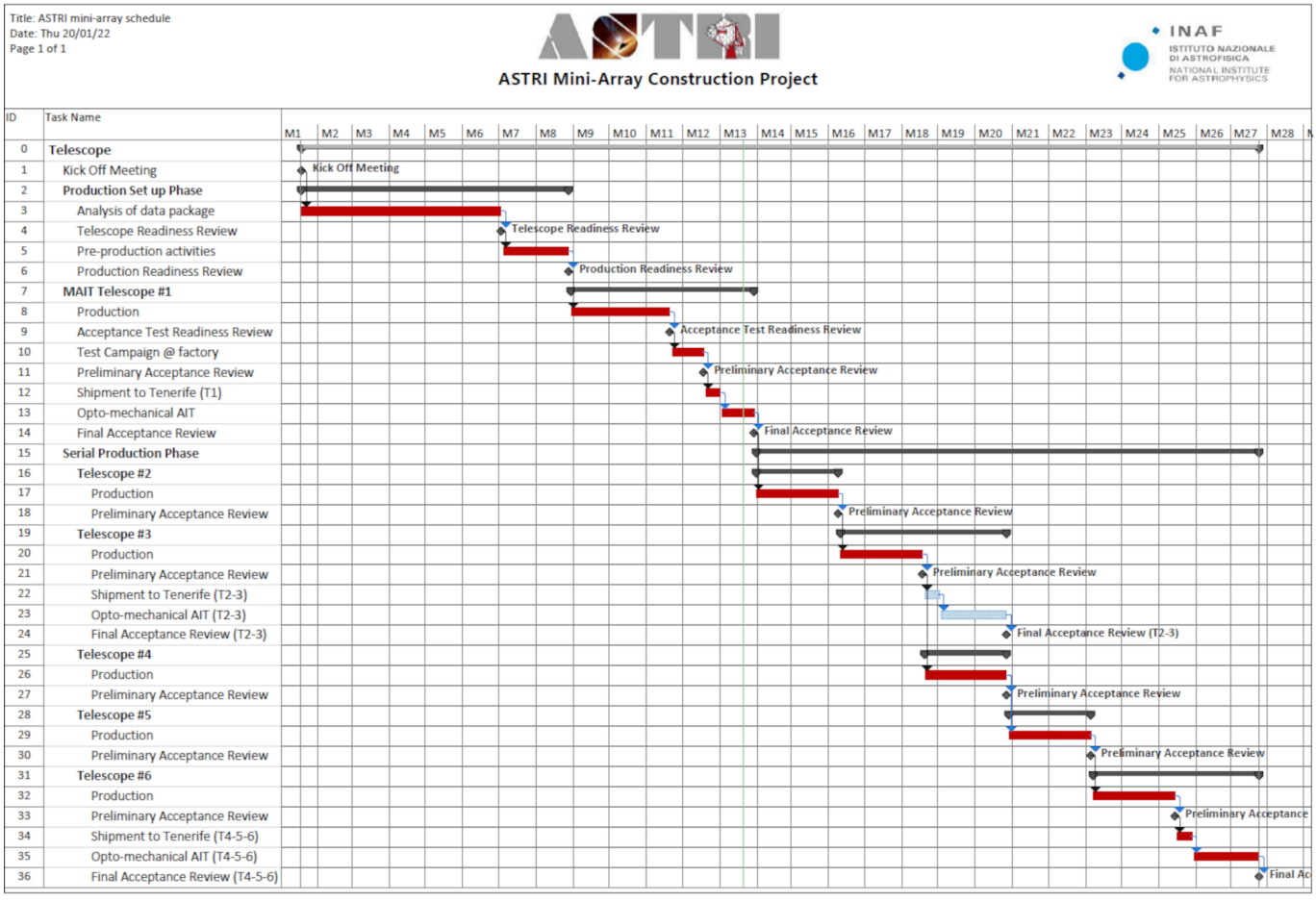

Figure 14. ASTRI Mini-Array Telescopes production master schedule

11 Environmental Conditions at the ASTRI Mini-Array observational site

The environmental conditions at the ASTRI Mini array site at Tenerife-Observatorio del Teide are fully described in [AD4].

In Table 10 those conditions are summarized and associated with a specified conditions and limits as defined in section 1.2.2

Table 10. Environmental conditions of the ASTRI Mini-Array site

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/m^2 on horizontal surface <50cm
Ice	none		none	≤20 mm thickness
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: ≤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

12 List of drawings and schemes

DWG Number	Description
D7100-000-00-00	Electro-Mechanics
D7110-000-00-00	Mount Assembly
D7110-000-01-00	Protection 01 for strip encoder
D7110-000-02-00	Protection 02 for strip encoder
D7110-000-03-00	Protection 03 for strip encoder
D7111-000-00-00	Base structure
D7111-000-01-00	Alignment block encoder
D7111-100-00-00	Base
D7111-100-02-00	Removable panels
D7111-100-03-00	AZ Locking pin bush
D7111-100-04-00	Lyra witness
D7111-100-05-00	AZ Switch Witness
D7111-100-06-00	Spring lock support
D7111-100-07-00	Support for door switch
D7111-100-08-00	Switch cam
D7111-100-09-00	AZ Locking pin shim bush
D7111-100-10-00	Door spacer
D7111-100-13-00	Door threaded rod
D7111-100-14-00	Door endstop
D7111-100-15-00	Support for door switch
D7111-110-01-00	Base door structure
D7111-110-03-00	Door gasket
D7111-110-04-00	Door locking bracket
D7111-210-00-00	AZ encoder head group
D7111-210-02-00	AZ encoder head support
D7111-210-03-00	AZ encoder head plate
D7111-210-04-00	AZ encoder head upper plate
D7113-000-00-00	AZ fork
D7113-000-01-00	AZ fork - Bumper Shim
D7113-100-00-00	AZ fork structure
D7113-100-01-00	AZ fork main structure
D7113-100-02-00	AZ fork hole cover
D7113-100-03-00	AZ fork adjuster block
D7113-100-04-00	AZ fork hole cover with cave

D7113-100-05-00	AZ Cable wrap support
D7113-100-06-00	AZ fork ELA adjuster block
D7113-100-07-00	AZ fork special key
D7113-110-01-00	Cabinet support R structure
D7113-110-03-00	Cabinets support central pipe
D7113-110-06-00	Cabinets support shim
D7113-110-07-00	Cabinets support cover
D7113-110-08-00	Cabinets support Tray bracket
D7113-110-12-00	AZ fork plane grating
D7113-110-13-00	AZ fork plane grating
D7113-120-04-00	Angular shaft
D7113-120-05-00	Upper cover
D7113-210-00-00	EL axis bearing
D7113-311-00-00	AZ Motor L
D7113-312-00-00	AZ Motor R
D7113-320-00-00	EL actuator
D7113-322-00-00	ELA lower hinge
D7113-510-00-00	AZ switches
D7113-620-00-00	EL cable wraps
D7113-620-01-00	Cable wrap support
D7113-621-00-00	AZ fork cable box
D7113-621-02-00	AZ fork cable box cover
D7113-621-03-00	AZ fork cable box gasket
D7113-710-00-00	AZ stow pin
D7113-720-00-00	EL stow pin
D7120-000-00-00	Optical Support Structure
D7121-000-00-00	M1 Dish
D7122-000-00-00	Counterweights
D7123-000-00-00	OSS Upper Structure
D7124-000-00-00	M2 Back-up Structure
D7124-000-02-00	Lower soft pad support
D7124-000-03-00	Upper soft pad support
D7124-000-04-00	Rubber Pad
D7124-000-05-00	M2 Shield 01
D7124-000-06-00	M2 Shield 02
D7124-000-07-00	M2 Shield 03

D7124-000-08-00	M2 Shield 04
D7124-000-09-00	M2 Shield 05
D7125-000-00-00	M1 Segment Support Assembly
D7125-000-11-00	Wedge 1° ring
D7125-000-12-00	Wedge 1° ring slot
D7125-000-13-00	Wedge 1° ring pin
D7125-000-15-00	Wedge 2° ring slot
D7125-000-16-00	Wedge 2° ring pin
D7125-000-17-00	Wedge 3° ring
D7125-000-18-00	Wedge 3° ring slot
D7125-000-19-00	Wedge 3° ring pin
D7125-100-00-00	M1 Support Triangle 1° Ring
D7125-200-00-00	M1 Support Triangle 2° Ring
D7125-300-00-00	M1 Support Triangle 3° Ring
D7126-000-00-00	M2 Support
D7126-100-00-00	M2 Actuator
D7126-200-00-00	M2 Actuator Driving Unit
D7126-400-00-00	M2 Load spreader
D7131-100-00-00	High-Power Cabinet Diagram
D7131-200-00-00	Low-Power Cabinet Diagram
D7634-000-01-00	Rolling spheres
D7634-100-00-00	LPS & Grounding AZ
D7634-110-00-00	LPS AZ Unit
D7634-110-03-00	LPS AZ brush support
D7634-120-00-00	LPS EL Unit
D7634-120-01-00	LPS EL strip
D7634-120-02-00	LPS EL brush support
D7634-120-03-00	LPS EL support shim
D7634-200-00-00	LPS & Grounding EL
D3150-000-05-00	Foundation ICD with Telescope structure
D3150-100-00-00	Anti-shrinkage mortar assembly