ASTRI Mini-Array
Infrastructure Design Description

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DOCUMENT HISTORY		
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1.0	02/07/2021	First release

1 Introduction

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

The ASTRI mini array will be operated directly by INAF, with support from IAC for the common infrastructure and common services.

1.1 Purpose

This is the ASTRI Mini-Array infrastructure design description document.

1.2 Scope

The document gives a general description of the ASTRI Mini-Array site infrastructure. The detailed description of the different elements is given in dedicated documents.

1.3 Content

Sections 3 and 4 are introductory as they give general information and a description of the general layout of the site infrastructure and of the driver that led to it.

Sections 5 to 10 describe the main elements of the infrastructure.

1.4 Definitions and Conventions

1.4.1 Abbreviations and acronyms

ASTRI	Astrofisica con Specchi a Tecnologia Replicante Italiana
BTU	British Thermal Unit
CCTV	Close Circuit TV
FGG	Fundación Galileo Galilei
IAC	Instituto de Astrofisica de Canarias
IACT	Imaging Atmospheric (or Air) Cherenkov Telescope or Technique
ICT	Information and Communication Technology
INAF	Istituto Nazionale di Astrofisica
I/O	Input/Output
LIDAR	Laser Imaging Detection and Ranging
OT	Observatorio del Teide
PLC	Programmable Logic Controller
PoE	Power over Ethernet
SiPM	Silicon Photo-Multiplier
UPS	Uninterruptible Power Supply

2 Applicable and reference documents

2.1 Applicable Documents

[AD1] ASTRI-INAF-SPE-1000-001 (i1.3) ASTRI Mini-Array Operation Concept

[AD2] ASTRI-INAF-DES-2000-001 (i1.8) ASTRI Mini-Array Product Breakdown Structure

[AD3] ASTRI-INAF-REP-1000-001 (i1.3) ASTRI Mini-Array Layout Proposal to IAC

[AD4] ASTRI-INAF-REP-1000-002 (i1.1) ASTRI Mini-Array Report to SUCOSIP Committee

[AD5] ASTRI-INAF-DES-8100-001 (draft) ASTRI Mini-Array On-Site ICT Hardware Architecture, to be released

[AD6] ASTRI-JJSG-DES-5100-001 (i1.0) Estudio geotecnico, to be released

[AD7] ASTRI-JJSG-DES-5100-002 (i1.0) Calculo de la cimentacion, to be released

[AD8] ASTRI-JJSG-DES-5100-003 (i1.0) Proyecto de Baja Tension, to be released

[AD9] ASTRI-JJSG-DWG-5100-001 (i1.0) Planos, to be released

[AD10] ASTRI-INAF-DES-5600-001 (i1.1) Service Cabinet Concept Design

2.2 Reference Documents

[RD1] ASTRI Mini-Array Core Science at the Observatorio del Teide, to be submitted to JHEAp

3 Introduction

The site of the ASTRI Mini-Array is located in Izaña, in the Canary island of Tenerife (Spain) in the area of the "Observatorio del Teide" (OT) at an altitude of 2390 m above sea level, a latitude of 28°18'04" N, and a longitude of 16°30'38" W (www.iac.es/en/observatorios-de-canarias/teide-observatory). Figure 1 shows the island of Tenerife and the position of the Teide Observatory.

Figure 1. The island of Tenerife and the position of the Teide Observatory (Image from Google Maps).

The area reserved to the Teide observatory is about 50 hectares in extent. The ASTRI Mini-Array area where the telescopes will be installed will cover a rectangular strip of approximately 650 meters in length and 270 meters in width corresponding to a surface of about 17 hectares.

Apart from the location that hosts the telescopes array and its support facilities the ASTRI Mini-Array will be distributed among other locations, in particular:

- The ASTRI Mini Array Support Site will be located at IAC premises in San Cristobal de La Laguna in Tenerife, hosting the remote control room, and warehouse spaces.

- The administrative services will be hosted by FGG in Breña Baja in the island of La Palma.
- Italy will host the off-site data centre in Rome and eventually remote control rooms

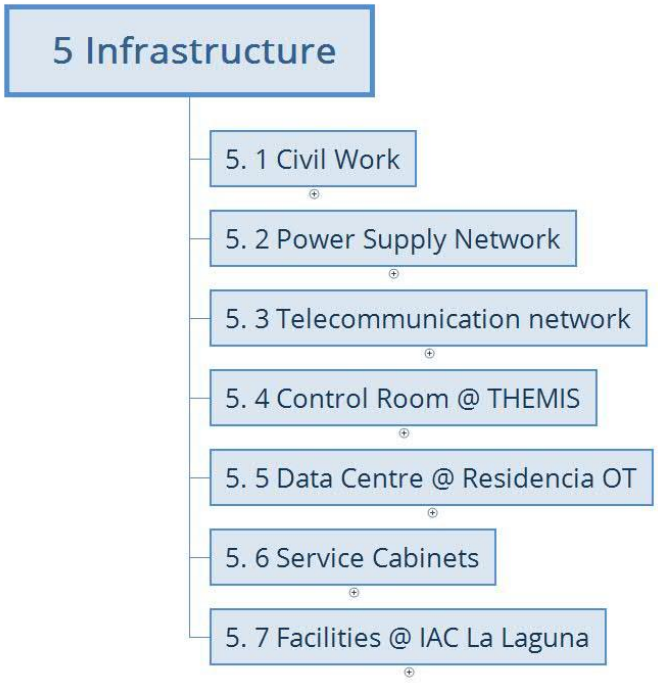

Figure 2. Product Breakdown Structure of the ASTRI Mini-Array on-site infrastructure.

Figure 2 shows the product breakdown structure of the on-site infrastructure of the ASTRI Mini-Array. This document will describe only the elements present at the site so items 5.1 to 5.6.

4 The layout of the site

With its nine telescopes the ASTRI Mini-Array will have a sensitivity better than existing facilities already at 10 TeV in the northern hemisphere and at 15 TeV in the case of the southern ones [RD1].

The number of the telescopes of the ASTRI Mini-Array resulted from a compromise between availability of funds and scientific capabilities.

4.1 Drivers to the site layout

The layout of the ASTRI mini-array has been designed starting from the following drivers:

1. Scientific requirements: position of telescopes
2. Infrastructures present at the site
3. Respect for the natural landscape.
4. Safety during activities.

4.1.1 Position of telescopes

The distance among telescopes and eventually their position is the product of Monte Carlo simulations. These simulations show that, assuming a symmetric layout, a distance among telescopes of about 250 meters yields the better compromise between a very good performance at high energies (>10 TeV) and a good sensitivity at lower ones [RD1]. Reducing the distance among telescopes implies a reduced sensitivity to high energies that is the strength of the Mini-Array. On the other hand, increasing it too much yields an energy threshold too high.

Then, the position of the telescopes has been chosen as a compromise between the necessity to preserve this distance as much as possible and the area available for placing the telescopes.

4.1.2 Infrastructures already available

The second driver had the purpose to take advantage of infrastructures (road, trenches, buildings, etc) already available at the site to minimize construction work, cost and environmental impact.

4.1.3 Respect for the natural landscape

The ASTRI Mini-Array telescopes will be placed in an area named "Forest Crown", near the national park "Las Cañadas del Teide". The area is of outstanding importance in natural landscape and vegetation. All efforts will be devoted to minimizing the impact on the environment both in the construction and in the operation of the telescopes.

4.1.4 Safety of operations

Finally, the last point affects mainly the design of the area around a telescope whose size shall allow to perform maintenance activities in safe conditions.

4.2 Description of the site layout

The following systems will form the ASTRI Mini-Array at the observational site:

1. 9 telescopes each placed in a dedicated area.
2. A control room hosted at Themis observatory building.
3. A data centre hosted at the OT Residencia building.
4. A LIDAR placed in a dome made available by IAC.

5. Two meteorological towers (nearby ASTRI-6 and ASTRI-2).
6. Access roads to telescopes.
7. Trenches, cable ducts, cable pits for power, data, timing and safety and security networks including electrical cables and optical fibres.
8. Medium to low voltage transformer station with UPS and diesel generator for power backup placed between the THEMIS building and ASTRI-3.
9. Illuminator: a device to calibrate the telescopes but that will not be permanently mounted at the site. The position(s) of the device is under definition as should allow the view of all of the telescopes.

The current layout of the ASTRI mini-array telescopes at the Teide Observatory is shown in Figure 3. The geographical coordinates of telescopes of the ASTRI Mini-Array are listed in Table 1.

Figure 3: ASTRI Mini-Array general Layout The figure shows the final positions for the 9 telescopes, the roads to access each of them, the position of the two meteorological towers, the current position of the LIDAR, and that of the local control room (@THEMIS) and of the data centre (@Residencia). (Image obtained with Open Street Map editor)

Figure 4 shows the dome where the LIDAR instrument will be installed. The dome is in the area among Carlos Sanchez, MONS and Groundbird telescopes. The closest telescope will be ASTRI-9 that will be installed just below the STELLA facility.

Figure 5 shows the position of the two weather stations placed closed to ASTRI-6 telescope, on the top part of the array and close to the ridge of the mountain, and to ASTRI-2 on the bottom part of the telescopes array.

Table 1. ASTRI Mini-Array Telescopes geographical coordinates

Telescope	Latitude N	Longitude W	Altitude(m)
ASTRI-1	28°18´03.69"	16°30´28.69"	2359.00
ASTRI-2	28°18´02.43"	16°30´23.78"	2348.00
ASTRI-3	28°18´08.53"	16°30´29.82"	2364.00
ASTRI-4	28°18´08.31"	16°30´23.90"	2356.00
ASTRI-5	28°18´08.73"	16°30´17.63"	2358.00
ASTRI-6	28°18´14.91"	16°30´24.88"	2351.00
ASTRI-7	28°18´15.56"	16°30´18.56"	2342.00
ASTRI-8	28°17´57.45"	16°30´31.34"	2359.00
ASTRI-9	28°18´02.75"	16°30´33.98"	2376.15

Figure 4. Position of the LIDAR's dome (image from Google Maps)

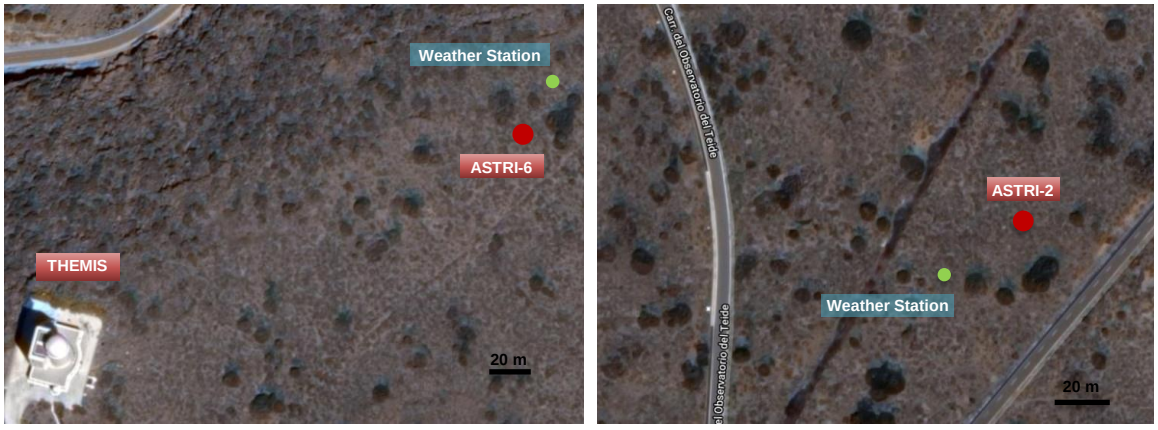

Figure 5. Positions of the weather stations (images from Google Maps)

5 Civil Work

5.1 Roads

Figure 6 shows the road network for the ASTRI Mini-Array. No new main road servicing the array will be realized but the existing ones (blue line in the figure) will be used. The new roads realized for the project are the access roads to the telescopes (yellow lines in the figure). The roads will be 3 meters wide to allow the passage of the vehicles necessary to the construction first and to maintenance and operation after. The total length of the new roads will be approximately 1400 meters. The access roads will not be asphalted but covered with gravel of local origin.

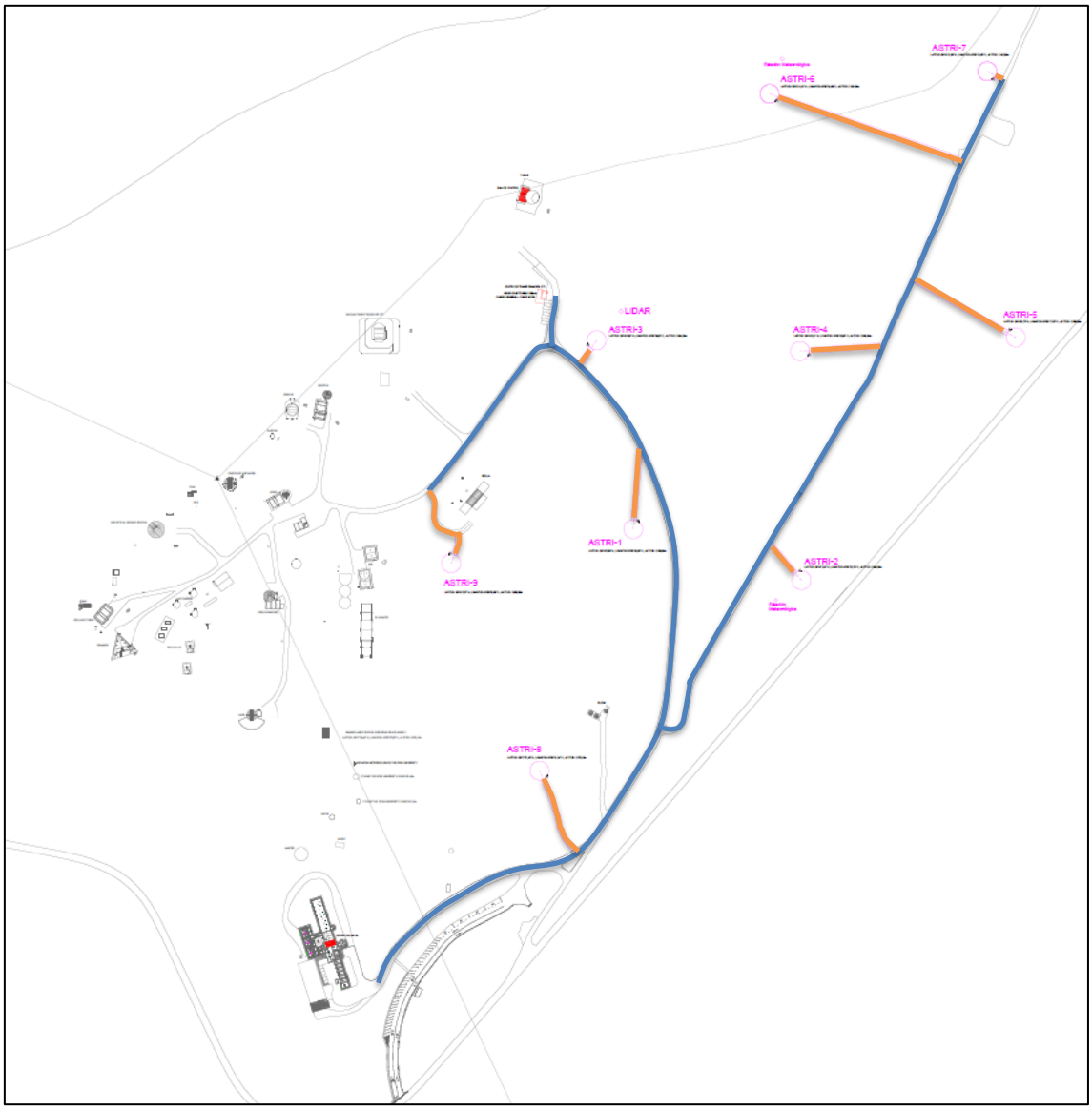

Figure 6. ASTRI Mini-Array roads layout. Blue lines are existing roads/paths, yellow lines are the new access roads to the telescopes

5.2 Telescope Area

The design ([AD3] and [AD4]) for the area around each telescope is shown in Figure 7.

The main components inside each area, are the following:

1. Telescope foundation
2. Service cabinet for power and data network interface
3. Security fence surrounding the area.
4. Access gate connected to the array interlock/alarm system for safety reasons.
5. Pits & cable ducts.

Four zones can be identified inside the fence that delimits the telescope's area:

1. Foundations zone
2. Telescope motion zone
3. Cherry picker zone
4. Untouched zone

Apart from the foundations zone, that will be made of concrete and then covered with gravel, no other zone inside the telescope area will be paved or asphalted.

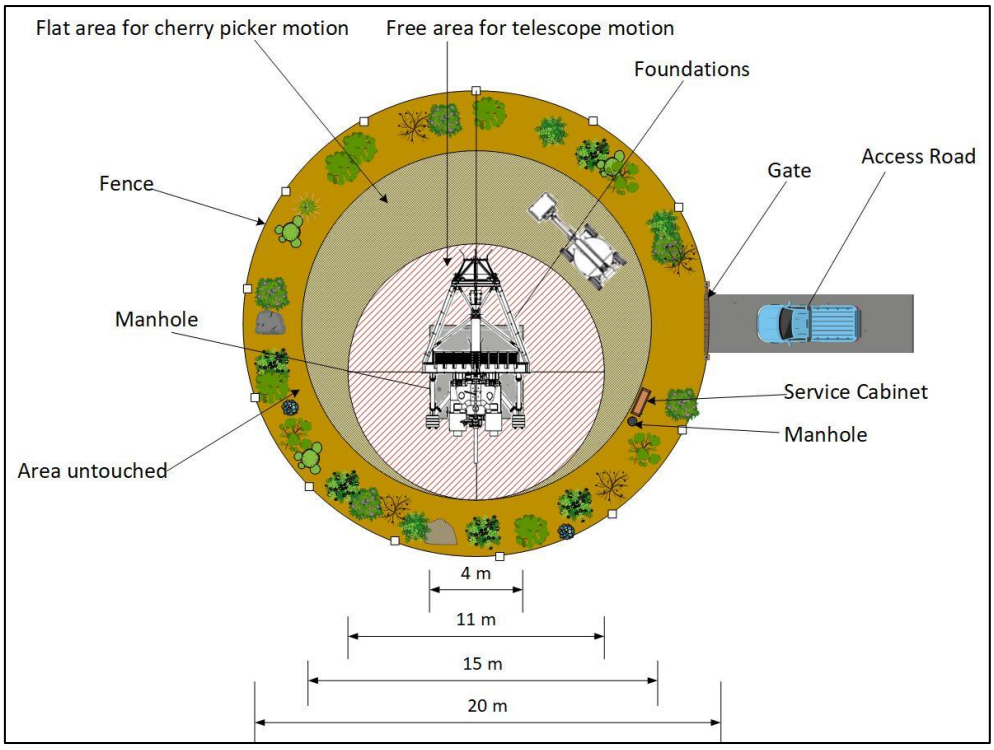

Figure 7. Adopted layout for the area around each telescope

The **foundations zone** is the area occupied by the foundations of the telescopes and has a size of 4x4 meters. See section 5.3 for details.

The **telescope motion free zone** is a circular area centred on the telescope that has to be flat and free from any obstacle to allow the telescope to be moved undisturbed. This area shall have a diameter not less than 11 meters.

The **cherry picker zone** is an area around the telescope of 15 meters of diameter that shall allow the use of a cherry picker for maintenance operations. The foreseen dimensions for the cherry picker will be 1.8 meters wide and 5 meters long when in parking position. The area is not centred on the telescope position because maintenance activity will happen mainly at the front of the telescope. The area shall be cleared and flat to allow safe motion of the cherry picker. The shape of the area has to be optimized, but this needs a more careful analysis of the maintenance operations. Also, this area will be covered with gravel.

The **untouched zone** will be the area with an external diameter of 20 meters and internal diameter of 15 meters. This area does not need to be cleared or flat, so vegetation will be untouched. The untouched zone delimits the telescope area and is surrounded by a fence. This zone is shown as circular and concentric to the cherry picker zone, but its actual shape will be adapted to the terrain conditions. The fence (Figure 8) is needed for security and safety reasons. The height of the fence will be 2 meters. The access will happen only through an access gate 3 meters wide connected to the interlock safety system of the array.

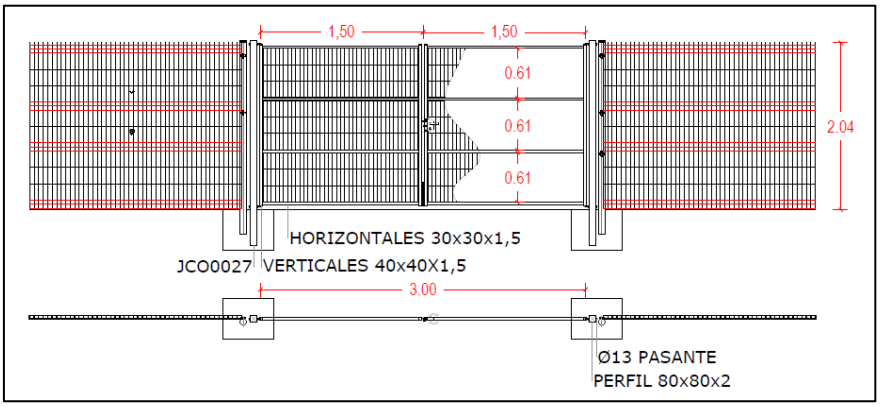

Figure 8. Design of the gate and fence

Figure 9 shows the locations of the trenches and pits in the telescope area that are part of the power and data networks.

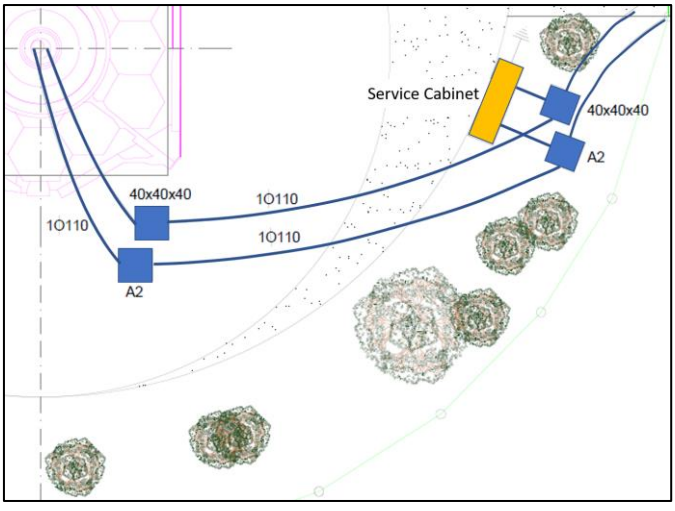

Figure 9. Layout of cable ducts and pits in the telescope area

5.3 Telescope Foundations

Figure 10 shows the concept for the foundations of the telescopes of the ASTRI Mini-Array. The foundations will be 4 m x 4 m wide and 1.5 m deep. In the figure 9 micropiles are also shown. The micropiles will be used when the concrete foundation does not lay on bedrock. The figure does not show the anchor bolts that are the interfaces to the telescope structure which, instead, are shown as example, as they refer to the ASTRI-Horn prototype telescope installed in Sicily, in Figure 11.

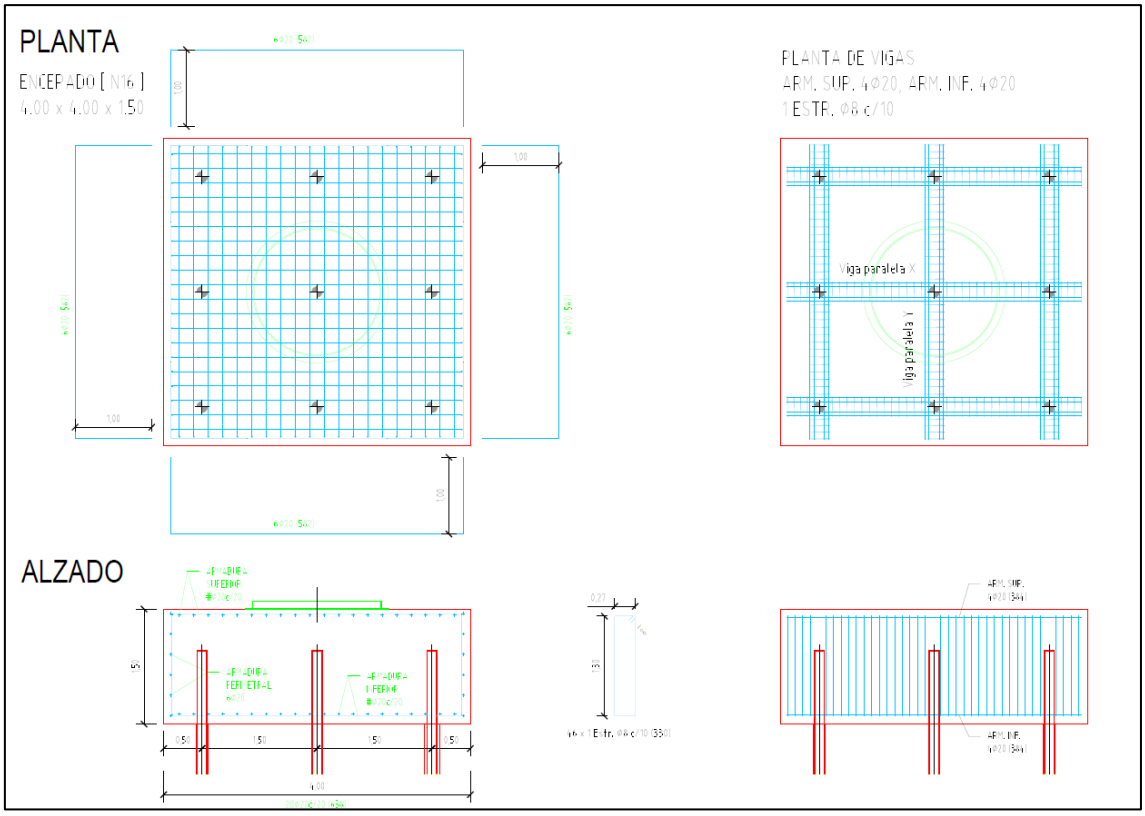

Figure 10. Design concept for the foundations of the ASTRI telescopes

Figure 11. Anchors bolts emerging from the foundations of the ASTRI-Horn prototype

To properly design the foundations a geotechnical study [AD6] was performed to determine the structure of the soil underneath the position of each telescope. For each area a couple of trial excavation were executed to analyse the soil composition. Figure 12 and Figure 13 show the findings of this study in the cases of telescopes ASTRI-1 and ASTRI-3. In both cases the structure of soil requires the use of micropiles. The following list summarizes the results of the study:

- ASTRI-1 foundation with 9 micropiles
- ASTRI-2 foundation with 9 micropiles
- ASTRI-3 foundation with 9 micropiles
- ASTRI-4 foundation with no micropiles
- ASTRI-5 foundation with 9 micropiles
- ASTRI-6 foundation with 6 micropiles
- ASTRI-7 foundation with 9 micropiles
- ASTRI-8 foundation with no micropiles
- ASTRI-9 foundation with 9 micropiles of larger diameter

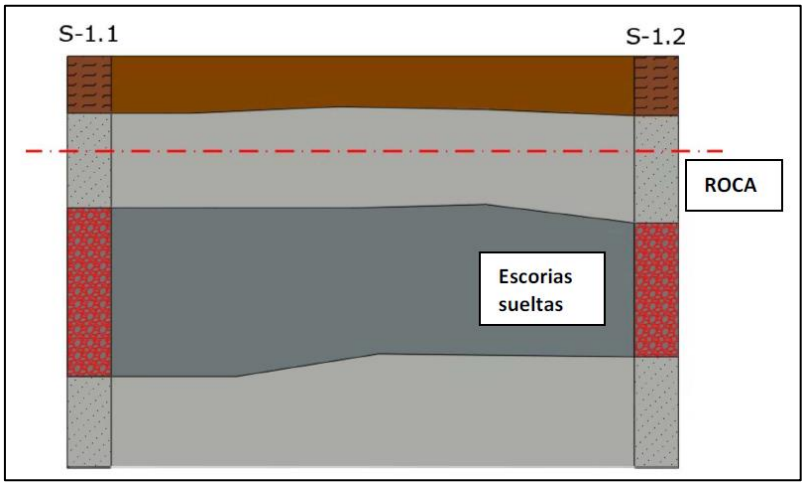

Figure 12. Structure of the soil underneath ASTRI-1. The dashed-dot red line refers to a depth of 1.5 m that corresponds to the size of the foundation.

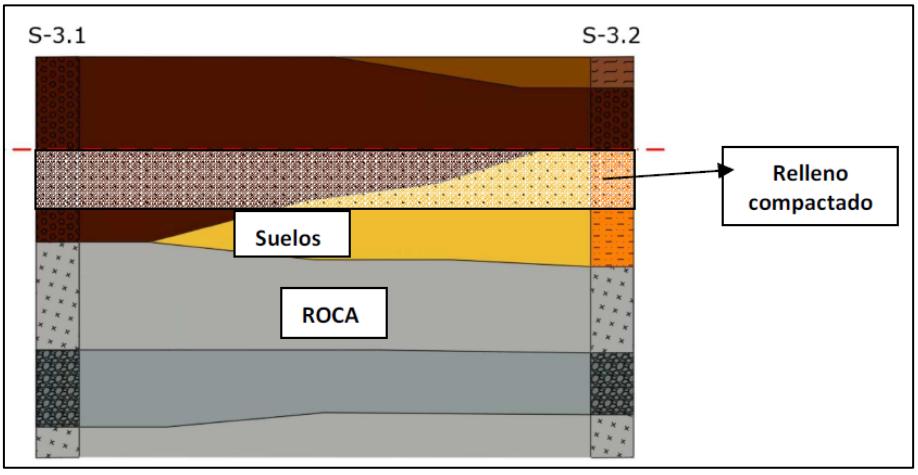

Figure 13. Structure of the soil underneath ASTRI-3

6 Power Network

The ASTRI Mini-Array power network layout is shown in Figure 14. As it can be seen from the figure the ASTRI power network described in this section does not include power distribution system for the data centre, the control room and the LIDAR. These subsystems are connected to the power network of the Themis observatory (control room) that of the IAC Residencia (data centre) and that of the dome that will host the LIDAR.

The main elements of the ASTRI Mini-Array power network are the following:

- The power substation.
- Two main power lines.
- Auxiliary devices.

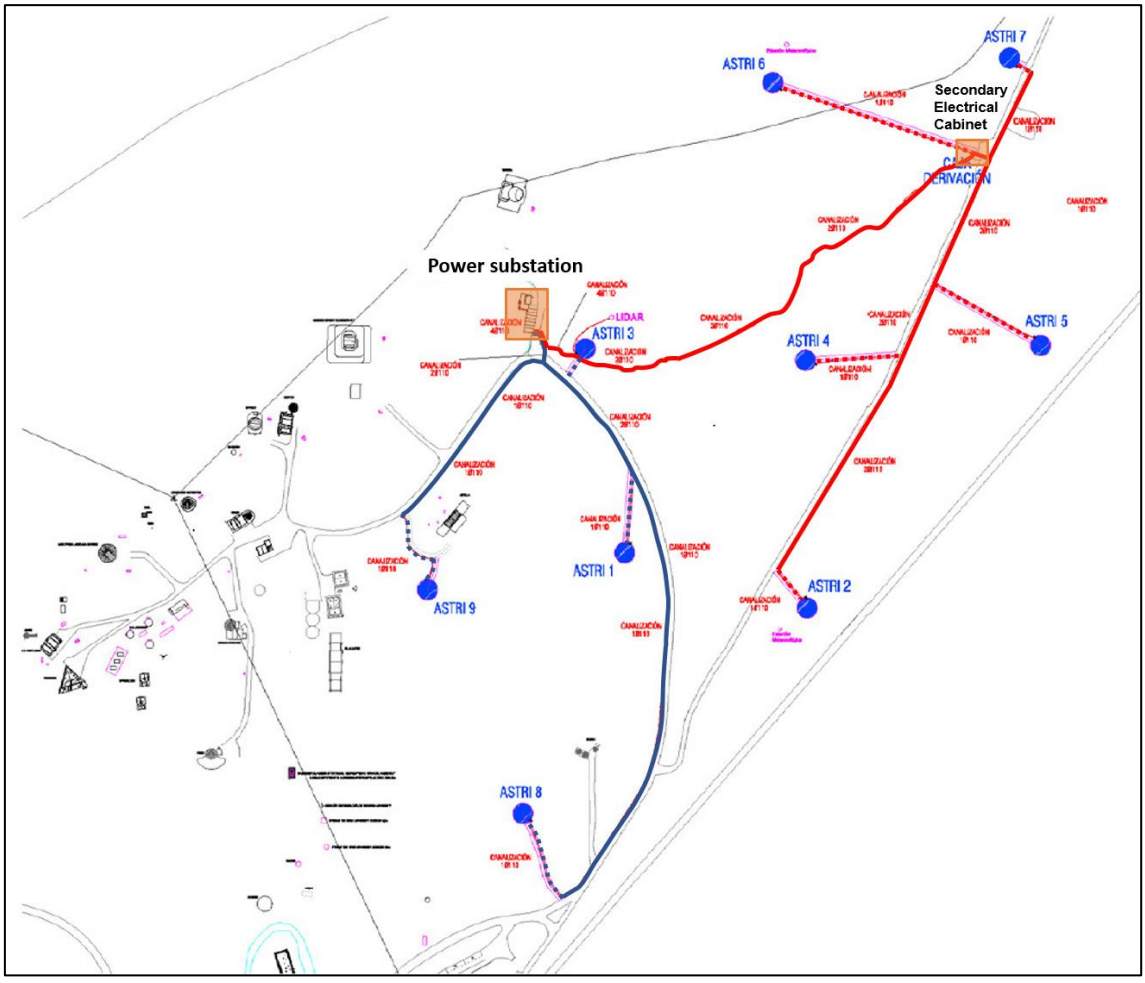

Figure 14. ASTRI Mini-Array power network. The orange shaded area is the position where the power substation is located. Blue and red lines are the two main power lines. Continuum lines indicates double cable ducts, dotted lines single cable ducts.

6.1 The power substation

The power substation is the place where the ASTRI Mini-Array is connected to electric network of the Canary Island (supplier Endesa). A medium to low voltage transformer

station (the first element of the ASTRI power network) allows to go from 20kV to 400 V. The nominal power of the transformer station is 630 kVA. The station will serve not only the ASTRI Mini-Array but will be of general use for the Teide observatory.

In the ASTRI Mini-Array power network the transformer station is the only component working at medium voltage. The remaining elements of the power network are all low voltage elements.

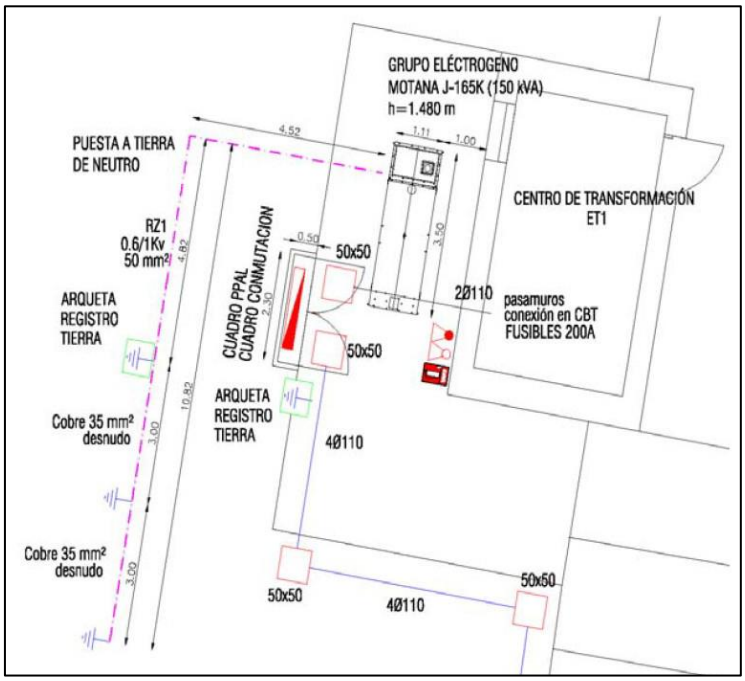

Figure 15. Design of the power substation. The power substation is located between ASTRI-3 and the Themis dome.

Apart from the transformer station the other elements (low voltage) of the power substation are a diesel power generator (nominal power 150 kVA) and an UPS (nominal power 125 kVA) that serve as power backup for the telescopes. Power backup allows the Mini-Array control system to put the telescope in safe state if necessary. Finally, the main electrical cabinet containing the main switchboard is the last element of the power substation. Figure 15 shows the design of the power substation.

6.2 Power lines

There are two main power lines departing from the power substation (blue and red lines in Figure 14). The reason for this distribution is related to the arrangement of the telescopes and the necessity not to have long power lines. The *blue* power line will power ASTRI-1,3,8 and 9 while the *red* one will power the remaining telescopes. The blue line is actually made by the set of individual lines powering the telescopes while the red line runs as a single line to the secondary electrical cabinet where it splits into the lines serving the telescopes. The cable ducts running along the main roads or pathways (solid line in the figures) are redundant with the empty duct to be used for maintenance or array expansion activities. The cable ducts (dotted lines in the figure) running along the access road to the telescope are instead single.

6.3 Auxiliary devices

The auxiliary devices are all those elements distributed along the main power lines such as the secondary electrical cabinet serving ASTRI-2,4,5,6,7 or the power section of all the service cabinets that interface the telescopes to the external world (see section 10).

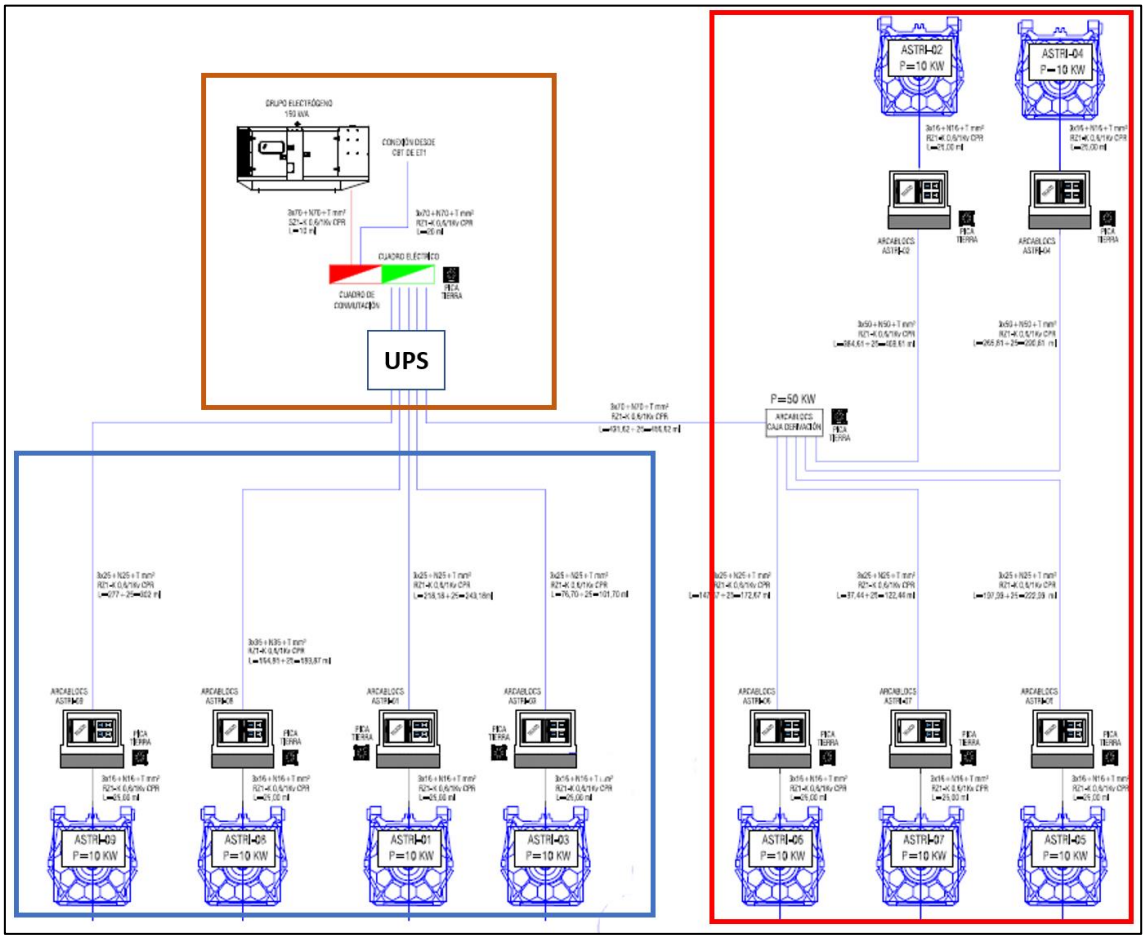

Figure 16. Low voltage power network [AD8]. Orange box identifies the elements of the low voltage power network that are parts of the power substation. Blue and Red boxes include the ASTRI Mini-Array elements connected to the two main power lines (see also Figure 14).

7 Communication Network

Figure 17 shows the concept design of the ASTRI Mini-Array communication network. The data centre is the starting point of the ASTRI network and the interface with the IAC internet network.

Several networks will make the ASTRI communication network. In particular:

- Data network for scientific data
- Commands network to run telescopes and auxiliary systems
- Telemetry/Monitoring network to monitor the status of the entire system
- Time synchronization system network to time tag scientific data
- Safety & Security network
- CCTV network

As shown in Figure 17 the various networks reach all the ASTRI Mini-Array subsystems but the time synchronization time network which is intended only for the telescopes.

The network will travel on optical fibre. There will be one fibre bundle (24 fibres, 12 couples) per telescope so each network will have a number of dedicated fibres in the bundle.

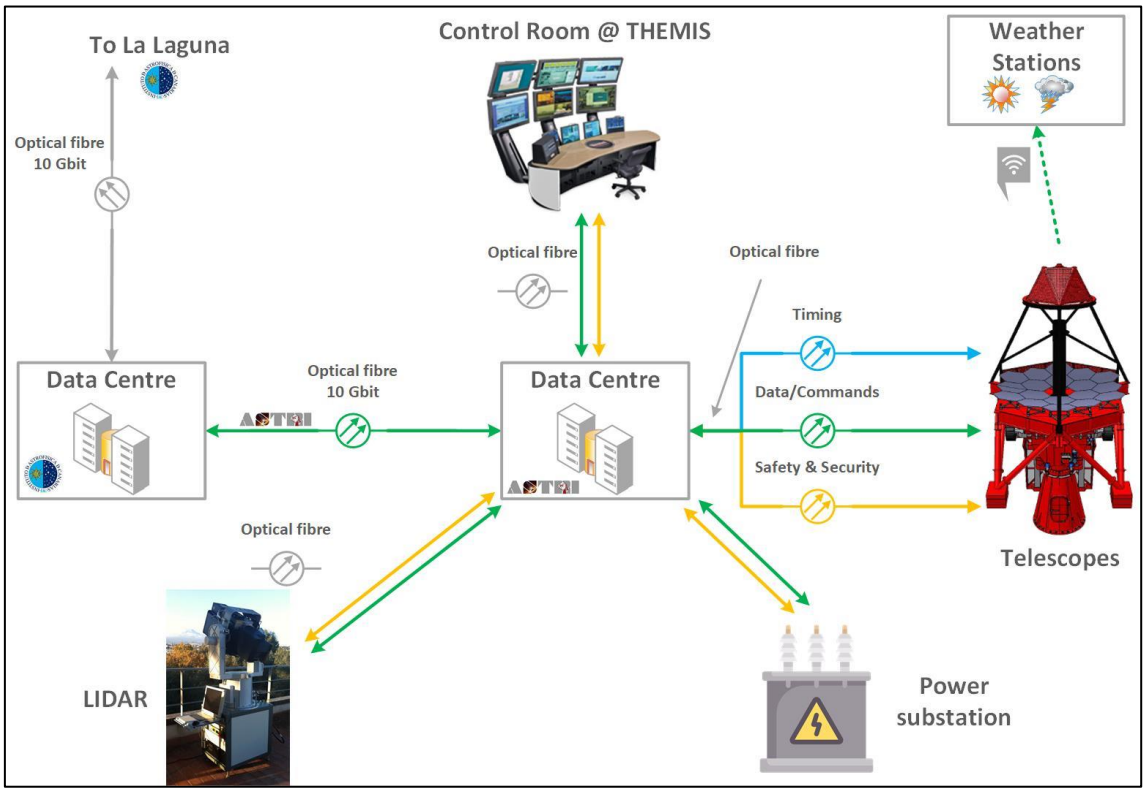

Figure 17. A concept design of the ASTRI Mini-Array Communication Network. Yellow lines are for the safety and security network, blue line is for the time synchronization system network and, for the sake of simplicity, green lines represent the data, commands, and monitoring networks. Weather stations are Wi-Fi connected to the closest telescope.

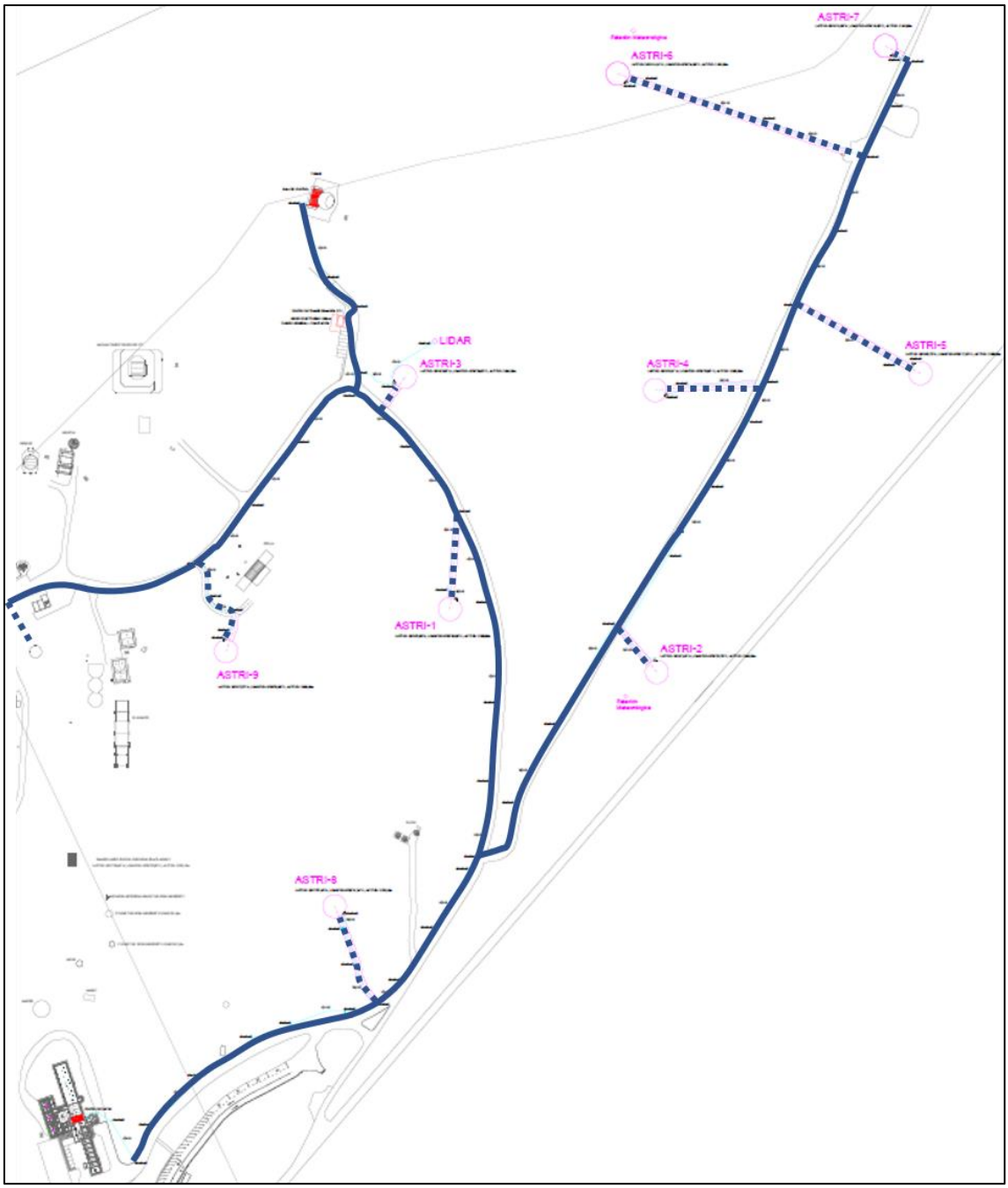

Figure 18. Layout of the ASTRI Mini-Array communication network. Data centre is in the lower left corner. Solid lines are redundant cable ducts, dashed line single cable ducts.

Figure 18 shows the layout of ASTRI Mini-Array Communication network. The cable ducts run along roads of the array. As for the power network the ducts are redundant along the main roads with the empty duct to be used for maintenance or possible array expansion activities. The cable ducts running along the access road to the telescope are instead single.

8 Control Room

The onsite ASTRI Mini-Array local control room will be located at the Themis observatory. Figure 19 shows the spaces reserved to the ASTRI project inside the Themis observatory, in particular:

1) Control room
2) Storage room
3) Meeting room

Furthermore, the personnel of ASTRI project will have access to common facilities like workshops (mechanical and electrical), toilets and cafeteria.

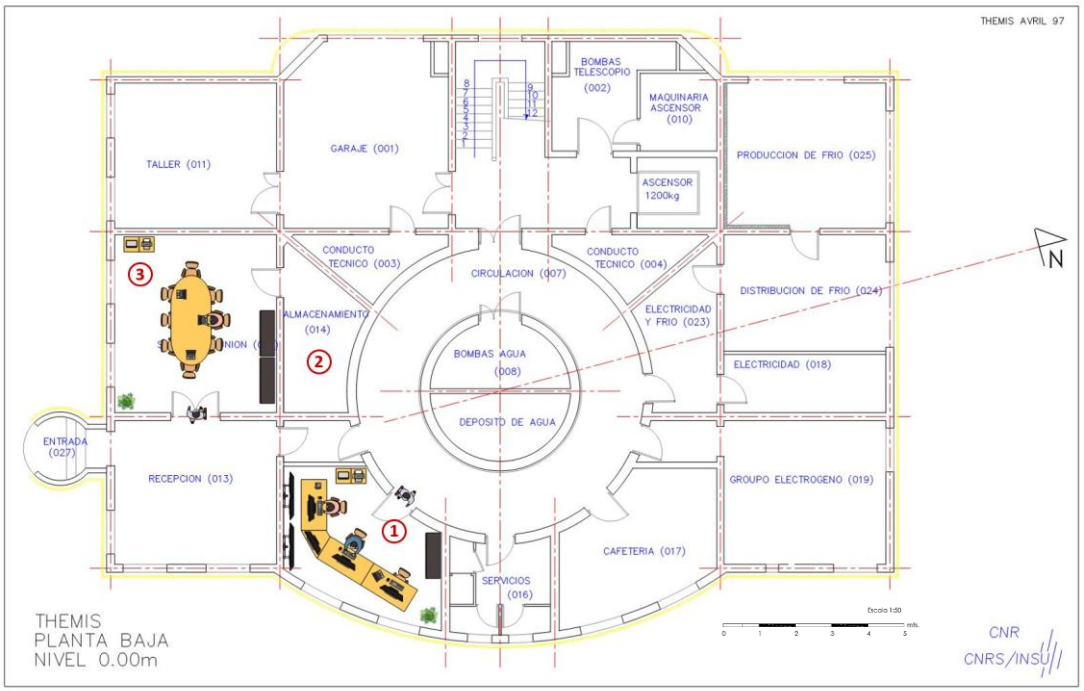

Figure 19. Map of the ground floor of the Themis telescope with indicated the area to be used by the ASTRI project. 1) is control room, 2) is a storage room and 3 is a meeting room (map courtesy of Themis observatory).

The control room will host up to three workplaces. It will allow to fully control the ASTRI Mini-Array and for this reason will be equipped with a number of workstations, monitors and network equipment, and connected to the data centre through a dedicated optic fibre.

The monitors of the CCTV will be hosted here as well as a console connected to the safety and security system with an emergency stop button for each telescope.

The ICT architecture and the equipment of the control room are described in [AD5].

9 Data Centre

The ASTRI Mini-Array on-site data centre includes the computing/storage hardware, the overall networking infrastructure (including cabling and switches) and all system services (operating system, networking services, name services, etc.) to control the array and monitor its health status, perform online observation quality analysis, store temporarily data at the site and guarantee internal and external network communications.

The ASTRI Mini-Array on-site data centre will be located at the Residencia at the Teide observatory (see Figure 20).

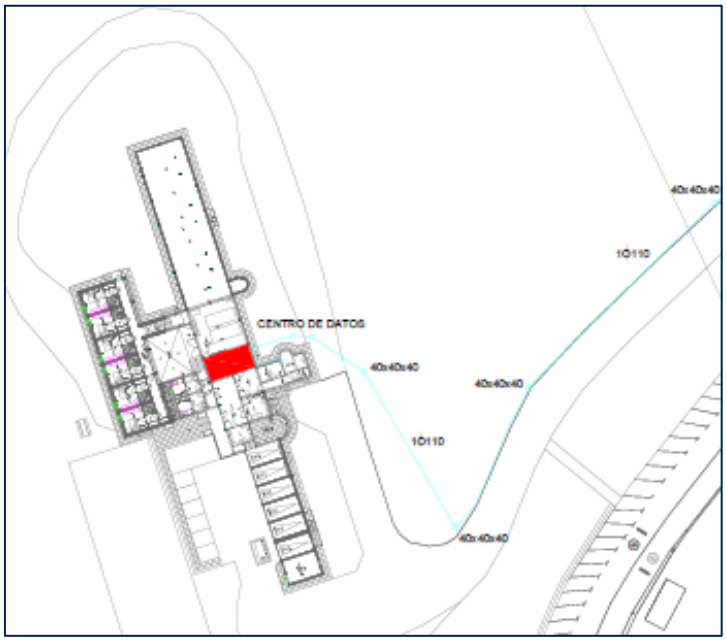

Figure 20. Map of the Residencia at the Teide Observatory. The red rectangle shows the location of the ASTRI Mini-Array on-line data centre.

Figure 22 shows a possible layout for the on-line data centre. The main element for the electric power subsystem will be the switchboard. The power consumption estimate for the data centre is of 17 kW on average with 25 kW of peak power. The data centre will be connected to the main IAC UPS system.

Two racks (see Figure 21) will host the servers (storage, computing, virtual machines) and one the network systems, finally, a small rack will contain the fibre optics patch panels for the connection to the telescopes and the control room. The detailed description of the architecture of the ICT apparatus is given in [AD5].

The heat power produced by the data centre that has to be dissipated is estimated to be 25 kW an external conditioning system based on fan coils will be used to meet the requirements.

Auxiliary systems as automatic fire alarm system and access control system will also be put in place.

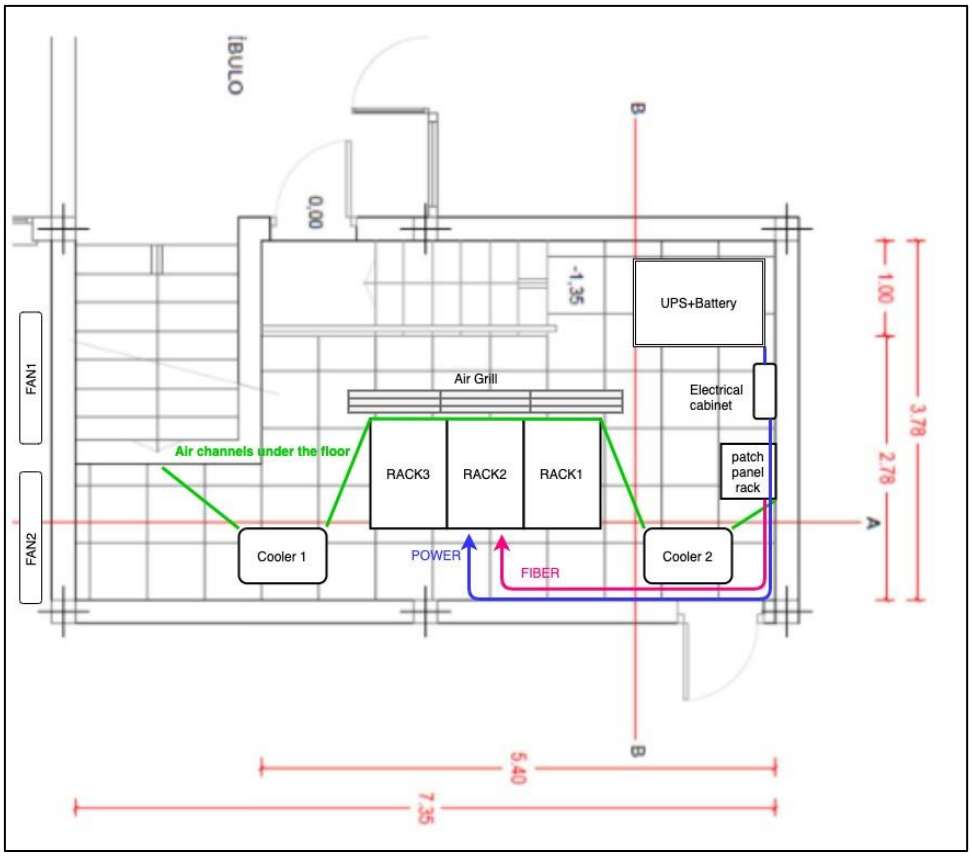

Figure 21. Map of a possible layout of the ASTRI on-site data centre.

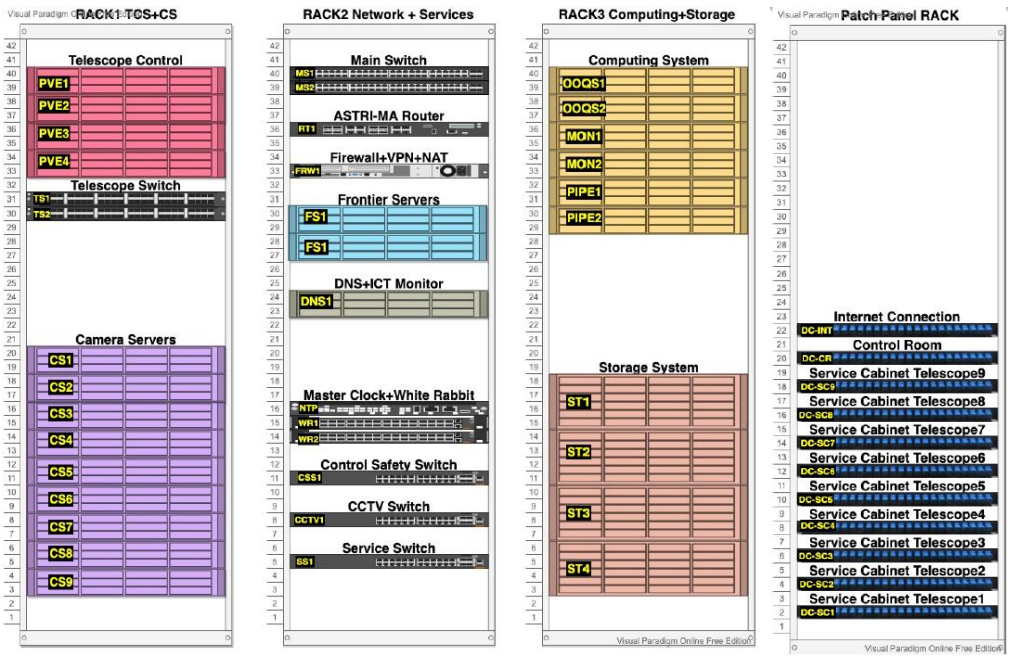

Figure 22. Possible configuration for the ASTRI on-site ICT equipment

10 Service Cabinet

Service cabinets [AD10] are the interfaces of the Telescope to the external world. In particular, they contain the power and communication networks interfaces. They also include part of the safety and security system (rain & humidity sensors, CCTV cameras).

Figure 7 and Figure 23 show the expected position of the service cabinet in the telescope area. Actual position will depend on the area characteristics.

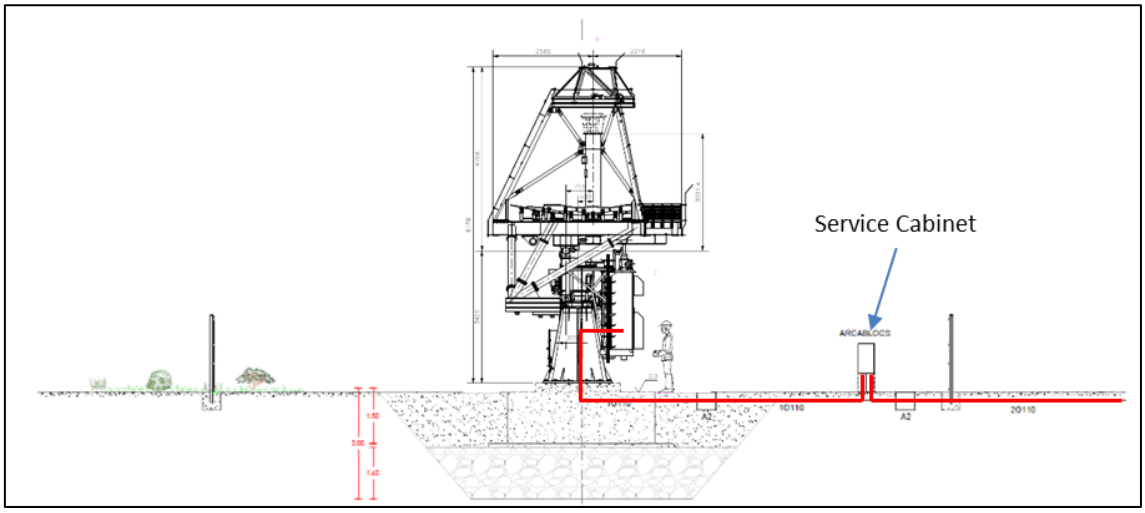

Figure 23. Location of the service cabinet inside the Telescope area. The red lines show the path of the fibres or the electric wires to the telescope cabinet.

Figure 24 shows in detail the design of the service cabinet. Apart from the cabinet there will be a post that will host environmental sensors, a CCTV camera, an antenna for Wi-Fi, the telescope emergency stop button, and, in two cases, an antenna for the weather station console.

The cabinet itself will be divided in two section a power section and network and control section.

The power section will contain:

- **Service cabinet power distribution module** that will distribute the power coming from the network to the telescope and to the devices present in the cabinet
- **Emergency generator socket** to power the single telescope with a portable power generator
- **Service electrical sockets**
- **24V power supply** to feed some of the equipment present in the cabinet

The network and control section (left in the figure) will contain:

- **Fibre patch panels** to interface the communication network with the telescope
- **Network switch** that serves all equipment on board the cabinet
- **Wi-Fi access point**
- **Beckhoff PLC** to manage I/O modules, controllers and safety functions
- **Digital and analog I/O modules**

- **Safety I/O modules**
- **Rain sensor controller**
- **PoE injector**
- **Weather station console** (ASTRI-2 and ASTRI-6 cabinets only)

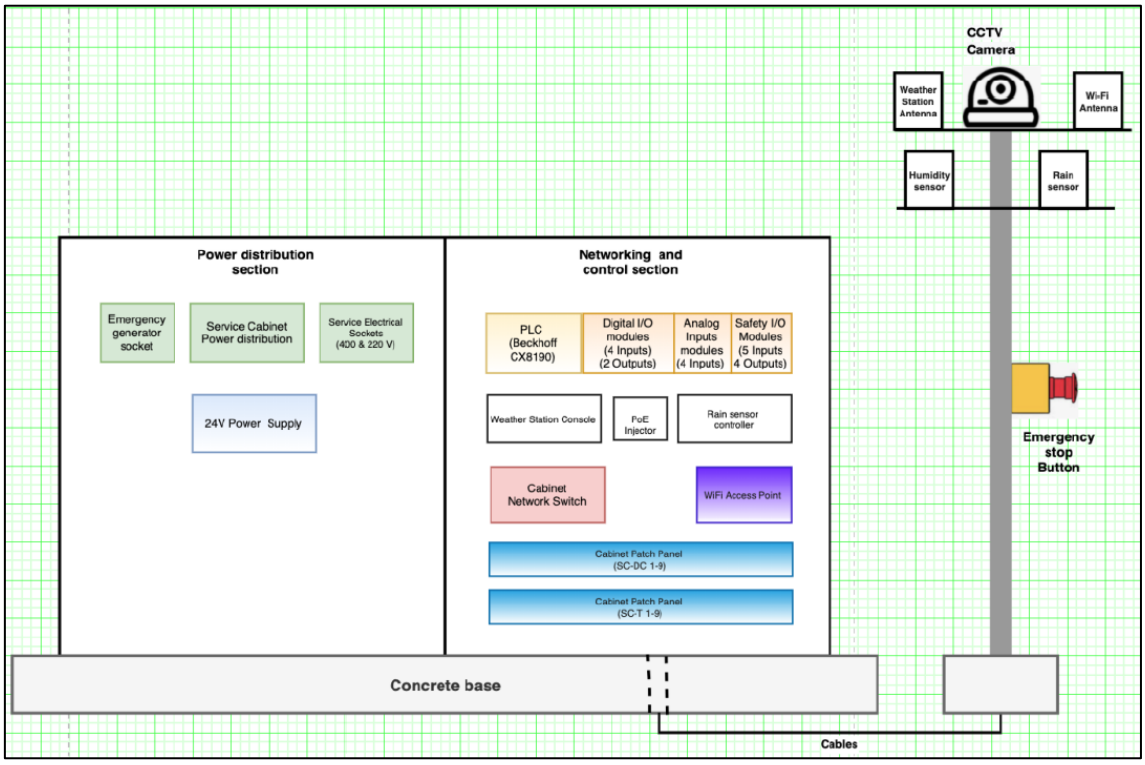

Figure 24. Design of the service cabinet. On the left side of the cabinet the power distribution section, on the right side the network and control section and outside the cabinet a post equipped with sensors, cameras, antennas and the telescope emergency stop button.

The approximate dimensions of the cabinet are given in Figure 25.

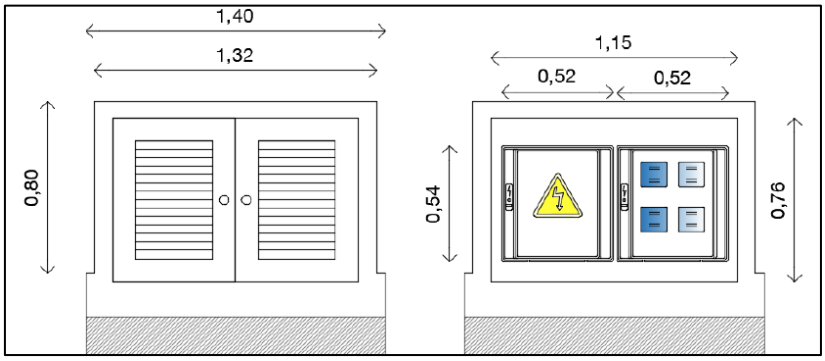

Figure 25. Dimensions of the service cabinets