SST Programme:
Engineering Development and Verification Plan

SST-PRO-PLA-009

Version 1b

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1. Introduction

1.1 Scope & Purpose of this document

This document presents the development status, the activity development and logic flow, the AIT/V organization and strategy, a high-level description of the tests and the work flows of the Telescope AIT/V. The plan has been prepared considering the share of responsibilities between the SST Consortium in kind contribution to CTAO.

1.2 Content

This document is organised as follows:

Chapter	Content
1	Introduction
2	SST Telescope Overview
3	SST Development Status
4	Activity Development and Logic Flow
5	The SST AIT/V Plan
6	The SST AIT/V Work Flow

1.3 Applicable Documents

[AD1] SST-PRO-PLA-001 Project Management Plan

1.4 Reference Documents

[RD1] SST-CAM-PLA_009 Camera Engineering Development and Verification Plan

[RD2] Cherenkov Telescope Array Observatory SST Engineering Review – DMA Disposition, CTA-INS-SST-305000-0001, 01-Nov-2020

[RD3] The ASTRI-Horn telescope validation toward the production of the ASTRI Mini-Array: a proposed pathfinder for the Cherenkov Telescope Array, Proc. SPIE. 11119

[RD4] The ASTRI mini-array at the Teide observatory, Proc. SPIE. 11822

[RD5] A Compact High Energy Camera (CHEC) for the Gamma-ray Cherenkov Telescope of the Cherenkov Telescope Array, 35th International Cosmic Ray Conference -ICRC217-10-20 July, 2017

[RD6] SST-PRO-ANR-006 Trade-off & top level analysis Report
[RD7] Mechanical optimization of the M1 Dish for the Small-Sized Telescopes of the future Cherenkov Telescope Array, Proc. SPIE. 12188
[RD8] Vassiliev, V., et al., "Wide field aplanatic two-mirror telescopes for ground-based γ-ray astronomy", Astroparticle Physics 28, 10-27 (2007)
[RD9] Pareschi, G., "The ASTRI SST-2M prototype and mini-array for the Cherenkov Telescope Array (CTA)", proc. SPIE, vol. 9906, 99065T (2016)

[RD10] Scuderi, S., et. al, "The ASTRI Mini-Array of Cherenkov telescopes at the Observatorio del Teide", JHEA 35, 52 (2022)

[RD11] Marchiori, G., et al., "ASTRI SST-2M: the design evolution from the prototype to the array telescope", Proc. SPIE vol. 10700, 107005W (2018)

[RD12] SST-MEC-ANR-008, Mechanical Structural Analysis Report

[RD13] SST Requirements - V1, JAMA REF: SET KEY: PROD_SST; GLOBAL ID: CTA-160212; ID: CTA_-SET-54

[RD14] Common Telescope Requirements - V1, JAMA REF: SET KEY: PROD_TEL; GLOBAL ID: CTA-200234; ID: CTA_-SET-67

[RD15] Common On-Site Requirements - V1, JAMA REF: SET KEY: PROD_ONSITE; GLOBAL ID: CTA-200443; ID: CTA_-SET-68

[RD16] Environmental Requirements - V1, JAMA REF: SET KEY: PROD_ENV; GLOBAL ID: CTA-200109; ID: CTA_-SET-66

[RD17] Minutes of 17th CTAO COUNCIL MEETING, 17-19 June 2019, Section 19, SST harmonization

[RD18] An SST-2M Implementation Concept Response to the Request for Information, ASTRI/CHEC groups, 31 Oct 2018

[RD19] CTA-SST Engineering Review Panel Report, CTA-RER-SST-305000-0001_2a, Issue 2, Rev. 0, 2020-09-01

[RD20] SST-PRO-DSR-002, Architecture & Design Summary Report

[RD21] SST-AIT-PLA_011, Factory AIT Plan

[RD22] SST-AIT-PLA_012, On site AIT Plan

[RD23] SST-PRO-PLA_013, AIV Plan

[RD24] Dournaux J.-L. Application of the topography optimization technique to the design of a lightweight primary mirror for the GCT, a dual-mirror telescope proposed for the CTA, Proc. SPIE 10706 (2018)

[RD25] MSC Software, [MSC Nastran, Design sensitivity and optimization user's guide], MSC Software Edns (2011)

1.5 General Specification and Standard Documents

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

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

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

[SD4] Basis of Structural Design - EN Eurocode 0

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

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

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

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

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

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

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

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

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

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

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

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

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

[SD18] EMC Directive 2004/108/EC

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

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

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

[SD22] Lightning protection standard - EN 62305:2011

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

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

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

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

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

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

1.6 Definition of Terms and Abbreviations

1.6.1 Abbreviations and Acronyms

ACADA Array Control and Data Acquisition System

AIT	Assembly Integration and Testing
AIV	Assembly Integration and Verification
ASTRI	Astrophysics with Italian Replicating Technology Mirrors
BKO	Bridging phase Kick-Off
CDR	Critical Design Review
CTA	Cherenkov Telescope Array
CTAO	Cherenkov Telescope Array Observatory
FAR	Final Acceptance Review
FRC	France Contribution
DR	Delivery Review
DVER	Design Verification Engineering Review
ERIC	European Research Infrastructure Consortium
ESC	Executive Steering Committee
IKC	In Kind Contribution
INAF	Istituto Nazionale di Astrofisica
INSU	Institut National des Science de l'Univers
KO	Kick-Off
MPIK	Max-Planck-Institut für Kernphysik
OP	Observatoire de Paris – PSL, CNRS
PA	Product Assurance
PBS	Product Breakdown Structure
PM	Project Manage
PR	Product Review
PMP	Programme Management Plan
PO	Project Office
PQR	Production Qualification Review
PR	Product Review
PRM	Programme Manager
PRR	Production Readiness Review
PSE	Programme System Engineer
QA	Quality Assurance
QM	Quality Manager
RAMS	Reliability, Availability, Maintainability & Safety
SE	System Engineer
SST	Small Size Telescope
TRR	Test Readiness Review
WBS	Work Breakdown Structure
WP	Work Package
WPD	Work Package Description

1.6.2 Glossary

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

TERM	DEFINITION
Work Breakdown Structure	Hierarchical representation of the activities necessary to complete a project.

2. SST Telescope overview

When a VHE gamma-ray interacts with the atoms and ions in the upper levels of the atmosphere, it induces a cascade of secondary particles which propagate over many kilometres at nearly the speed of light through the atmosphere. These particles emit Cherenkov light, forward-beamed with an opening angle of about one degree. A Cherenkov light event consists of a time-correlated multi-photon image with a typical timescale of ~10 ns. Cascades originate at an altitude of ~10 km above ground and create a light pool on the ground of ~120 m radius. Telescopes placed on the ground, containing large reflectors, focus the light to and imaging camera. Such Cherenkov cameras must be highly pixelated, cover a large field of view, and be able to detect UV/blue light down to the single photon levels with exposure times of approximately a billionth of a second. To provide a high imaging sensitivity over an extensive energy range, from a few tens of GeV up to a few hundreds of TeV, the Cherenkov Telescope Array Observatory (CTAO, see web page link at https://www.cta-observatory.org) will be made of sub-arrays with three different types of telescopes: large-sized (LST, 23 m diameter), medium-sized (MST, 12 m diameter) and small-sized (SST, 4 m diameter) telescopes. They are distributed in two observing sites, the Northern one in La Palma, the Canary Islands, and the Southern one in the Chilean Andes in the Paranal area. The CTA South "Alpha Configuration" would include LSTs, MSTs and SSTs. In particular, it envisages the construction and installation of 42 SSTs (a number that could increase up to 70 in future upgrades).

The SSTs are developed by an international consortium of institutes that will provide them as an in-kind contribution to CTAO. The SSTs rely on a Schwarzschild-Couder-like dual-mirror polynomial optical design, with a primary mirror of 4 m diameter, and are equipped with a focal plane camera based on SiPM detectors covering a field of view of ~9°. They are sensitive in the band from ~0.5 TeV up to ~300 TeV, providing the Observatory with sensitivity to the highest energies. The current SST concept has been validated by developing the prototype dual-mirror ASTRI-Horn Cherenkov telescope and the CHEC-S Cherenkov camera. Table 2-1 reports main properties of the Small-Sized telescope (SST).

Table 2-1. Small-sized telescope main properties

Small-Sized telescope (SST) main properties:	
Optical Design	modified Schwarzschild-Couder
Primary reflector diameter	4.3 m
Secondary reflector diameter	1.8m
Effective mirror area (including shadowing)	>5 m^2
Focal length	2.15 m
Total weight	17.5 t
Field of view	>8.8 deg
Number of pixels in SST Camera	2048
Pixel size (imaging)	0.16 deg
Photodetector type	SiPM

Telescope data rates (before array trigger)	>600 Hz
Telescope data rates (readout of all pixels; before array trigger)	2.6 Gb/s
Positioning time to any point in the sky (>30° elevation)	90s
Pointing Precision	< 7 arcsecs

2.1 SST Telescope Product Breakdown Structure

The top-level product breakdown structure of the SST Telescope is give in Figure 2-1: SST Telescope Product Breakdown Structure.

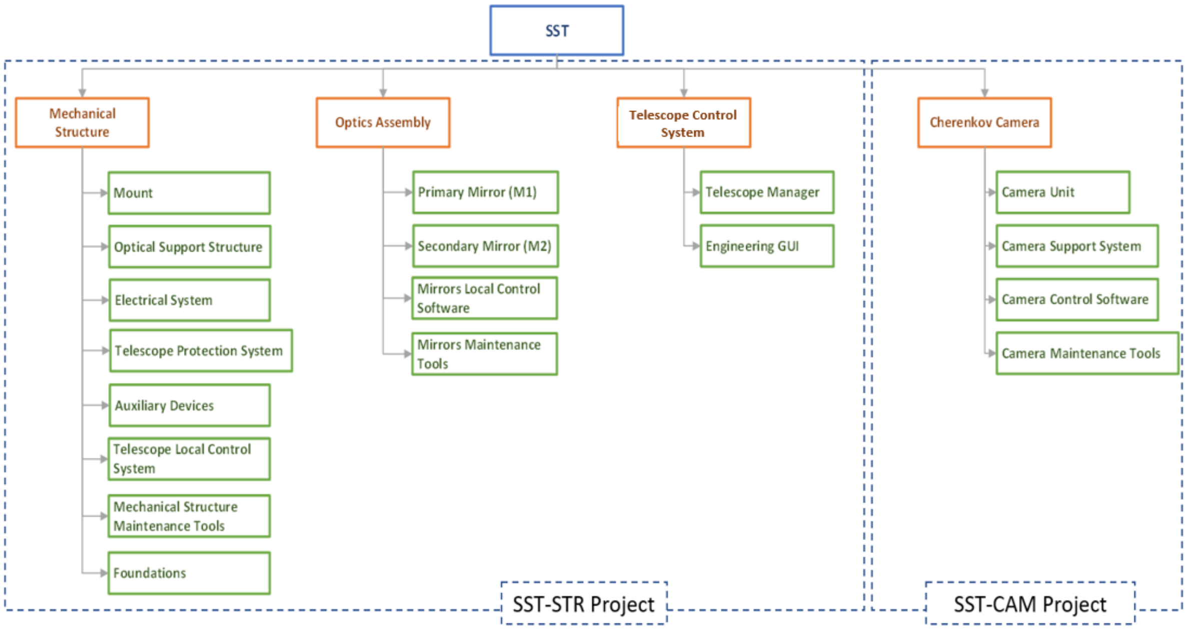

Figure 2-1: SST Telescope Product Breakdown Structure

The SST Consortium responsibility is considering the levels detailed in the following bullets.

- *SST Telescope (SST-TEL):* It is the whole contribution of the SST Consortium to CTA. It consists in the provision of all the equipment necessary to perform the imaging of the Cherenkov Light, providing the whole telemetry, both scientific and engineering, and guarantee an autonomous managing of the telescope equipment.

- *Mechanical Structure (STR-MEC)*: The Telescope Mechanical Structure (TMS) includes all the hardware and software that allow the telescope to point to different parts of the sky with the required performances. All mechanical parts (structural elements, bolts, screws, bearings, gears, springs, bumpers, accessories) needed to support the telescope optics to collect light are part of the TMS. The TMS provides the motion capabilities that allow the Telescope to point and track over its specified range. All the electromechanical parts are provided with power and communication via dedicated supply lines. The TMS is fixed to the concrete foundation by means of anchor bars.

- *Optics Assembly (SST-OPT):* The Optical Assembly (Optics) includes the primary and secondary mirror and their control hardware.

- *Telescope Control System (SST-TCS):* The Telescope Control System (TCS) interfaces the Telescope with the CTAO facility (ACADA). The TCS includes a Telescope Engineering GUI to operate the SST Telescope in standalone mode during installation, calibration and maintenance activities.

- *Cherenkov Camera (SST-CAM):* The SST Camera comprises all the hardware, software and documentation associated with Cherenkov image detection, digitisation, trans project and pre-processing. The SST Camera is modular, it consists of a number of subsystems These modular subsystems greatly simplify the organisation and division of activities within the production phase, and also form the basis of the international SST Camera Project (SST Camera).

The SST Structure (SST-STR) is composed by the Mechanical Structure, Optics Assembly and Telescope Control System.

3. SST Development Status

At the moment of writing this plan, the development status achieved by the SST program is based on the following prototypes:

- An SST Structure prototype, ASTRI-Horn Cherenkov telescope, has been produced and tested extensively in Catania, Serra La Nave, during the years 2014-2020. [RD3].
- ASTRI/ASTRI1 Structure prototype [RD4]
- A Camera Unit prototype (CHEC-S SiPM) [RD5]
- Trade-Offs analysis performed during the bridging phase [RD6]

3.1 Structure development status

The current structure baseline selected for the SST Structure is the outcome of a project initiated in 2011 as a “flagship project” funded by the Italian Ministry of University and Scientific Research (MUR). This project is named ASTRI and was led by INAF. It started with developing a prototype Cherenkov telescope of the 4-m class, relying on an innovative dual-mirror optical configuration based on a polynomial-modified Schwarzschild - Couder design previously proposed by Vassiliev et al., [RD8], for IACT telescopes. The Italian ASTRI team developed this telescope as a technological demonstrator in the context of the SST–CTAO project in its early phase. In 2014 it was installed on the Mount Etna volcano, at the M.G. Fracastoro astronomical station operated by INAF–Osservatorio Astrofisico di

Catania (see Figure 3-1: The ASTRI-Horn telescope prototype on the Mount Etna station of the INAF-Osservatorio Astrofisico di Catania, and [RD9]). This prototype has been named ASTRI-Horn after Guido Horn D'Arturo; the astronomer who pioneered the segmented mirrors approach for the realization of primary mirrors of large diameter telescopes. The ASTRI-Horn is now available as a test bench for implementing hardware and software developed by the SST team.

Figure 3-1: The ASTRI-Horn telescope prototype on the Mount Etna station of the INAF-Osservatorio Astrofisico di Catania

Following the successful realization of the ASTRI-Horn prototype, the ASTRI team moved toward implementing 9 other telescopes, named the ASTRI Mini-Array. This mini-array was supposed to be a pathfinder for the southern site of CTAO, also representing the first seed around which the SST array would have been developed. However, the ASTRI timeline, dictated by the funds' availability and time-frame in which they had to be spent, was ahead of the CTAO site-building timeline. Therefore, in 2019 INAF and the Instituto de Astrofisica de Canarias (IAC) agreed to install the ASTRI Mini-Array at the Teide Astronomical Observatory in the Canary Islands of Tenerife. ASTRI Mini-Array has been designed on the basis of the high-level SST requirements.

Figure 3-2: left: a 3-D model of the SST telescope structure; right: the first ASTRI Mini-Array telescope fully assembled in a warehouse in Italy before being shipped to the Tenerife Canary Island. This is also the baseline of the SST telescopes, currently under study for further possible improvements.

Taking advantage of the lessons learned during the development and operations of the ASTRI-Horn prototype, the design of the ASTRI Mini-Array electro-mechanical structure has been further optimized (see Figure 3-2 left panel), and in Autumn 2020, CTAO defined this to be the SST structure baseline configuration. In this optimization, the mass has been reduced by ~5 tons (from 22 to 17 tons) while the stiffness has either been maintained or improved for some aspects. The structure supporting the segments of the primary mirror (M1 dish) and the system supporting the secondary mirror (M2) were deeply revisited, improving their functionality, reliability, and maintainability, besides making them lighter. For a detailed description of these improvements, see [RD10] [RD11]. The electromechanical structure of the first ASTRI Mini-Array telescope has now been constructed and fully integrated at the EIE GROUP srl company warehouse in Mira, near Venice (Italy, see Figure 3-2, right panel). Then it has been dismounted, and shipped to Tenerife (Canary Islands) and has been integrated at the Teide Astronomical Observatory.

Given the strong commonality, that there is between the ASTRI Mini-Array and the SST Array and that the ASTRI team is largely present also in the SST team, we are directly experimenting all procedures necessary for the fabrication, integration, verification, shipment of the telescope from Europe to the remote observing site, on-site integration and related AIT/V activities. That is, we are directly proving all the steps necessary to go from a telescope design to a fully mounted and working telescope at the observing site. This allows us to put the construction of the SST array on a very solid basis.

As said, the original ASTRI-Horn M1 dish has been significantly modified. Now for the ASTRI Mini-Array it is made in two parts, simplifying its transportation to the Observatory site and its onsite integration. Given that this has to be done for 42 telescopes, it has an important impact on the onsite AIT/V activities. Also, the way to support the M1 segments has significantly changed. The current layout provides complete modularity of the segment supports, which are reduced to only 3 types, compared to the 18 types before. This has been obtained by using a cylindrical symmetry, while before the position was based on Cartesian coordinates. With this configuration, the M1 segment integration and alignment is achieved in less than one day.

3.1.1.1 Trade-offs during Bridging Phase and Structure Technology Roadmap

During the current Bridging Phase, several trade-offs have been performed to improve the SST design [RD6]. The most important trade-off we performed has been the optimization of the M1 dish design [RD7]. A team from the Observatoire de Paris - PSL/CNRS leaded these studies on the basis that interfaces and global philosophy must stay the same to propose an alternative design. For this purpose, an optimized design process, based on structural optimization tools, is used. This process allows us to reduce required iterations between the computer aided design (CAD) and the finite element analysis (FEA). This work is based on previous experiences of the French team in this field, namely for mechanical studies for CTAO SST before the selection of the ASTRI design after the DVER [RD24]. This optimization focuses on the redefinition of the beam layout of the M1 dish. The mechanical interfaces with the elevation fork, the M1 segments, the counterweights of the optical support structure, the AIT and shipping philosophies are kept. The SOL 200 of the Nastran FEA code has been used to carry out the optimization study [RD25].

The combined use of topology and topography optimizations, a kind of shape optimization, and post-processing of these results allowed to obtain a different beam layout, as shown in Figure 3-3.

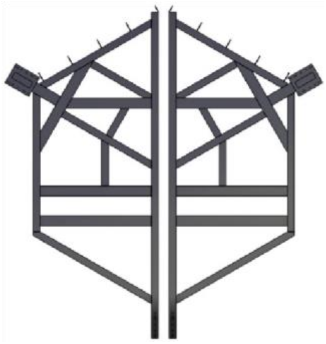

Figure 3-3: Main beam layout of the alternative design.

A second step of the work consisted in defining the geometry of the sections of these beams. The choice was to adopt standard U and I profiles for the beams, in order to make easier the fabrication process. The resulting 3D design is shown in Figure 3-4.

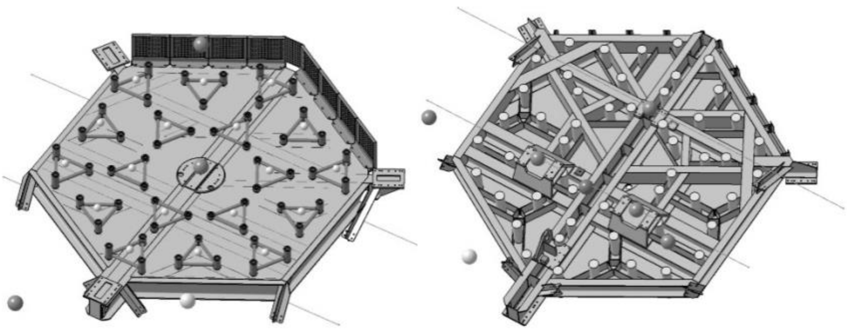

Figure 3-4: Alternative conceptual design of the M1 Dish.

The performance of this design is compared to the performance of the baseline first in terms of mass and mechanical behaviour (stresses, displacements and normal modes). The mechanical performance has been preliminary evaluated thanks to local finite-element models of the M1 dish (baseline and alternative) and by using the SOL 101 (linear static analysis) and SOL 103 (normal modes analysis) packages of Nastran. As a result, the alternative proposed design is slightly lighter than the ASTRI dish baseline and allows a significant increase in the first eigenfrequency, with also an important decrease of the Von Mises stresses. The alternative design seems to have a low impact on the displacements of the M1 segments. **Table 3-1** and **Table 3-2** summarize the achieved results.

Table 3-1. Comparison of the two designs.

	Baseline	Alternative
Mass (kg)	3 004	2 859
1^{st} eigenfrequency (Hz)	57,4	93,4
Max Von Mises stress @0° (MPa)	11,9	2,8

Table 3-2. Average displacements and rotations of M1 panels Centre of Gravity for the two designs (elevation angle).

	Decentre (µm)	Piston (µm)	Tilt x (µrad)	Tilt y (µrad)
0 degree				
Baseline	4,5	0,3	3,1	-0,1
Alternative	5,4	1,1	2,8	0,2
90 degrees				
Baseline	1,7	12,6	-7,0	0,1
Alternative	1,5	7,7	-0,7	0,2

Performance is the same for both designs in static analysis but there is a clear improvement for the dynamic analysis. On the other hand, this alternative solution has to show a proper performance to sustain the demanding seismic load that is required to the SST telescope in Chile. For this reason, the alternative proposed design has been injected in the global design for the seismic analysis to have the complete FEA comparison between both solutions. Based on the structural analysis results [RD12] and the trade-off analysis [RD6], the M1 Dish Optimization has been integrated into the baseline configuration.

3.1.1.1 Structure Technology Roadmap

As already described in the previous section, with the ASTRI Mini-Array we are directly experimenting all procedures necessary for the fabrication, integration, verification, shipment of the telescope from Europe to the remote observing site, on-site integration and related AIT/V activities. This process will involve the entire ASTRI Mini-Array provision of 9 telescopes.

The M1 Dish Optimization, derived from the study conducted during the bridging phase, will be validated with the first structure produced for the qualification model of the Telescope (see section 5), nominally the first telescope of the SST array.

3.2 Cherenkov Camera development status

For the SST Cherenkov Camera development status and technology roadmap refers to [RD1].

4. Telescope Verification and Model Philosophy

The verification approach of the SST Telescopes has been designed to confirm (through demonstration) that equipment (design) is compatible with the requirements.

4.1 Verification Strategy

The Telescope verification strategy consists in the use of prototypes for the main subsystems of the Telescope, engineering and qualification model for the Camera Unit and the Optics.
Therefore, the first provision of one camera and one structure will be integrated to compose the first telescope that will be used as qualification model.

The verification strategy of the SST Telescope has been designed to confirm (through demonstration) that equipment (design) is compatible with the requirements of the project.

The SST Telescope AIT/V campaign is to demonstrate that:

- the Telescope design at subsystems level is qualified at the environmental condition;
- the overall Telescope (including software, procedures and resources) is able to fulfil the project requirements, providing all the performances requirement during the project period;
- the structure verified in conjunction with the camera work properly;
- the Final Models are delivered in due time;

In addition to the AIT/V campaign goals, the Telescope activities have to be organized taking into account the following master drivers:

- Operational period;
- Structural design to allow easy accessibility for maintenance, alignment and testing;
- Privilege the use of standard or recurrent equipment;
- Privilege the use of well-known and already proven technologies.

On the basis of the SST Team experience, the “best fit” of those drivers can be met by means of the following models:

- Ten Structure Prototype Models (1 telescope ASTRI HORN and 9 telescopes from ASTRI Mini-array) for validation of the TMS, OA, and TCS design;
- Engineering Models of the subsystems for functional and electrical validation at subsystems level;
- Qualification Models of the Optics for physical and performance validation;
- One Qualification Model of the Telescope to verify interfaces, functions and performance, and to verify the AIT/V process.
- 41 Telescope Final Models to compose, together with the qualification model, the entire foreseen array of 42 Telescopes on the CTAO south site;
- Subsystem Spares in order to provide AIT/V and maintenance activities.

4.2 Model Philosophy

Error! Not a valid bookmark self-reference. presents the preliminary Model Philosophy, to be consolidated during the next project phase.

This approach streamlines the SST's activities making maximum use of hardware already developed.

Table 4-1. SST Telescope Model Philosophy.

SST Telescope Matrix		Acronym	PRM	MAM	MM	EM	QM	FM	Spare
Telescope		TEL					1	41	TBD
Structure		STR	10				1	41	TBD
Mechanical Structure		TMS	10	1			1	41	TBD
	Mount	MOU	10				1	41	
	Optical Support Structure	OSS	10				1	41	
	Electrical System	ES	10				1	41	
	Telescope Protection System	TPS	10				1	41	
	Auxiliary Devices	AD	10				1	41	
	Telescope Local Control system	TLLS	10				1	41	
	Maintenance Tools	MT	10				1	41	
	Foundations	FO	10				1	41	
Optical Assembly		OA		1			1	41	TBD
	Primary Mirror	M1	180				18	738	
	Secondary Mirror	M2	10				1	41	
	Mirrors Local Control Software	MLCS	10				1 (TBC)	1* (TBC)	
	Mirrors Maintenance Tools	MT	2				1 (TBC)	3 (TBC)	
Telescope Control System		TCS							TBD
	Telescope Manager	*TM*	2				1	1	
	Engineering GUI	*EG*	2				1	1	
Cherenkov Camera (1)		CAM	1	1	1 (TBC)	1	1	41	TBD
	Camera Unit	*CU*							
	Camera Support System	*CSS*							
	Camera Control Software	*CCS*							
	Camera Maintenance Tools	*CMT*							

(1) Cherenkov Camera Model Philosophy is documented and described in [RD1]

With reference the matrix previously presented, the following models and terms are better detailed.

PRototype Model (PRM)

The SST Prototypes models have been used and they will be used for the verification of the main components of the telescope: Structure and Camera. They provided sufficient information (proof of concept/model correlation) to enable the progression of the project to the next representative models.

Mass Model (EM)

Mass Model of the Camera will be produced to support the structure AIT/V.

Mathematical Model (MAM)

The Mathematical Models will be representative of the Telescope and its subsystems. They will be used for qualification of the design (i.e., M1 Dish Optimization).

Engineering Model

Engineering Model of the Camera will be fully representative of the relevant functions. This model is indicated as ECAM in [RD1].

Qualification Model (QM)

The first telescope will be integrated on Factory and then on site in order to verify all the camera/structure interfaces and to qualify the AIT/AIV process. The camera will be the engineering model. The QM will also be used to validate the M1 Dish optimization. The first telescope will become part of the SST Consortium provision of 42 telescopes.

Final Model (FM)

The Final Models will be the nominal serialized products delivered to CTAO south site. After to be integrated and tested, they will be fully verified and calibrated and formally provided to CTAO.

Subsystems Spare (SS)

In order to operate a prompt recovery of unit malfunction, the SST Consortium will provide several spare parts that will be defined during the consolidation phase and reported in the maintenance documents.

5. Activity Development and Logic Flow

5.1 SST Master Schedule and Key Milestones

The SST Master Schedule is reported in [AD1]. Furthermore, Table **5-1** shows the key milestones and the main goals that have to be met to ensure the milestone achievement (more details in [AD1]). The key milestones dates have to be agreed on the basis of a consolidated schedule from CTAO, jointly agree the subsystems activities. The table reports internal and external milestones.

Table 5-1: SST key milestones (TBW)

Event		Type	Participants	Frequency	Date	Note
Pre-Bridging						
DVER	Design & Value Engineering Review	Review	CTAO, SST-PRO SST-STR & CAM	Once	July 2020	- Completed
Bridging Phase						

BKO	Bridging Phase Kick-Off	Kick-Off	CTAO, SST-PRO SST-STR & CAM	Once	July 2021	- Completed
PR	Product Review	Review	CTAO, SST-PRO SST-STR & CAM	Once	February 2023	
Design-Consolidation						
PKO	Programme Kick-Off	Kick-Off	CTAO, SST-PRO SST-STR & CAM	Once	July 2023	
IKCS	In-Kind Consortium (IKC) and SST Partnership Agreement Signing	Decision Point	CTAO, SST-ESC SST-PRO	Once	2023 (TBC)	
CDR	Critical Design Review	Review	CTAO, SST-PRO SST-STR & CAM	Once	January 2024	
PRR	Production Readiness Reviews	Review	CTAO, SST-PRO SST-STR, SST-CAM	Once	February 2024	- May be combined with CDR
TRR	Test Readiness Review	Review	CTAO, SST-PRO SST-STR, SST-CAM	Once (*delta* if procedures change)	May 2024	- Before the integration of the first telescope on Factory
DRB	Delivery Review Board	Review	CTAO, SST-PRO, SST-STR, SST-CAM Industrial Partners *(as applicable)*	Per batch shipped	August 2024	- the date refers to the first telescope shipped
On-Site AIV Phase						
O-TRR	Onsite Test Readiness Review	Review	CTAO, SST-PRO, SST-STR, SST-CAM Industrial Partners *(as applicable)*	Once (*delta* if procedures change)	December 2024 – April 2027	the date refers to the first and last telescopes + margin
ACRV	Provisional Acceptance Review	Review	CTAO, SST-PRO, SST-STR, SST-CAM Industrial Partners *(as applicable)*	Per batch verified	March 2025 – August 2027	the date refers to the first and last telescopes + margin

5.2 SST Development Phases

The Programme is divided into four phases as detailed in [AD1]:

- Bridging Phase -> Preliminary design
- Design Consolidation -> Consolidation of the Design
- Production -> Production and Implementation
- AIV -> On Site assembly, Integration and verification

Details of work to be completed in each Phase and timeframe are specified in the following sub-sections.

5.3 Bridging Phase Completion (closed by the Product Review)

The Programme starts with a Kick-Off once the SST Programme Plan is approved by SST-ESC. The Kick-off activates the Bridging Phase, during which the design of the ASTRI structure, CHEC camera and

Optics will be iterated with the support of all involved stakeholders to define a shared SST design, the reference for the IKC agreements.

The Bridging Phase goals include:

(a) the Level B requirements assessment with CTAO as well as the presentation of lower-level requirements from SST Consortium;

(b) the identification of interfaces both between SST Projects and to CTAO;

(c) closure of actions assigned at DVER in Bridging Phase ([RD2]).

Being the Bridging Phase in advance with respect to the IKC Agreement signing this phase is internal to the SST consortium with an active participation of CTAO. The Bridging Phase is planned to conclude early 2023.

5.4 Consolidation Phase (closed by the Production Readiness Review)

After the Product Review conclusion, the Design Consolidation Phase will start. During this phase there will be the final release of Level B requirements by CTAO and the assessment of lower level Requirements from the SST Consortium. The outcomes of this phase is the final SST design, optimised for simplicity, maintainability, and cost.

This phase also sees the production of plans and documentation for the Production and AIV Phase. It is expected that the Design Consolidation Phase will take approximately 2 years from the start of the Program and concludes upon passing the PRR (Production Readiness Review).

5.5 Production Phase

In the Production Phase the SST Structures, Cameras and Optics will be produced by the SST Partners and delivered to the CTA southern site over a period lasting approximately 2.5 years following the plans developed and approved in the Design Consolidation Phase. The Production Phase begins in anticipation of the first and second Camera and Structure. Telescope production will be authorised at the PRR. The Production Phase ends with the delivery of the final components to site.

5.6 AIV (closed by the Final Acceptance Review)

During the AIV Phase of the Programme, Structures and Cameras are received on site, installed, integrated, commissioned and handed over to CTAO following the plans developed and approved in the Design Consolidation Phase. The AIV Phase begins in anticipation of receipt of the first and second Camera and Structure with on-site preparation. Due to the large number of units, Telescope Production and AIV will run in parallel. AIV phase will end with the acceptance of the final SST by CTAO and the removal of any temporary equipment and personnel on-site.

6. Verification Approach

6.1 Verification Methods

For each requirement a suitable verification approach needs to be determined.
The verification shall be accomplished by one or more of the following:

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

All safety critical functions shall be verified by test.

The allocation of these methods is based upon design analyses, design maturity, complexity of the item, criticality category and associated cost. Analysis and Testing are the primary methods used to verify performance.

6.1.1 Tests

Test is a method of verification in which technical means, such as the use of special equipment, Telescope simulation, simulation techniques, and the application of established principles and procedures, are used for the evaluation of components or equipment to determine compliance with requirements.

Testing is selected as the prime method of requirements verification and shall be used when analytical techniques do not produce adequate results; failure modes exist which could compromise personnel safety, adversely affect flight systems or payload operation, or result in a loss of project objectives.

The analysis of data derived from tests is an integral part of the test program, and should not be confused with analysis as defined above.

6.1.2 Analysis

Verification by analysis is a process used in lieu of, or in addition to, other verification methods to verify compliance to specification requirements. The selected techniques may include, but not be limited to, engineering analysis, statistics and qualitative analysis, computer and hardware simulations, and analogue modelling.

Analysis may be used when it can be determined that:

- rigorous and accurate analysis is possible;
- test is not cost effective or not possible;
- verification by inspection is not adequate.

Verification by similarity is the process of analysing the specification criteria for hardware configuration and application for an article to determine if it is similar or identical in design, manufacturing process, and quality control to an existing article that has previously been qualified to equivalent or more stringent specification criteria. Special effort will be made to avoid duplication of previous tests from this or similar programs. If the previous application is considered to be similar, but not equal to or greater in severity, additional qualification tests shall concentrate on the areas of new or increased requirements.

6.1.3 Review-of-design

Review-of-design is verification method in which verification is achieved by validation of records or by evidence of validated design documents or when approved design reports, technical descriptions, engineering drawings unambiguously show the requirement is met.

6.1.4 Inspection

Inspection is a method of verification that determines conformance to requirements without the use of special laboratory equipment, procedures, test support items or services. Inspection uses standard quality control methods to verify compliance with requirements of construction features, document and drawing compliance, workmanship standards, and physical condition.

Emphasis is on observation of physical characteristics, possible degradation or defects rather than performance.

6.1.5 Demonstration

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

6.1.6 Certification

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

6.2 Test Matrix

The test matrix for each subsystem is shown in the next tables.

Table 6-1. Mechanical Structure Test Matrix (A = Analysis; T = Test; C = Certification)

TMS Test Matrix	PRM	MAM	QM	FM
Functional & Performance				
Reduced Functional Test	T		T	T
Full Functional Test	T		T	T
Reduced Performance Functional Test	T		T	T
Performance Functional Test	T		T	T
Physical Properties				
Mass	A/T		A/T	
Structural Test				
Vibration	A	A	TBD (1)	
EMC				
Conducted/Radiated			C	
Environmental				
Dust and sand	T		T	T
Flood	T		T	T
Others TBD				

(1)Eventual vibration tests for specific TMS subsystems will be defined during the consolidation phase

Table 6-2. Optical Assembly Test Matrix (A = Analysis; T = Test; C = Certification)

Optics Test Matrix	PRM	MAM	QM	FM
Physical Properties	X		X	X
Mass	A/T		A/T	A/T
Shape	T		T*	T*
Reflectivity	T		T*	T*
Structural Test				
Vibration		A		
Environmental				
ISO9022	T		T*	T*

Table 6-3. Telescope Test Matrix (A = Analysis; T = Test; C = Certification)

TMS Test Matrix	PRM	MAM	QM	FM
Functional & Performance				
Reduced Functional Test	T		T	T
Full Functional Test	T		T	T
Reduced Performance Functional Test	T		T	T
Performance Functional Test	T		T	T
Physical Properties				
Mass	A/T	A	A/T	
CoG		A	A	A
MoI		A	A	A

Structural Test				
Vibration	A	A	TBD (1)	
Thermal Test				
Thermal Cycling			T	
EMC				
Conducted/Radiated			T	
Environmental				
Rain, Snow, Ice and Hail	T		T	T
Dust and sand	T		T	T
Flood	T		T	T
Others TBD				

6.2.1 Functional and performance

A functional test is intended to check the health of a Telescope or subsystem and will be performed at the following times:

- Before and after any structural test
- Before and after thermal test
- Before, after and during any EMC test
- After and during any integration main step
- Any other times as deemed necessary by the AIT/V team

6.2.1.1 Full functional Test

It's a comprehensive test that demonstrates the integrity of all functions of the item under test, in all operational modes.

6.2.1.2 Reduced functional Test

For the SST Telescope, the idea is to minimize costs and time while respecting all the main standards to assure a well-proven product. Instead of doing a full functional test one or more short functional tests can be done. In these cases, an accurate reduced selection of tests is applied so that all verification sectors can be investigated. The aim still remains the correct qualification of the Telescope and its subsystems.

6.2.1.3 Performance Test

It's a comprehensive test that demonstrates the performance of the item under test, in all operational modes.

6.2.1.4 Reduced Performance Test

It's a short test that demonstrates the main performance of an item under test, in all operational modes.

6.2.2 Physical Properties

The physical test involves measuring the physical properties of equipment, including:

- Dimensions
- Mass
- Centre of gravity
- Moment of inertia
- Shape
- Reflectivity

6.2.3 Structural Tests

6.2.3.1 Vibration

The purpose of the vibration test is to demonstrate that the equipment can withstand the vibration environment encountered at the CTAO South Site. It will be performed by analysis using the mathematical models and/or or by test.

6.2.3.2 Thermal Test

6.2.3.2.1 Thermal Cycling

The purpose of temperature cycling tests is to demonstrate that the element is capable to withstand the thermal conditions encountered during the project phases remaining in the requirement limits.

6.2.4 EMC/EMI

EMC and EMI tests are performed to verify that the SST Telescope is compliant with the requirements.

6.2.5 Environmental

6.2.5.1 ISO9022

Environmental tests of optical items as specified by the standard ISO9022.

6.2.5.2 Dust and Sand

A test to verify the protection from dust and sand contamination.

6.2.5.3 Flood

A test to verify the protection of the product from flood.

7. AIT/V Tools

7.1 AIT/V TOOLS

7.1.1 Ground Support Equipment (GSE)

The Ground Support Equipment are a set of test equipment to be procured to support the SST Telescope AIT/V program.

7.1.2 Mechanical Ground Support Equipment (MGSE)

Mechanical Ground Support Equipment, to provide the mechanical supporting interface to the SST Telescope and its constituent parts during all its ground and testing operations. The MGSE set includes the following items (TBC):

- Mechanical tools to be utilized by the SST Team for the integration of the subsystems;
- Mechanical tools to be used during qualification tests;
- Mechanical tools to be used during calibrations, of the stand-alone subsystem or the integrated telescope;
- Transport Container of the subsystems.

Transport Container will protect the SST Telescope Units from outside environment during transportation and will monitor the transportation environment. The transport container will be composed by a base frame, carrying the transportation loads and supporting a damping subsystem interfacing to the SST Telescope subsystems.

7.1.3 Electrical Ground Support Equipment (EGSE)

Electrical Ground Support Equipment and Operational S/W will enable the practical demonstration of correct functioning of SST Telescope and its subsystems during its operations

7.1.4 Optical Ground Support Equipment

An OGSE is considered for verification of the mirror’s alignment. The OGSE to be considered is based on special actuators, optical camera and custom SW as described in [RD20].

7.1.5 Standard Laboratory Equipment

Standard Laboratory Equipment will be made also available to support the manufacturing, integration and test activities as required in the dedicate AIT/V program. They will consist of standard mechanical tools, calibration and measurement equipment (ohmmeter, voltmeter, oscilloscope, etc.), power supplies, Interface Test Boxes and test adapters for environmental testing.

7.2 AIV/T Facilities

AIV/T facilities breakdown is in Table 7-1 and reports the facilities/Site for testing.

- TMS: Factory TBD
- Optics: Factory TBD
- TCS: Institute TBD
- Camera: Institutes TBD
- Telescope AIV/T: Factory, CTAO South Site

Table 7-1. AIT/V Facilities

Item	AIT/V Facility
	TBD

7.2.1 Cleanliness and contamination control

An effective cleanliness and contamination control program for the most sensible telescope parts (Camera) will be implemented in order to prevent contaminant-induced degradation from exceeding permitted levels.

8. Verification Control Methodology and Documentation

8.1 General

The correct implementation of the verification program is monitored following a day by day verification control concept oriented to prevent potential problems and to reduce risks of schedule slippage.

The implemented verification control will make use of a Verification Control Document.

8.2 Documentation

This section provides the specific documents originated in addition to the Design and development plan to accomplish the system level AIV activities.

8.2.1 Test Procedure

The test procedures will have a standard content and will be written according to TBD.

8.2.2 Test Reports

The test reports will have a standard content and will be written according to TBD.

8.2.3 Verification Control Document

The Verification Control Document (VCD) centralizes all the information relevant to the verification status of the applicable requirements.

The Verification control document will have a standard content and will be written according to a TBD template. It contains the default data like requirement text, number, title and verification entries at the applicable level.

8.2.4 Other Documents

NCR, RFW, RFD and etc. will be prepared and treated, if any, according to the PA rules.

9. AIT/V Organization and management

This section describes the overall organization and management techniques for performing the SST Telescope assembly, integration and verification activities presented in this plan.

The main tasks to be performed are:

- Design and development plan preparation and control
- Verification Control Document preparation and control
- Integration/Test Procedures preparation
- Integration/Test activity execution
- Integration documentation preparation
- Test and Verification Reports preparation
- Control of analysis reports for verification purposes
- Monitoring of activities external to the SST Team for verification purposes

Furthermore, also the cost target has to be accomplished in the AIT/V philosophy.

9.1 Organization

The organization of the AIV/T activities and its relationship with the SST team organization is presented in this paragraph.

The following groups are involved in the overall verification process:

- INAF
- OBSPM
- Camera Team
- Industrial Contractors

9.1.1 AIV/T Team

Each SST Team institution is organized with a specific AIT/V team, which will provide a Program Verification Manager of the equipment to be developed, by means of dedicated personnel (System or AIV engineers), of the following tasks:

- Verification management
- Interface with the Teams involved in the verification activities
- Design and development plan preparation
- VCD preparation
- Preparation of detailed Integration & test planning and schedules
- Preparation of Integration and Test Procedures
- Design, preparation and utilization of integration and test tools (H/W & S/W)
- Procurement and maintenance of AIV tools
- Interface with Test Facilities
- Execution of Integration and Test activities
- Chairing of Test Readiness Review (TRR) and Post Test Review (PTR)
- Preparation of Test Reports
- Monitor Integration and Test execution and participation to Material Review Board (MRB)
- Chairing of Verification Control Board (VCB)

9.1.2 Quality Control

Each AIT/V Team will provide a Quality Manager which is in charge, by means of dedicated personnel and entities, of the following tasks:

- Participation to the review
- Participation and QC monitoring of Integration and Test execution and attendance to Daily Meetings
- Chairing of MRB
- Execution of Quality Control Inspection and preparation of relevant reports
- Certification of H/W, S/W and documentation
- Non-Conformances Report (NCR) preparation and management
- Review and approval of Integration/Test Procedures and VCD Documents

9.2 Management tools

The major management tools that are utilized for the control of the AIV/AIT activities are the follows.

9.2.1 Verification

The verification activities will be performed in the following main steps:

- establishing Verification Control Documents analysing the requirements of applicable Specifications
- engineering approval of VCD and verification activity planning

- verification control, monitoring of the XPOL activities, documents and reviews on the light of the applicable specifications

9.2.2 Verification Control Board (VCB)

The objective of the VCB is to review VCD, check its completeness, delete existing requirements duplication.

The VCB has also the purpose to evaluate the verification results on the basis of the information provided by the verification groups. The Verification Control Board decides upon the acceptance of a verification or on a further action necessary to close a verification requirement.

The Verification Control Board required members are:

- AIV Manager (chairman)
- Integration and Test Engineers
- Engineering disciplines representatives
- Project and/or Programme Quality Manager
- Configuration Control Responsible

9.2.3 Integration and testing

9.2.3.1 Incoming Inspection

Before starting the integration activities an incoming inspection shall be performed on each delivered item to check the quality of the H/W to be integrated. As a minimum the following checks are foreseen:

- completeness of H/W according to the shipping documentation visual inspection (no degradation has occurred)
- completeness of the data package
- conformity of identification markings and serial numbers
- cleanliness

9.2.3.2 Hardware Storage

All inspected H/W will be stored under controlled environment. Special storage conditions will be provided if necessary.

9.2.3.3 Mechanical /Electrical Integration

The integration will be performed according to fully signed and released Integration Procedure.

The handling and integration activities of the H/W in the various integration and testing facilities shall only be carried out by trained and briefed personnel having the necessary experience and using the dedicated tools (i.e. GSE).

9.2.3.4 Integration and Testing control

The Integration and Test activities will be followed and monitored by QC inspectors which will control:

- documentation and hardware / software availability
- NCR status
- Performance of each step-by-step operation and its certification
- Filling of the Integration Log-book
- Work Items / Deviation Work Items completion

In particular, will be adopted the meeting and review described in the following sub-sections.

9.2.3.5 Test Readiness Review (TRR), Preliminary Test Review (PTR) and Test Review Board (TRB)

A TRR shall be held before the start of the test activity to verify that all conditions allow to proceed with the test. The objectives of this review is declare the readiness for the test authorising the start of the test

A PTR shall be held in order to formally declare the test completed and allow the release of the item under test and test facility for further activity

A TRB shall be held to review all results and conclude on the test completeness and achievement of objectives.

The TRR, PTR and TRB are held by the Test Review Board in which the following members are required:

- AIV manager or his representative (chairman)
- Integration and Test Responsible
- System Engineer
- Quality Control Responsible
- Configuration Control Responsible

9.2.3.6 Material Review Board (MRB)

In case of major Non-Conformances during verification activities, a Non Conformance Report is written and processed to ensure correct actions and disposition through a MRB in line with PA project requirements.

9.2.3.7 Delivery Review Board (DRB)

At the end of the verification activities a DRB will be held to prove to CTAO that there is adequate documentary evidence to demonstrate that the product has satisfied all requirements.

The DRB will be composed by System Engineer, AIV Manager, Quality Control Responsible and CTAO representatives.

10. SST AIT/V Flow

In this section is presented a preliminary flow of the AIV/AIT activities of the SST Telescopes.

10.1 Structure AIT/V Flow

Refer to the documents [RD21] and [RD22].

10.2 Camera AIT/V Flow

Refer to document [RD1].

10.3 Telescope AIT/V Flow

10.3.1 Telescope Qualification Model AIT/V flow

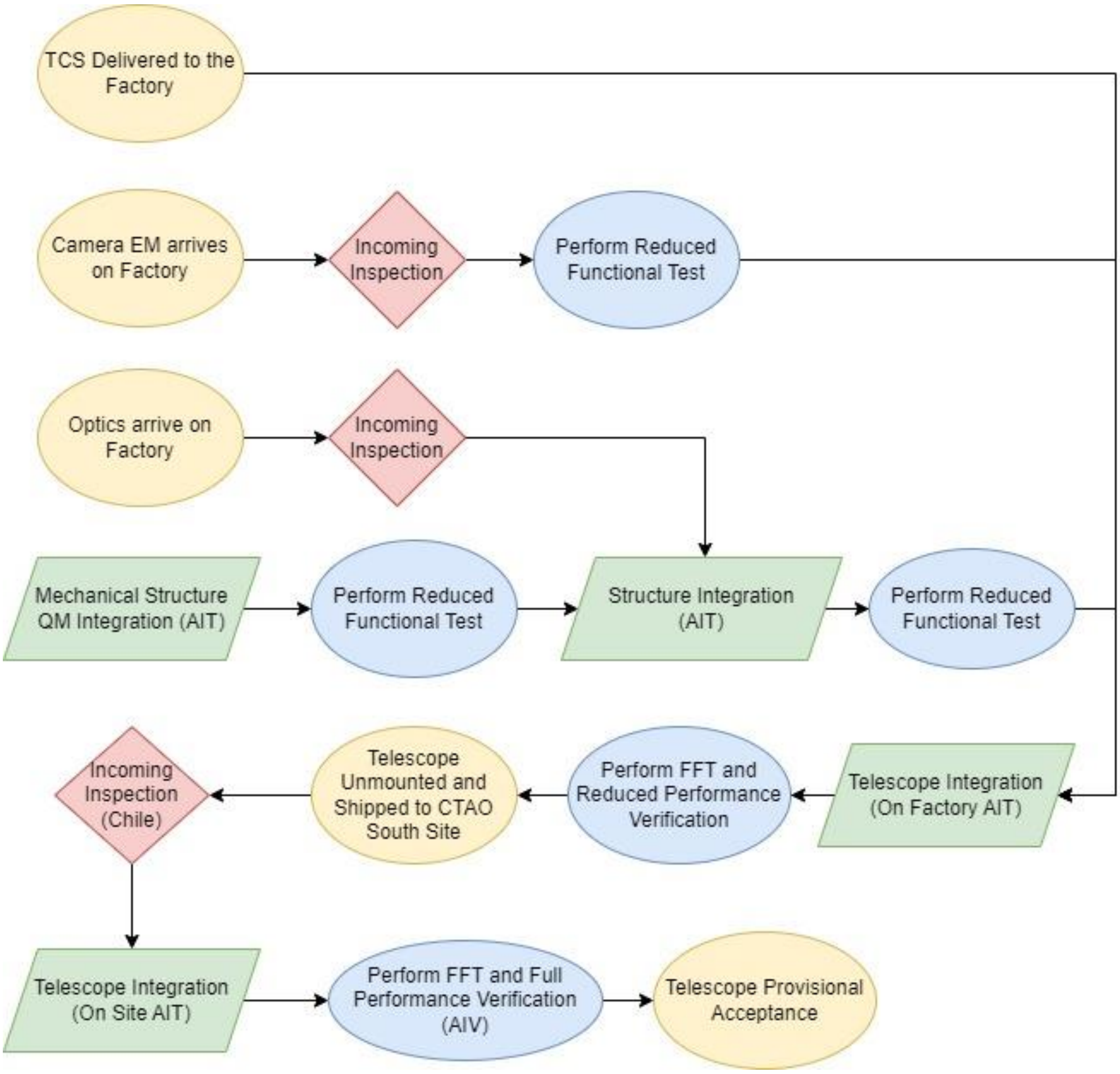

Figure 10-1: Telescope Qualification AIT/V flow

Figure 10-1 describes the work flow foreseen for the first SST telescope called qualification model. As described in the previous sections, we intend to validate the I/Fs, to validate the M1 dish optimizations and the entire AIT/V process including calibration activities.

This process will be performed integrating the first telescope first on factory and then on site.

The first camera (EM), the optics and the TCS will be provided to the industrial contractor responsible for the Mechanical Structure provision, in order to be integrated to compose the telescope.

The telescope will be fully tested and the performance partially verified on factory. Based on the readiness of the test results, the telescope will be unmounted, shipped to CTAO south site and then integrated and fully tested and verified prior to being formally delivered to CTAO. The process is more detailed in [RD21], [RD22] and [RD23].

10.3.2 Telescope Final Models AIT/V flow

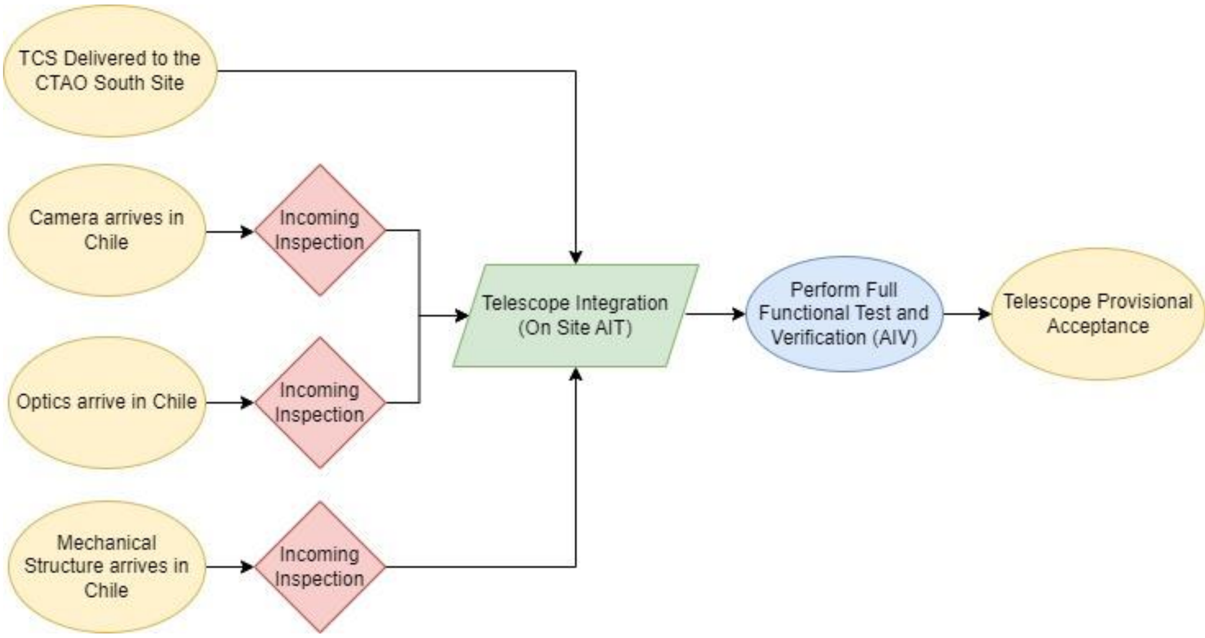

Figure 10-2: Nominal Serialized Product AIT/V flow

Figure 10-2 describes the work flow foreseen for the 41 SST telescopes called Final Models. As described in the previous sections, after the qualification of the first model, the production of 41 telescopes subsystems will start.

The subsystems will be delivered to the CTAO south Site and then, after an incoming inspection, will be integrated [RD22]. After the integration, the telescope will be fully tested and verified as described in [RD23].

End of the document