Small Sized Telescopes (SST) to Foundation at CTAO-South ICD

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	First/Last Name, Organisation, Role	Digital signature
Prepared by (1)	Amaya Paredes CTAO Telescope Engineer	Amaya Paredes Digitally signed by Amaya Paredes Date: 2023.07.03 13:24:17 +02'00'
Prepared by (2)	Stefano.Stanghellini CTAO Telescope Coordinator	Digitally signed by Stefano Stanghellini Date: 2023.07.03 13:30:10 +02'00'
Prepared by (3)	David Bristow Site & Infrastructure Coordinator	David Bristow Digitally signed by David Bristow Date: 2023.07.03 16:03:15 +02'00'
Prepared by (4)	Chiara Montanari CTAO Interface Manager	Chiara Montanari Digitally signed by Chiara Montanari Date: 2023.07.03 16:42:15 +02'00'
Approved by (1)	Alessio Trois Small Sized Telescope Project Manager	TROIS ALESSIO 03.07.2023 19:11:29 GMT+01:00
Approved by (2)	Nick Whyborn CTAO Lead Systems Engineer	Nick Whyborn 2023.07.04 09:41:41 +02'00'
Released by	Wolfgang Wild CTAO Project Manager	Wolfgang Wild Digitally signed by Wolfgang Wild Date: 2023.07.04 12:18:09 +02'00'

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Issue	**Rev.**	**Created**	**Reasons / Remarks / Section**	**Author**
draft 01 – draft 06b		2023-02-24	CTAO internal drafts	S.Stanghellini, A.Paredes
draft 06	c	2023-03-01	First draft shared with SST team	
draft 06	e	2023-04-11	SST Comments included (note that version d was never issued)	SST + EIE Team (Jean-Laurent Dournaux, Salvo Scueri
draft 07	a	2023-05-16	Implementation of changes agreed in joint meeting (CTAO+SST+EIE) held on 3rd May 2023. Various requirements rephrased to improve their definition and understanding. In addition: -Figure 3 added -Environmental conditions (SST-MEC-0101) and lifetime requirements (SST-MEC-0110) added - Introduction of new sketch with ducts positioning in the concrete. Bending radii introduced Added figure related to the depth of the cables arriving at the foundation. -Minimum distance (TBC) between the chiller and the telescope added. -Loads tables (template) added. -Rephasing of responsibilities and deliverables chapter - Alignment + Grouting details moved to appendix	S.Stanghellini, A.Paredes
Draft 08	a	2023-06-29	Final rework. Eliminated template from ICD, as being part of foundation design Added humidity in the environmental requirements Need of verification of maximum residual tilt after an NCR event Adherence to LPS standard Modification of scope of supply Ducts Diameter 120 mm The ducts shall extend horizontally outside the foundation minimum 1.5m.	S. Stanghellini, A.Paredes, V. Heinz
Issue 1	a	2023-07-03	Typos correction in page 10. AD1 & AD2: revision 01 added. Requirement for the chiller earthing added (chapter 5.4.1). Title slightly changed. A new digit at the beginning of the requirements' numbering has been added (one zero). Last sentence of first paragraph 1.1 has been moved to 1.2 (scope).	A.Paredes

Authors	
First/Last Name, Organisation	**Contribution Subject/Chapter**
Amaya Paredes, CTAO	All
Stefano Stanghellini CTAO	All
SST Team	All

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1 Purpose and Scope

1.1 Purpose

This document establishes the requirements and the detailed specification for the interface between the Small-Sized Telescope (SST) and the telescope foundation at the CTAO-South site.

This document is applicable to all SST telescopes installed at the CTAO-South, irrespective of their position in the site.

1.2 Scope

The scope of this Interface Control Document (ICD) is to define the interface between the Small-Sized Telescope (SST) and the CTAO-South foundation. This includes the mechanical interface and, where applicable, interfaces elements linked to electric power and signals, which are provided to the SST via the foundation.

This is a Mechanical Interface Design, as described into the Interface General Definition Document [RD-1], and it covers the following Interface subcategories:

- General Layout, including spatial coordinates, mounting characteristics, etc.
- Mechanical interface design, stiffness and interface loads.
- Earthing requirements to achieve equipotential bonding.
- Routing through the foundation of communication power distribution to the SST
- Routing through the foundation of the cooling pipes between SST and the Chiller.

This document does not cover:

- The absolute position of the telescope´s foundations in the CTAO-South site, in latitude, longitude, and elevation. Coordinates of the SST´s foundations at the site are not part of this document.
- The electrical aspects related to the interface between the Telescope and the Power Distribution system, which are covered by a separate ICD.
- The communication aspects associated to the fibers provided to the telescope, which are covered by a separate ICD.

1.3 Conventions

This document contains two types of items: Requirements and Information.

- Requirements have to be verified by the individual party supplying the interface elements while information items do not.
- Requirements are identified with a requirement tag following the provisional format SST-MEC-NNNN where NNNN is a unique, non-speaking number. The NNNN identifier does not need to be sequential or continuous.
- Verification method(s) is (are) associated to each requirement, namely: A: Analysis, C: Certification, D: Demonstration, R: review of Design, I: inspection, T: Test.

- Information, which is not identified with a tag: this information, which is fully binding to this document, refers usually to context, conditions or definitions that must be taken into consideration for all or for specific requirements.

2 Applicable and reference documents

2.1 Applicable documents

These are integral part of the document. They are applicable in case of a Specification or a Statement of Work. Do not add AD's in technical reports (only RD's).

AD-1	SST Foundation interface with Telescope Structure – Mechanical Interface; Rev 1. CTA-DWG-TEL-405000-0001
AD-2	SST Foundation interface with Telescope Structure – Ducting and Chiller Location; Rev1. CTA-DWG-TEL-405000-0002
AD-3	Telescope Grounding and LEMP protection CTA-SPE-TEL-000000-0002_01c

2.2 Reference documents

These are documents aimed for general guidance only and need not to be applied.

RD-1	Interface General Definition Document (IGDD) CTA-STD-SEI-00000-0002 (to be released)

3 Abbreviation and Acronyms

Abbreviations	
AD-X	Applicable Document No. X
CAD	Computer Aided Design
CTAO	Cherenkov Telescope Array Observatory
CTAO-S	Cherenkov Telescope Array South
DIN	Deustche Industrie Norm
DWGXX	Applicable Drawing No. XX
ESO	European Southern Observatory
ICD	Interface Control Document
I/F	Interface
RD-Y	Referenced Document No. Y
SST	Small-Sized Telescope
TBC	To be confirmed at a later date, during the design of the foundation
TBD	To be determined
w.r.t	with respect to

4 Interface Context and Description

4.1 Interface Description

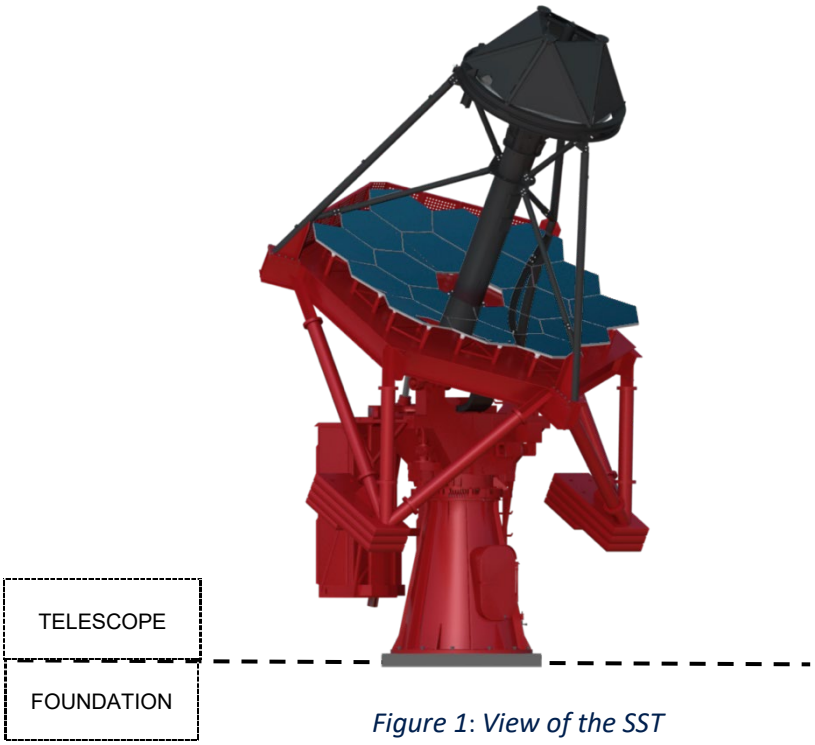


Figure 1: View of the SST

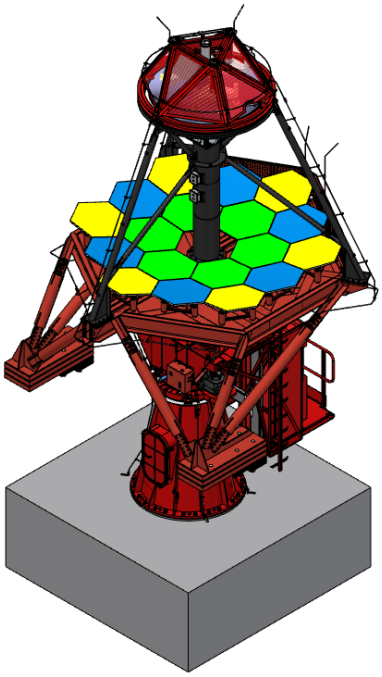


Figure 2: View of the SST with its foundation (indicative design)

The telescope foundation is the interface between the telescope structure and the surrounding soil. The role of the telescope foundation is to transfer the load of the telescope to the soil, and to ensure the stability of the telescope against overturning during operational conditions and extreme environmental conditions (wind, ice load, seismic activities). It provides also grounding and cable routing from the outside distribution to inside of the tower and cables and cooling routing between the tower and the chiller positioned outside the concrete slab.

The foundation of the SST telescope consists of:

- A reinforced concrete slab whose final shape and dimensions have to be determined by the foundation designer.
- The anchor assembly embedded in the concrete, used to bolt the base of the SST telescope. The anchor assembly will result in 24 M30 rods protruding from the top of the foundation on a specified diameter. The design of the anchor assembly with the protruding rods is not object of this ICD and it will be designed by the foundation designer.

A descriptive view of the pattern of the anchor rods protruding from the visible in the figure below.

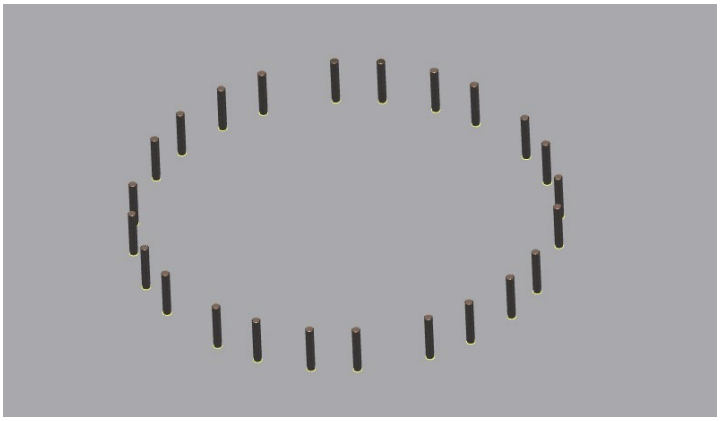


Figure 3: Interface: M30 anchor rods, protruding about 200 mm from the top of the concrete

- An earthing grid will be present outside of the foundation, where to connect the earthing system of the foundation necessary for grounding.
- For mounting the telescope, a layer of anti-shrinkage grout will be poured between the telescope base plate and the top layer of the foundation, after setting the telescope onto it. A baseline procedure is provided in Appendix.
- The chiller for the camera will be positioned on a separate cast support in proximity of the telescope foundation slab, in the North-East.
- All electrical and data cables, as well as the cooling pipes are guided through the foundation into the bottom of the telescope structure base using cable ducts.

5 Interface Requirements

5.1 General Interface Requirements

5.1.1 Environmental Conditions

SST-MEC-0101 **Environmental Conditions** **R**

The interface shall be compatible with the environmental conditions applicable to the CTAO-South Site, located at app. 2200m asl +/-100m.

- Air temperature range: -15 to 35 °C
- Air temperature gradient 0.5 °C/min (over 20 min)
- Rain precipitation: max 40mm/h, max 60mm/24h, 100mm/ yr
- Humidity: 2% to 100% (typically < 10%)
- Snow 25kg/m^2 (from Chilean Norm NCh 431)
- Solar radiation up to 1200 W/m^2

5.1.2 Lifetime

SST-MEC-0110 **Lifetime** **R**

The foundation including the parts interfacing the SST shall have a lifetime of 30 years, under consideration of the operational loads and of the environmental conditions.

5.1.3 Foundation System of Coordinates

SST-MEC-0201 **System of Coordinates** **R**

The system of coordinates to be used is a Cartesian system, based on the right-hand rule, as shown in Figure 4, with

- the Z_a corresponding to the local vertical, coordinate increasing with height (opposed to local gravity).
- Y_a axis pointing to the geographical North.
- X_a axis pointing to the geographical East.

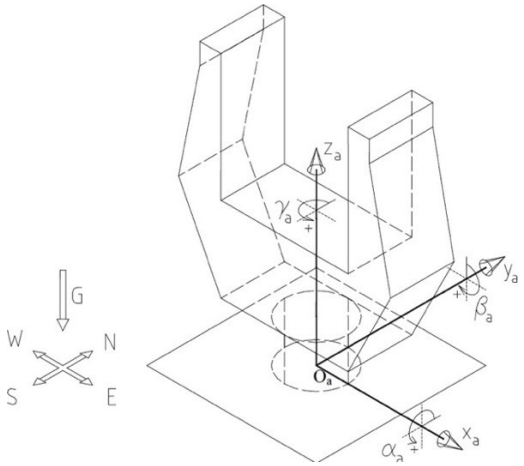


Figure 4: System of coordinate

SST-MEC-0202 **Origin of the system of coordinates** **R**

For the sake of this document the origin of the system is in the top plane of the foundation before the grouting. Hence X=0, Y=0 and Z=0 are at the center of the foundation, at the top surface.

5.2 Mechanical Interface Design

5.2.1 Mechanical interface to telescope structure

SST-MEC-0301 **Base anchor design** **R**

- The mechanical interface between the structure base and the foundation shall be realized by means of 24 vertical anchor rods M30 embedded in the foundation. The length and the fixation of the embedded rods will be defined by the foundation designer, while defining the embedded anchor assembly.
- The rods shall be made of a suitable steel grade compatible with the applied loads herein defined.
- The rods shall protrude from the finished foundation not less than 200mm.

SST-MEC-0302 **Base anchor rods protection** **I**

The protruding part of the anchor rods extending above the Interface plane of the foundation shall be protected against dirt and concrete using proper plastic pipes covers in order to have a clean interface before assembling the SST base.

SST-MEC-0303 **Anchor rods positioning** **R, I**

The positioning diameter of the rods and the positioning pattern of the rods and the associated tolerances shall be according to [AD-1].

SST-MEC-0304 **Base anchor preload** **R, A**

Each M30 anchor rod shall be able to accept a preload of 200 (-20 +0) kN. The strength of the rod shall be such that the preload does not exceed 90% of the yield strength of threaded rod.

5.2.2 Positioning tolerances

SST-MEC-0305 **Tower anchor rods alignment towards the north/south axis** **R, I**

The anchor rods shall be aligned towards the north/south axis (Y axis) with an accuracy lower than +/- 0.25 deg as shown in [AD-1]

SST-MEC-0306 **Vertical alignment of the anchor rods** **R, I**

Each anchor rod shall be vertically aligned with an accuracy better than 1.0 mm/m, with respect to the local gravity vector, as shown in [AD-1].

5.2.3 Telescope structure Foundation Stiffness

SST-MEC-0307 **Foundation stiffness** **A**

The minimum global stiffness, which the foundation shall exhibit is:

- Vertical stiffness (Z) > 6.3×10^8 N/m
- In X/Y plane > 3.7×10^8 N/m
- Tilting stiffness: 8.8×10^8 Nm/rad

This stiffness shall include the effect of the embedded rods, the concrete slab and the soil. The assumed soil modulus of subgrade reaction shall be 50 MN/m^3.

5.2.4 Load Capability

SST-MEC-0308 **Maximum load capability** **A**

During the 30 years of operational life of the SST, the telescope foundation will experience the following maximum loads [RD02]

a) Loads during observation at any angular Azimuth or any Elevation

	Shear [kN] $(Fx^2+Fy^2)^{0,5}$	**Vertical [kN]** *Fz*	**Maximum Tilting moment (kNm)** $(Mx^2+My^2)^{0,5}$	**Torsion [kNm]** *Mz*
Self-weight	**/**	**- 169**	**25**	**/**
Wind *(36km/hr)*	**1**	**0**	**3**	**0**
NCR Earthquake *(max of all orientations)*	**257**	**115**	**781**	**145**

b) Loads in parking position (Az North, Elevation 0 deg)

	Shear [kN]		**Vertical [kN]**	**Tilting moments [kNm]**		**Torsion [kNm]**
	Fx	*Fy*	*Fz*	*Mx*	*My*	*Mz*
Self-weight	0	0	- 169	-25	**0**	0
Wind (50 km/hr)	0	-2	0	6	0	0
Wind (survival 140 km/hr)	0	-15	0	44	0	0
Snow/Ice	0	0	-19	16	0	0
NCR Earthquake	126	232	138	784	475	245

C) Local load at rods

For the verification of the rods the resultant maximum force acting on any of the 24 anchor rods is the following *(computed as the maximum of the survival load cases combinations)*

M30 Rod force [kN]	Self-weight	Wind (140 km/h)	Snow /Ice	NCR Earthquake	Preload
Maximum horizontal shear $(Fx^2+Fy^2)^{0,5}$	3.0	1.8	0.7	33.0	0
Maximum Pull (+Fz)	0	5.3	1.0	108	200
Maximum compression (- Fz)	11.8	5.0	2.9	108	0

SST-MEC-0309 **Residual tilt under load** **A**

Under application of the above loads, and the initial settlement, the foundation shall behave in a perfect elastic mode, which means that no permanent residual alignment error shall be generated by the loads, except in the case of the NCR earthquake.
For this case the residual tilt of the Z axis (settlement) shall not exceed 2 arcmin (TBC).

5.2.5 Chiller Positioning Requirements

SST-MEC-0310 **Mounting of the camera chiller** **R**

The chiller shall be positioned on top of a small pre-cast, or cast-in-place, concrete slab, in proximity of the telescope structure foundation, in **the North-East direction.**
The cooling chiller is to be fixed to the foundation with anchor bolts or dowels inserted into holes drilled in the concrete during the installation.

SST-MEC-0311 **Dimension of the chiller slab** **I**

The chiller slab shall extend at least 10 cm around the base of the chiller. For the sake of the design the chiller slab dimension shall be assumed to be 1.5m X 1m (TBC), unless more precise data are available.

SST-MEC-0312 **Minimum distance of the chiller from structure of telescope** **I**

The minimum distance between the center of the telescope foundation and the center of the slab supporting the chiller shall be d $\geq$ 5000 (TBC), and the clearance of the chiller to any part of the telescope shall be at least 1000mm **.**

5.3 Routing of cable and fluids ducts

5.3.1 General functional interface requirements

SST-MEC-0401 **Cable and Fluids ducts inside the structure base foundation** **R, I**

a) Two (2) separate ducts shall be routed inside the foundations, on each side along the +Y and -Y, (North – South, total 4) from the outside to the centre. Depending on the site of the arrival of the incoming lines either the North or the South ducts will be used. Power and data lines shall be routed in separate ducts to avoid EMC influence on the signal cables.

b) Additionally, two ducts shall be routed between the centre of the foundation and the chiller location one for the fluids, and one for power, and communication to the Chiller as per AD-2.

The sketch below shows the indicative position and routing of the cable ducts inside the concrete.

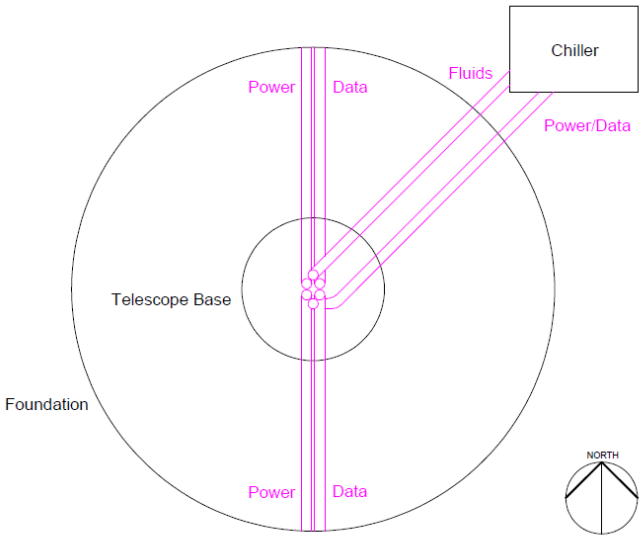


Figure 5: Indicative Routing of the cable ducts inside the concrete

SST-MEC-0402 **Diameter of ducts** **R,I**

Diameter of ducts reaching the telescope base shall be min 120 mm for power and for communication fibers**.** Diameter of the ducts between the telescope base to the chiller shall be at least 120 mm for the power & signal duct and 120 mm for the fluids duct.

SST-MEC-0403 **Bending radius and routing** **R,I**

a) The routing of the cable ducts inside the telescope structure foundation shall be such that the cables can enter the telescope base in proximity of the centre and oriented vertically.

b) The power and communication cable ducts shall have angles with min 600mm curvature radius, to allow the pulling of pipes and cables during the installation.

c) The ducts used for the cooling hoses, communication and power between the telescope and the chiller shall have a minimum curvature radius of min 400mm.

d) The cable ducts in excess of the foundation at the telescope structure base shall extend at least 50 cm above the top surface of the concrete layer. (The excess will be cut during the installation of the telescope).

e) The ducts shall be routed from the outside of the foundation with an inclination which will prevent the flooding of the ducts in presence of water.

f) The ducts shall extend outside the external face of the foundation of at least 1.5m.

g) For the detail design of the cable duct the typical burial dept and arrangement of the power and communication cables routed to each foundation shall be considered as provided in the figure below:

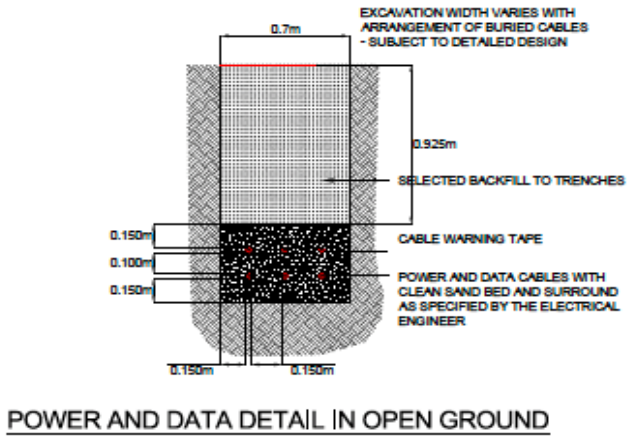


Figure 6: Layout of cables in open ground

5.4 Earthing Requirements

5.4.1 Earthing

SST-MEC-0501 **Earthing of the telescope** **R,I**

The grounding of the telescope shall be obtained by means of the embedded anchor rods and their connection to the earthing system within the foundation.

SST-MEC-0502 **Earthing of the chiller** **R,I**

There shall be means of connecting the casing of the chiller to the earthing grid.

SST-MEC-0503 **Adherence to Standards** **R**

The earthing system within the foundation shall comply with AD-3.

SST-MEC-0504 **Connection to the earthing grid** **R, I**

The earthing connections on the foundation shall be connected to the global earthing grid. The earthing system is used also as ground termination of the telescope integrated lightening protection system.

6 Responsibilities and deliverables

6.1 Scope of supply by SST

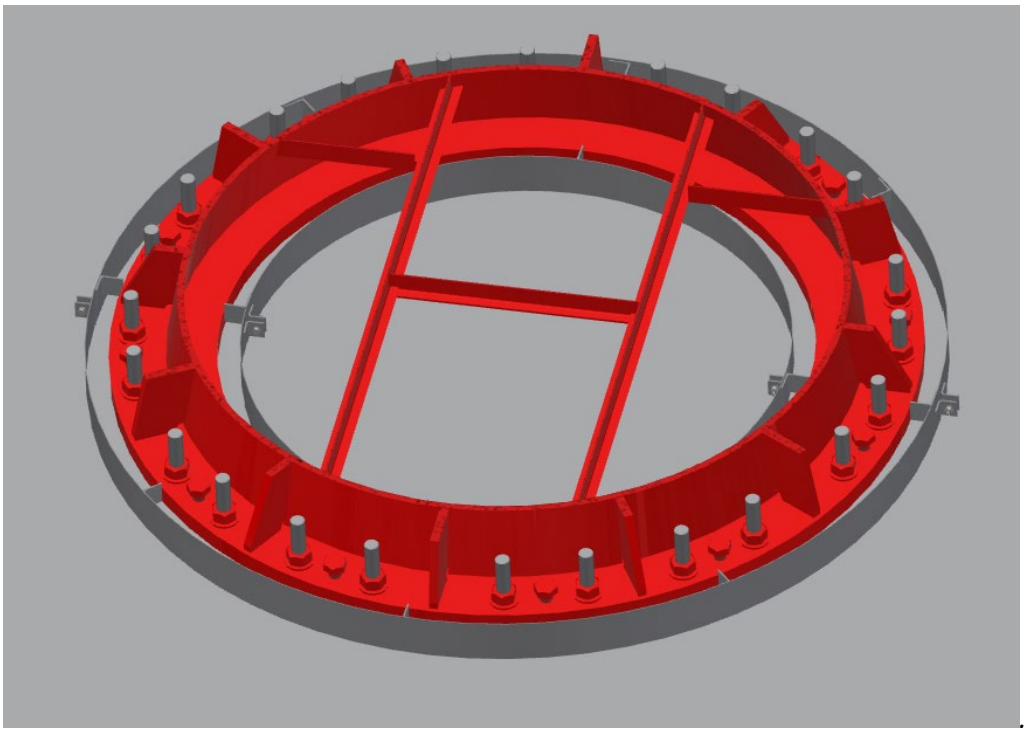
- Develop the procedure for mounting the telescope. This includes the design of the jigs for grouting, the selection of the type of shrinking grout and any associate tools. A typical procedure is provided in Appendix 1 to this document.
- Procure the parts needed for performing the mounting of the telescope, including the non-shrinking grout.
- Perform the mounting of the telescope including the prestressing of the bolts according to the design.
- Deploy inside the cable duct(s), embedded in the concrete, the fluids, communication and power between the camera chiller cabinet and the base.

6.2 Scope of supply by CTAO

- Design of the SST foundation. The design shall be compliant with the foundation requirements of this ICD, also considering the geotechnical characteristics of the site. Compliance with loads and stiffness requirements shall be demonstrated by detailed computations and analysis.
- Manufacture the elements of the embedded anchor (rods and/or any additional mechanical element according to the approved design).
- Construction of the foundation according to the approved design, including earthing and all other provisions foreseen in the design. For achieving the positioning of the rods according to the specified tolerances a specific procedure will be developed and used. The alignment procedure may be based on the use of a special jig and/or a template.
- Provide and embed all ducts as herein specified in the foundation, according to the foundation design.
- Prepare the earthing system and connect to the foundation earthing.
- Measure and certify the earthing resistance at the interface elements of the foundations to comply with standards and requirements.
- Route the cables and communication fibers to the telescope inside the foundation center.

Appendix 1: Typical grouting procedure for mounting the telescope

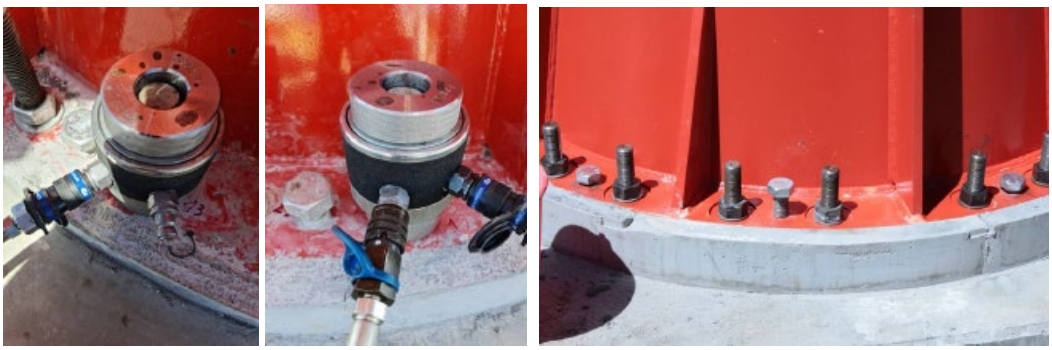
- After the SST base is installed and levelled, a layer of anti-shrinkage grout is used to level the telescope. Baseline products used for this grouting operation are: BASF MasterFlow 928, SIKA SikaGrout-212 or 213 or equivalent.
- Grout is poured between the telescope base and the top layer of the foundation after having positioned an internal and external removable metal formworks to contain the grout until it is cured.
- Details of the anti-shrinkage mortar assembly are provided in the following figures.



Section view of the telescope base with the grouting formwork positioned in place

Grouting the Mechanical foundation interface

After the grout has cured sufficiently, the anchor bolts are preloaded to the design preload, by means of a hydraulic cylinder.



Anchor preloading