The ASTRI Mini-Array

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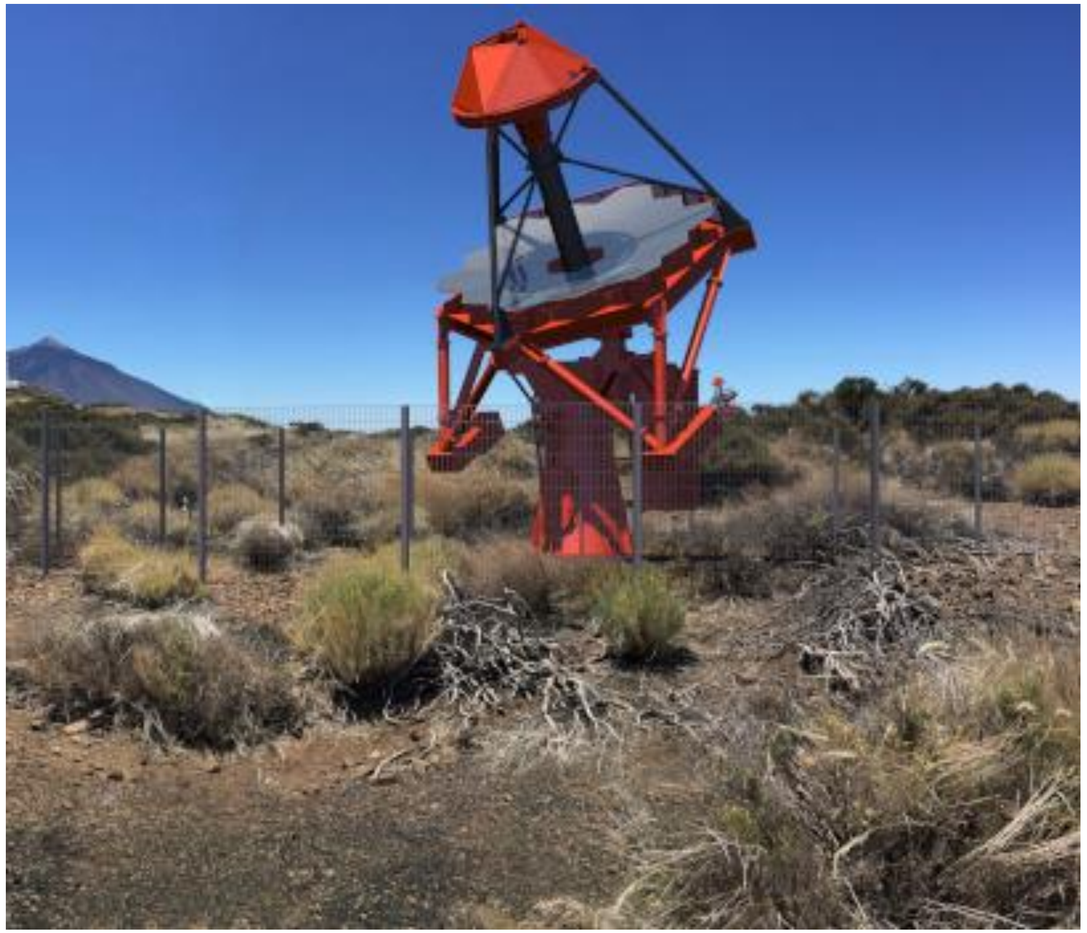
for the ASTRI Project

OAS Very High Energy meeting: towards ASTRI and CTA, 08-09 June 2022

Layout of the presentation

- The ASTRI Mini-Array project
- Architecture of ASTRI Mini-Array
- Teide infrastructure
- Status of production:
  - Mechanical structure & mirrors
  - Telescope's auxiliaries
  - Cherenkov cameras
  - ICT
  - Software
- Operation concept
- Mini-Array implementation



The ASTRI Mini-Array Project

ASTRI (Astrofisica con Specchi a Tecnologia Replicante Italiana) was born as “Progetto Bandiera” funded by MIUR with the initial aim to design and realize an innovative end-to-end prototype of the 4 meters class telescopes in the framework of the CTA observatory

The ASTRI Mini-Array is the second step of project whose purpose is to construct, deploy and operate an array of 9 Cherenkov telescopes of the 4 meters class at the Observatorio del Teide in Tenerife (Spain) in collaboration with IAC.

More than 150 hundred researchers belonging to

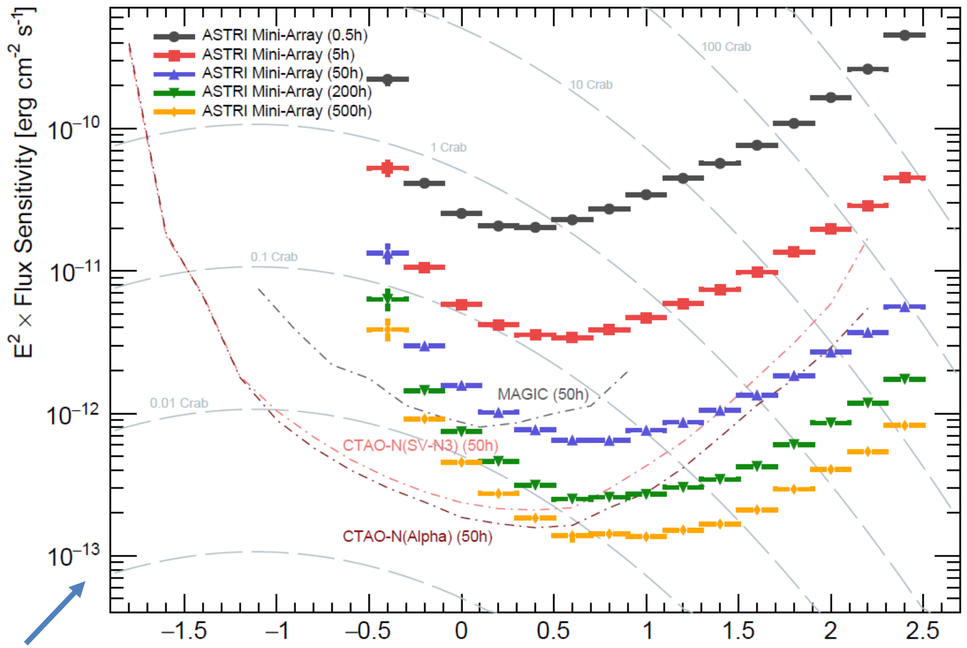
- INAF institutes (IASF-MI, IASF-PA, OAS, OACT, OAB, OAPD, OAR)
- Italian Universities (Uni-PG, Uni-PD, Uni-CT, Uni-GE, PoliMi)
- International institutions (University of Sao Paulo – Brazil, North-West University – South Africa, IAC – Spain).

Italian and foreign industrial companies are and will be involved in the ASTRI Mini-Array project with important industrial return.

The ASTRI Mini-Array Project

- The ASTRI mini-array can be considered a new pathfinder of the arrays of Cherenkov telescopes
- Hosting agreement foresees 4 + 4 years of operations for the ASTRI Mini-Array starting from beginning of operations
- During the first 3/4 years of operations the array will be run as an experiment
- The ASTRI Science team will develop a strategy to concentrate the observational time on a limited number of programs with clearly identified objectives (Vercellone's talk)
- After this initial period the project will gradually move towards an observatory model in which a fraction of the time will be assigned to scientific proposals through a Time Allocation Committee procedure

Mini but not small…



Lombardi, S., Antonelli, L. A., Bigongiari, C., et al., Proc. 37th ICRC, Berlin, PoS(ICRC2021)884 (2021)

Largest Imaging Atmospheric Cherenkov Telescopes facility until CTAO will start to operate

Expected performance

- **Sensitivity: better than that of current IACTs (E > a few TeV):**
  - Extend the spectra of already detected sources and/or measure cut-offs
- **Energy/Angular resolution: ~ 10% / ~ 3‘ (E > a few TeV)**
  - Characterize the morphology of extended sources at the highest VHE
- **Wide FoV (≥ 10°), with almost homogeneous off-axis acceptance**
  - Optimal for multi-target fields, surveys, and extended sources
  - Enhanced chance for serendipity discoveries

- **Wide-field stereoscopic observations in the 1 – 300 TeV energy band**
  - Restricted number of targets/deep exposures (≥ 200 h)
  - Galactic sources: wide FoV → multi-target fields
  - Extragalactic sources: survey of a few promising targets at > ~10 TeV scale
  - Fundamental physics: studies on LIV, EBL, Axion-Like Particles, …
- **Stellar Hambury-Brown intensity interferometry in the visible band**
- **Direct measurements of cosmic rays**

The ASTRI science team is developing a core science program (see Vercellone’s talk)

Operation modes

- **Normal (science) observation mode**: this is used to observe the targets as defined by the Science Operation Plan. Usually science observations require dark time, although it is also possible operate also during moderate moonlight conditions. Calibration activities are included in the normal operation mode.

- **ToO Mode**: the science operation plan will identify some astrophysical targets (either a specific object or a class of objects) that, giving raises to transient phenomena, will require a response from the night operator and a change in the night schedule. This means that no dedicated automatic software procedure to react to these transient phenomena is foreseen. Depending on the type of transient object the reaction time will vary from 1 hour to 1 day.

- **Coordinated Mode**: Synergies with the current VHE arrays (MAGIC, LST) in the northern hemisphere are foreseen in the science operation plan. This means that simultaneous observations will be possible. Usually, those observations, will be scheduled well in advance.

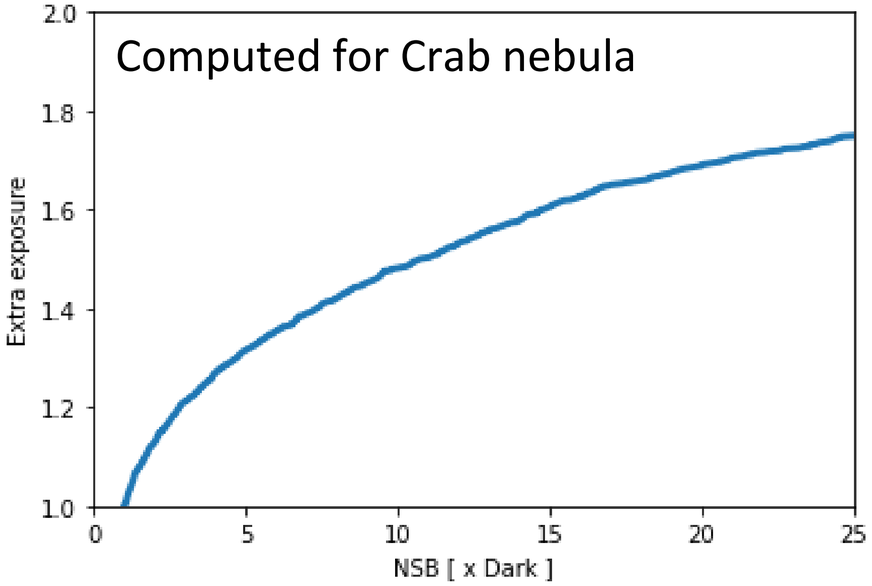
- **Maintenance mode**: this mode deals with all activities necessary for the maintenance of the telescopes, the on-line control software, the monitoring, characterization and calibration devices, and the infrastructures (e.g. network, data center, etc). This is the only daytime operation mode.

Science Operations

- No real time analysis of the data is foreseen but only a data quality check. Data analysis policy adopted will then be next day processing.
- No array trigger (stereo trigger) will be implemented at the site. Any search for Cherenkov events detected in coincidence by more than one telescope will be performed via software off-line at the Rome Data Centre.
- No subarray operation is foreseen.
- Night science operations will be controlled remotely from La Laguna @ IAC $\rightarrow$ no people required at the site during the night.
- The local control room at the Themis Observatory will be used during commissioning and science verification phase, during maintenance activities or in case of other special activities.
- Other Array Operation Centers (control room) from Italy.

Duty cycle for Cherenkov observations

Moonless Night Hours	1565 h
Fraction of clear nights (cloud coverage <20%)	0.79
Fractional loss due to bad weather	0.04
Fractional loss due to “Calima”	0.07
Average Annual Observation Time	1104 h



Setting 15 NSB as limit → AAOT ~ 1800 h

Duty cycle: 21%

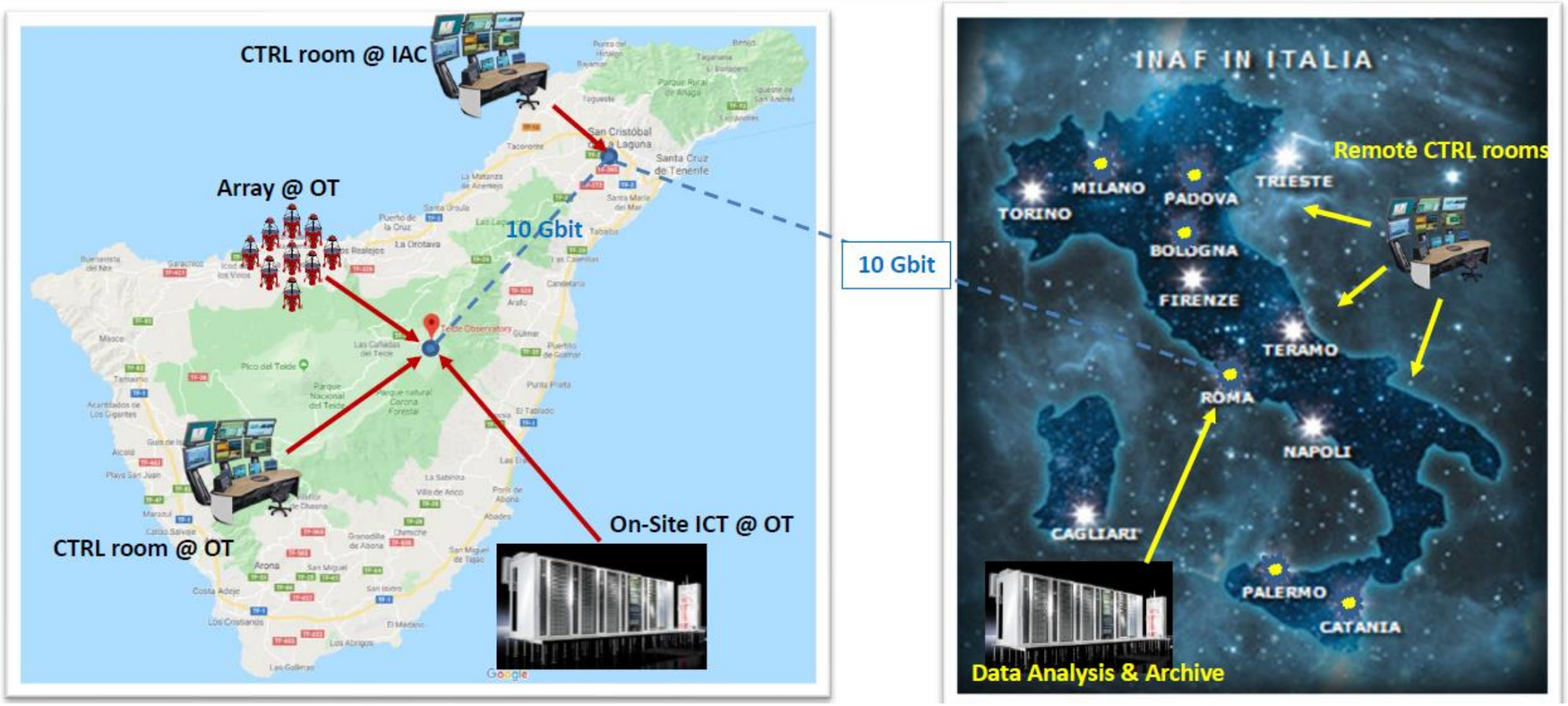
The ASTRI Mini-Array locations

The ASTRI Mini-Array in Tenerife

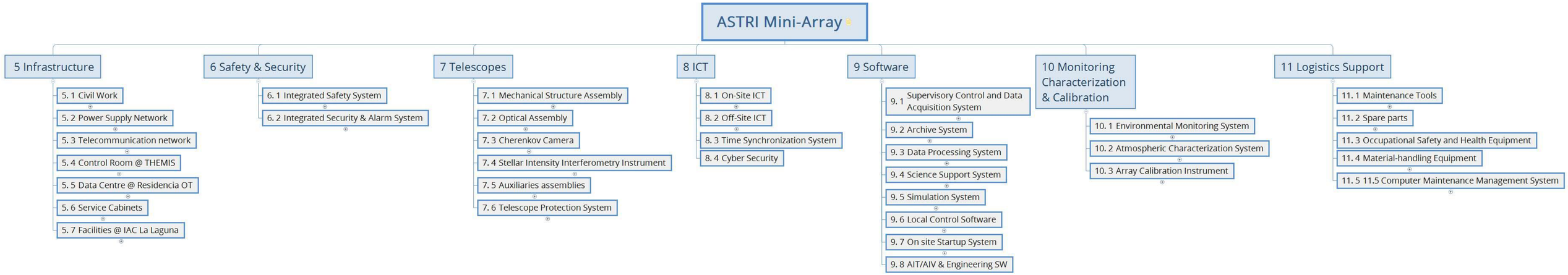
- Telescope Array & auxiliaries (Observatorio del Teide - OT)
- Local Control Room @ THEMIS building (OT)
- On site Data Centre @ IAC Teide Residencia (OT)
- Array operation center @IACTEC in La Laguna

The ASTRI Mini-Array in Italy

- Data Centre in Rome
- Remote Array operation centers

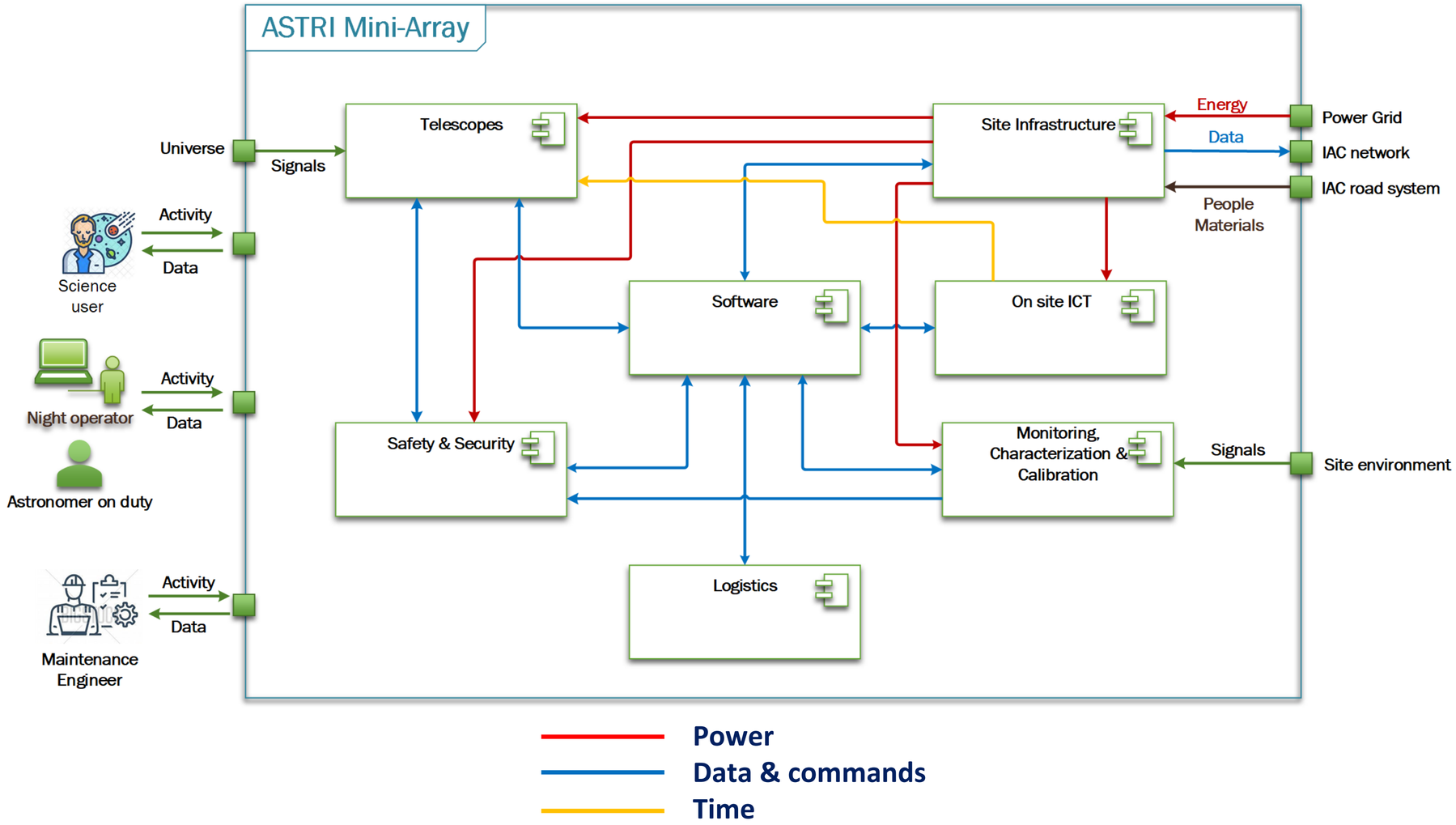


The ASTRI Mini-Array architecture: PBS



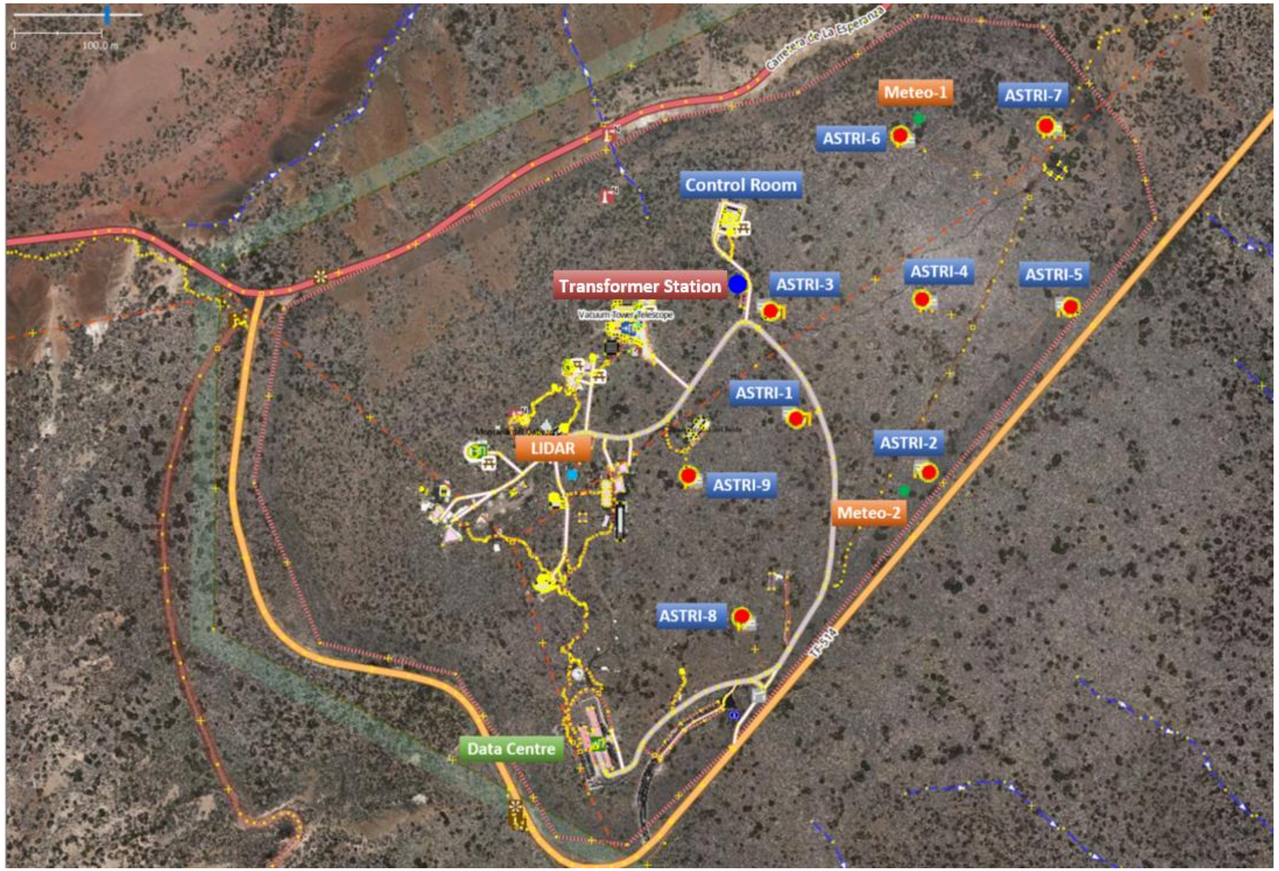
Infrastructure: composed by all those parts needed to make the observational site suitable to host the telescopes of the ASTRI Mini-Array.
Safety & Security: an independent system for the protection of people and site assets
Telescopes: include mainly the hardware used to collect and image Cherenkov light from air showers and the auxiliary assemblies needed to support this function.
ICT: includes all computing/storage hardware, the overall networking infrastructure (including cabling and switches) and all system services (operating system, networking services, name services, etc.) necessary on site and off site to control and monitor the array and to archive and analyse the scientific and engineering data.
Software: The Mini-Array software will provide to the user a set of tools from the preparation of an observing proposal to the execution of the observations, the analysis of the acquired data online and the retrieval of all the data products from the archive.
Monitoring, Characterization and Calibration: the set of devices that allows the environmental monitoring the atmospheric characterization and the array calibration.
Logistics Support: includes all the hardware & software necessary for the preventive and corrective maintenance of the ASTRI Mini-Array.

The ASTRI Mini-Array architecture: context diagram



The Teide Infrastructure

- Civil Work (including foundations for telescope and auxiliaries, roads, trenches)
- Power supply network (including transformer station, UPS and emergency power generator)
- Telecommunication network
- Control room @ Themis
- Onsite Data Centre
- Service cabinets
- Facilities in La Laguna



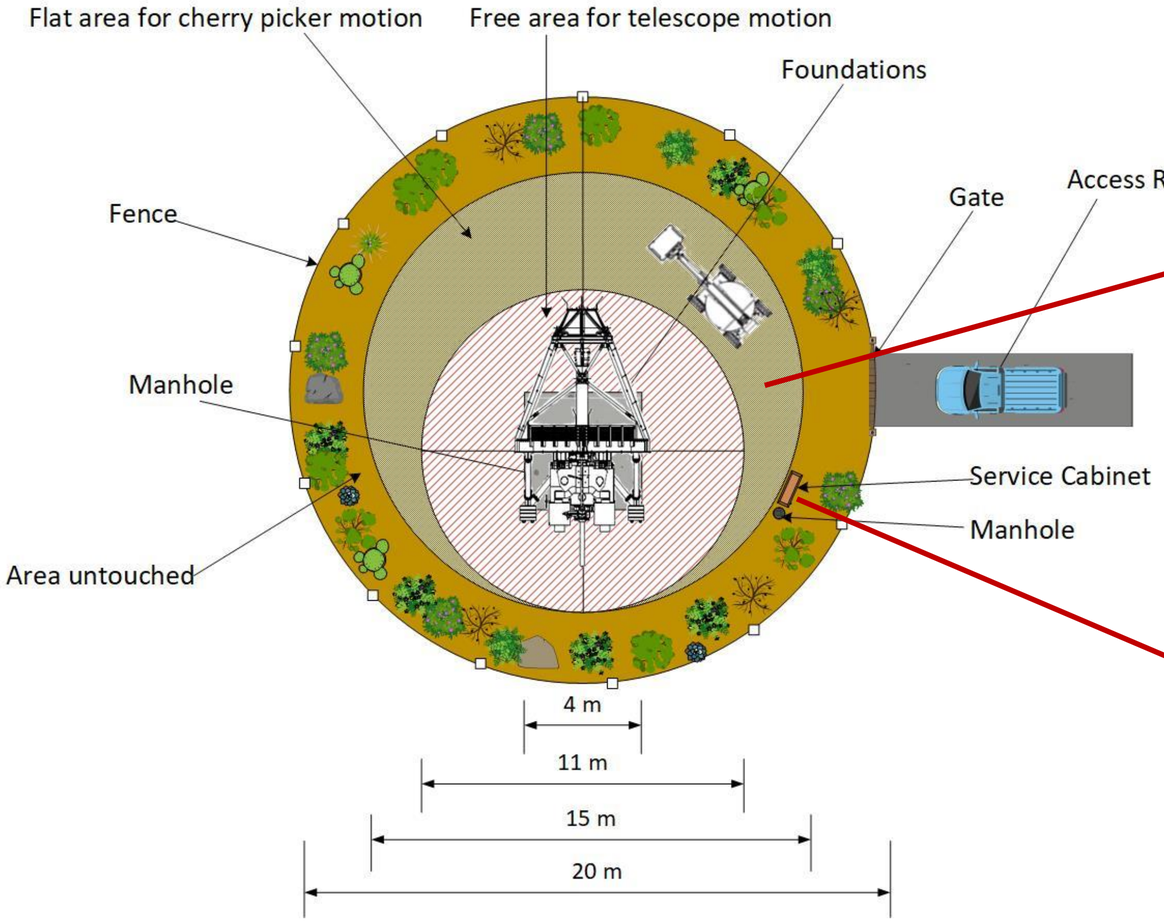
Infrastructure: foundations

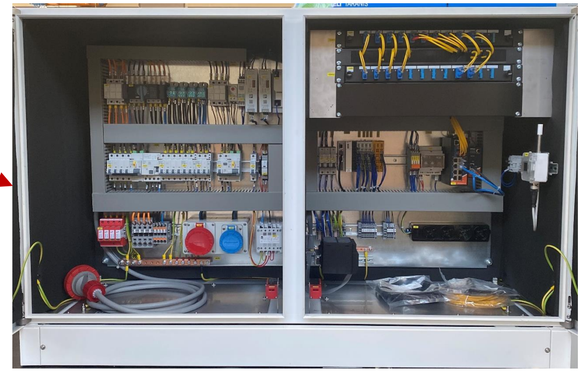






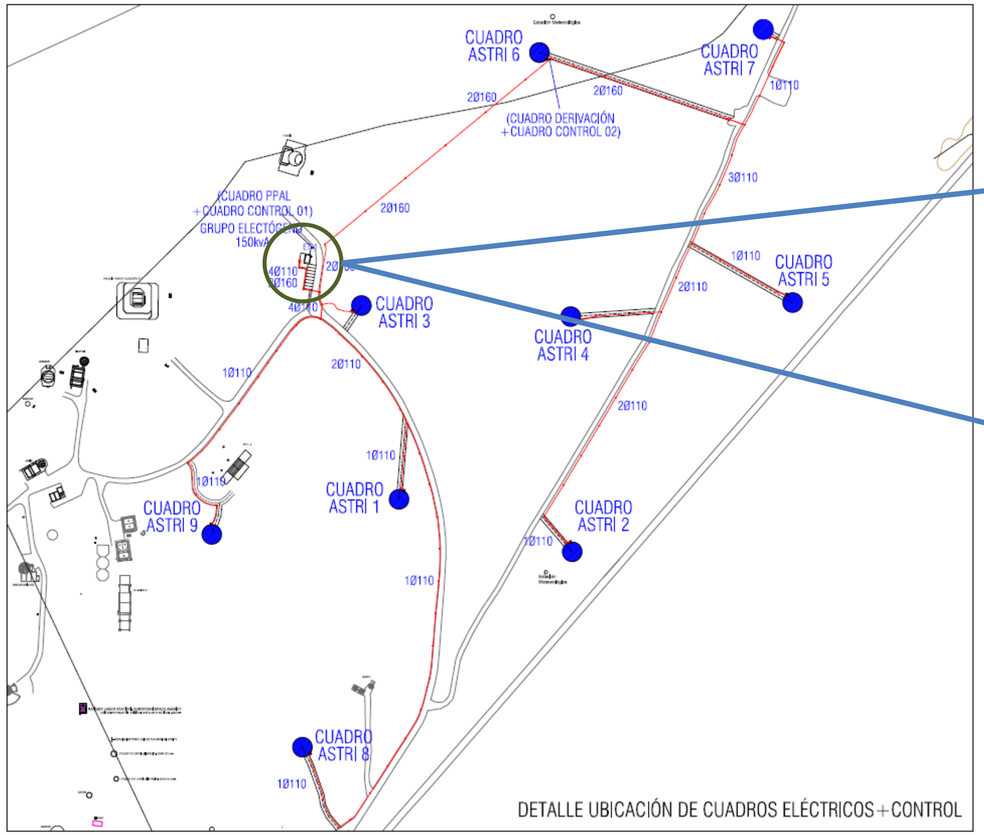

Infrastructure: Telescope's area

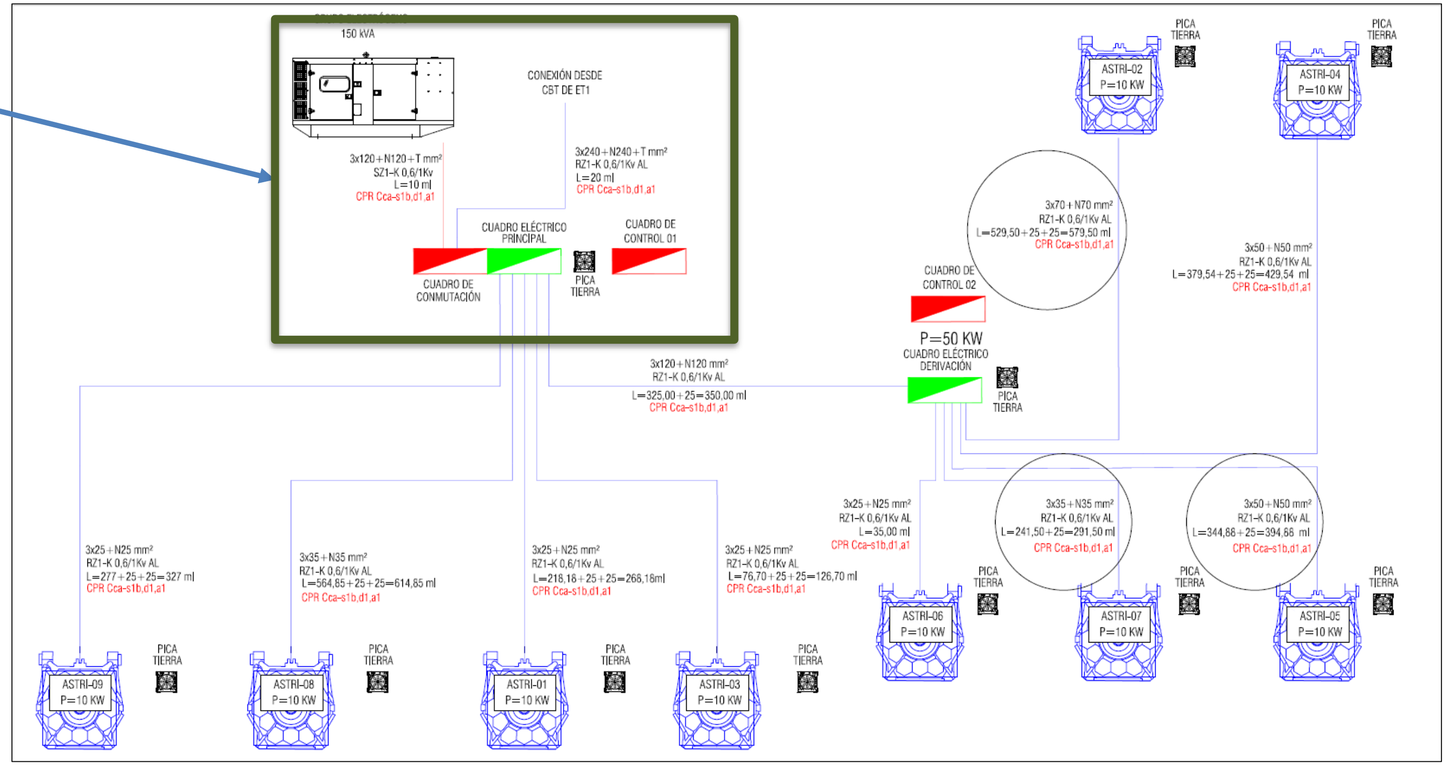




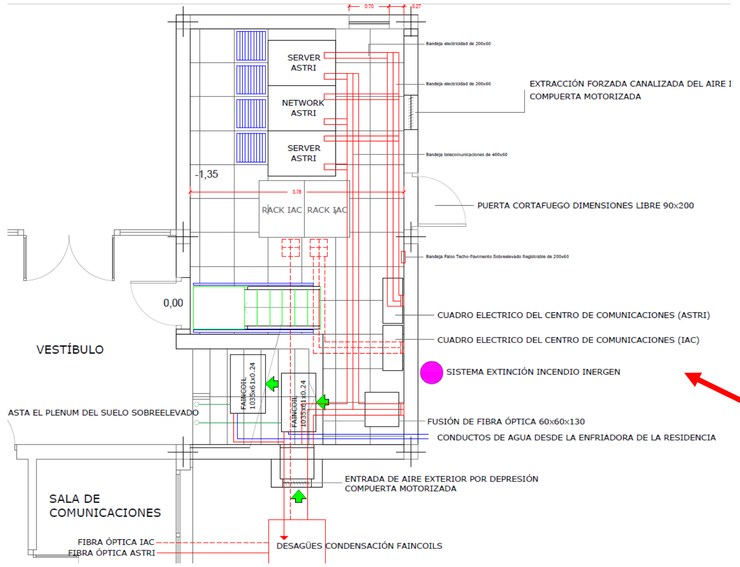
Service cabinet

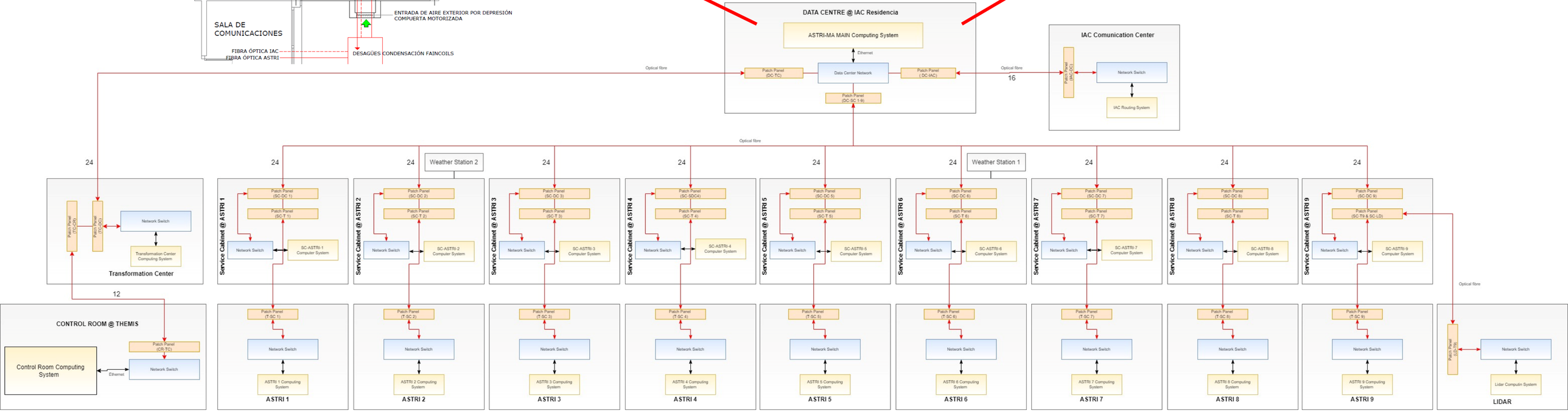
Infrastructure: Power network





Infrastructure: Telecommunication network





Infrastructure: Care of environment

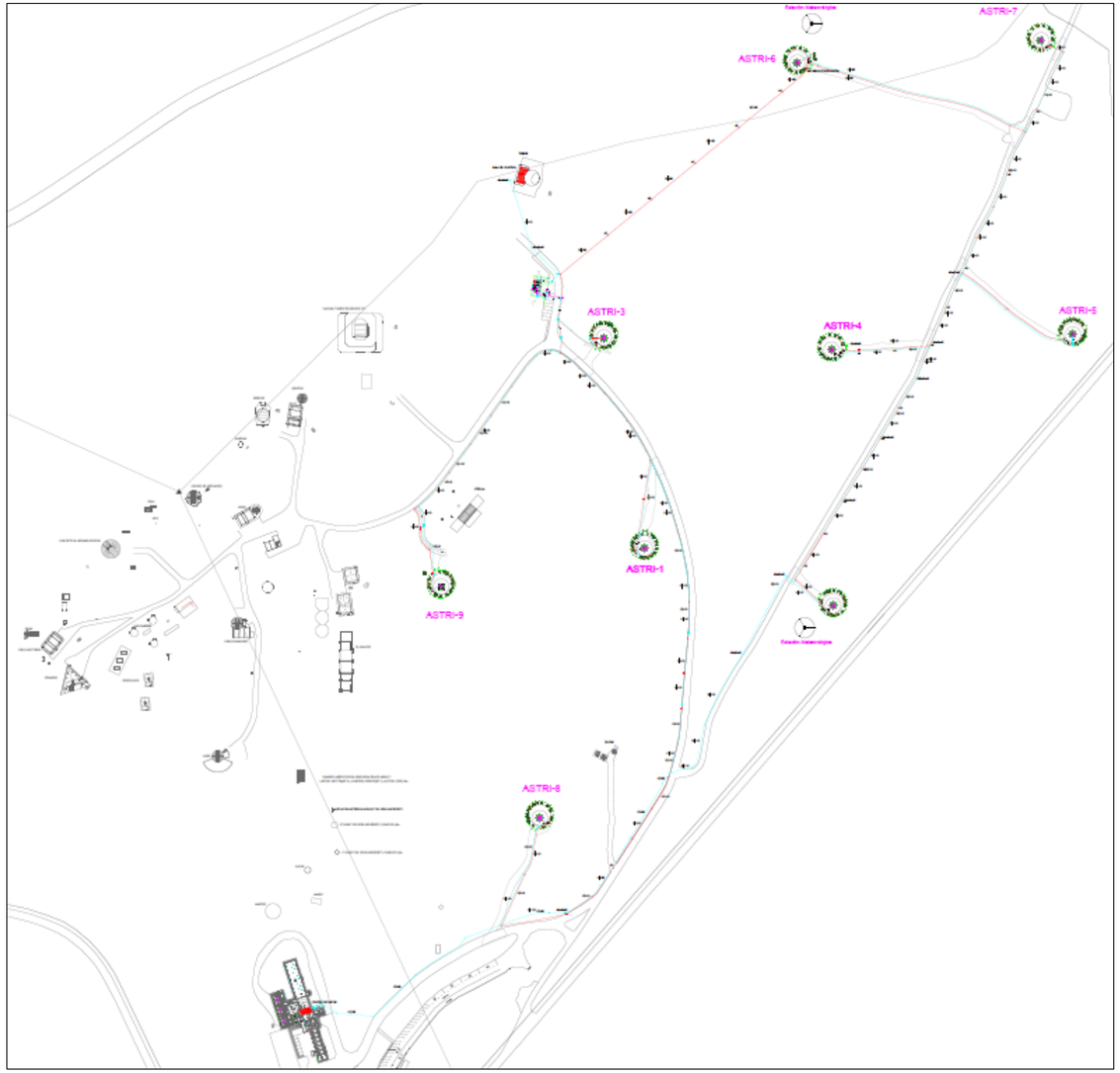
Continuous contact with botanist of *Medio Ambiente* to address and resolve any issue related to protected species of plants (*Retama*) in the areas of construction.

- ***Replanting (young plants)***
- ***Keeping in place (treat affected roots and branches)***
- ***Removing (old plants > 4 years)***
- ***Planting new specimen***

Status of the infrastructure

- All telescope foundations completed
- Excavations and tubes for power and data network completed
- Control room @ Themis completed

- Data Centre completed by half June
- Transformation Centre to be completed by the end of June with UPS and Power diesel generator
- Electric cables & optical fibres being laid

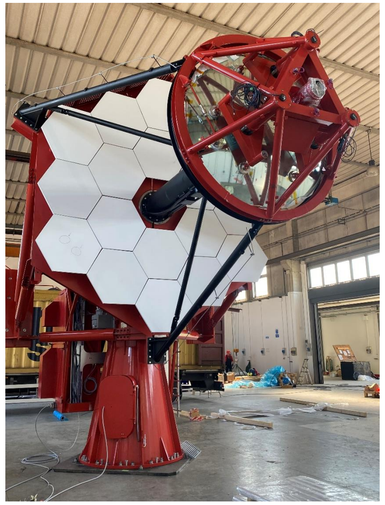


Status of production: ASTRI-1 integration

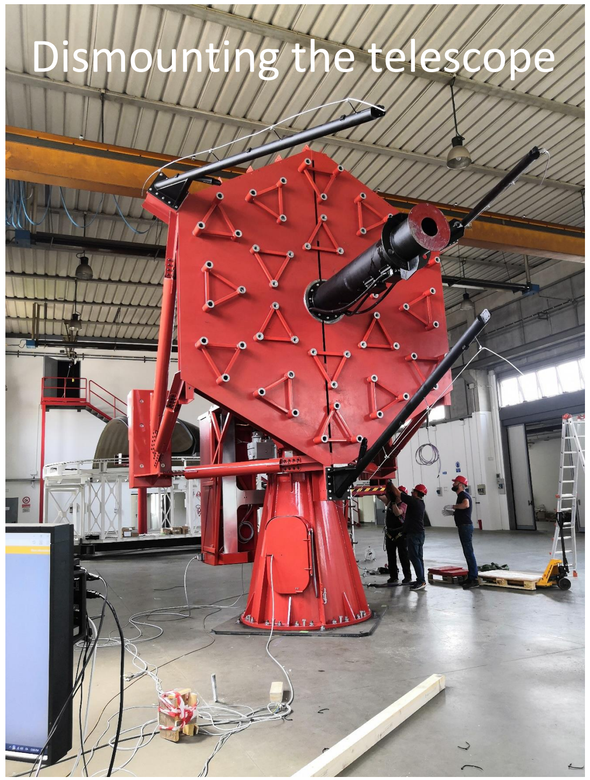


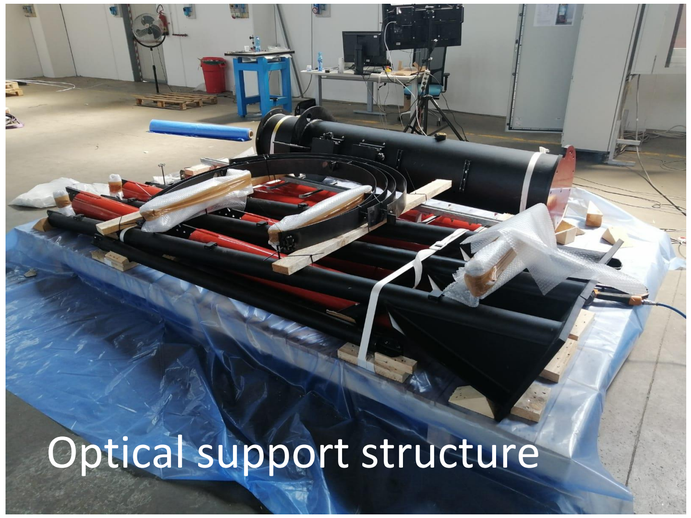




ASTRI-1: disassembling, packing and transportation



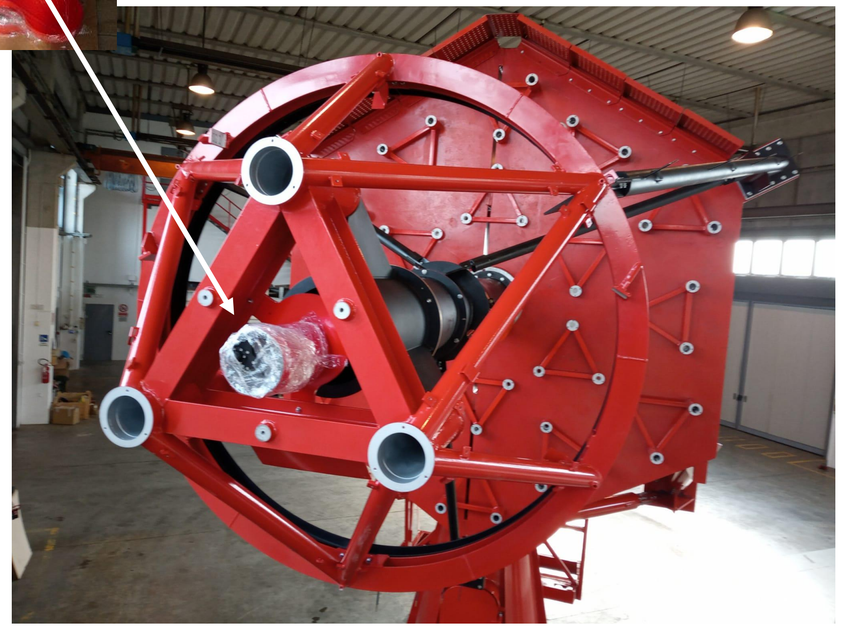


Telescope's auxiliaries

Pointing Monitoring Cameras (Uni-PG)

→ First three delivered at Italy integration site

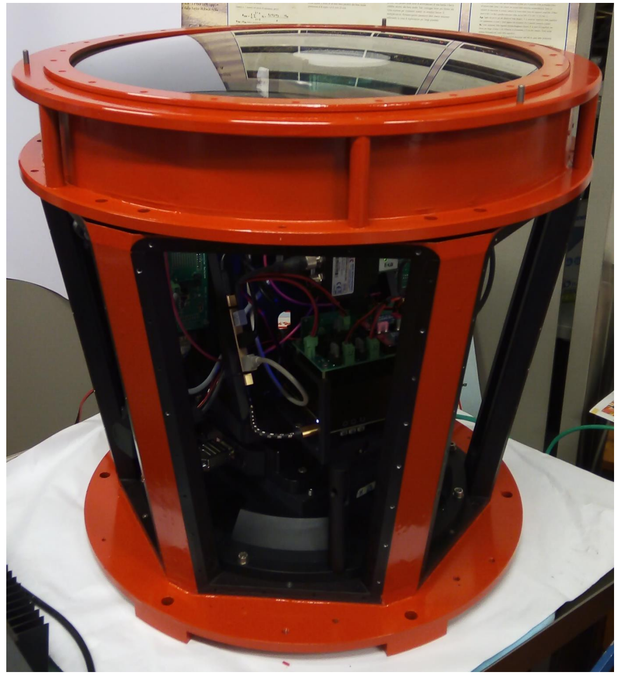
→ PMC of ASTRI-1 shipped mounted on the telescope

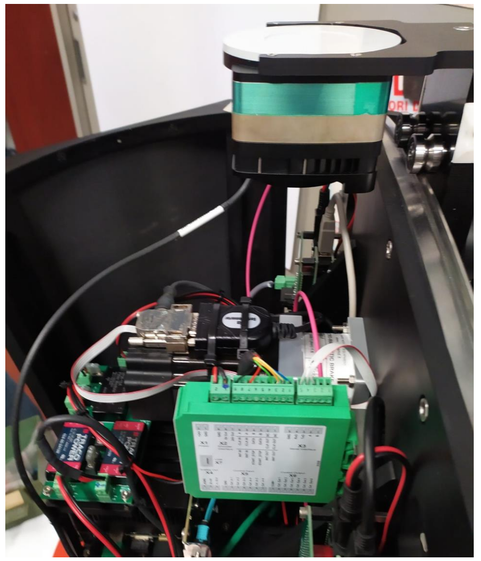


CCD camera placed on the M2 support structure used to monitor pointing and tracking performances of the telescope.

Optical Camera (IASF-MI, OAPD, OACT, OA Brera)

→ Ready to ship



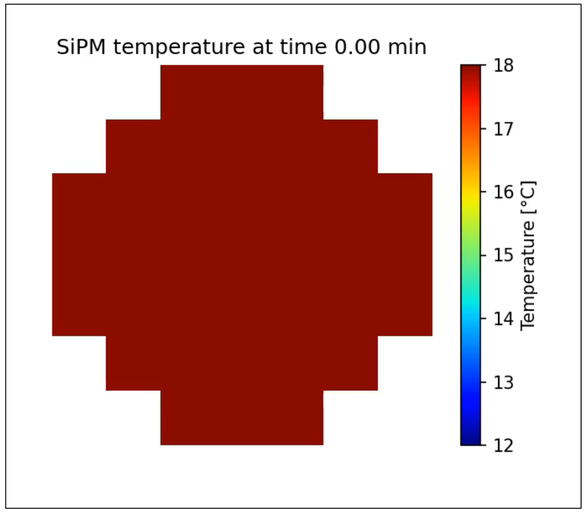


CCD camera placed on the telescope focal plane to align the panel of M1

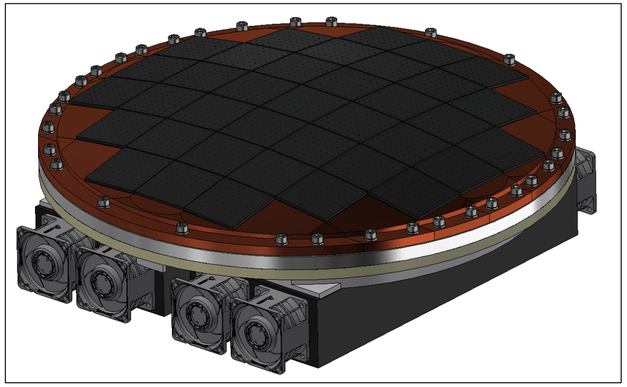
Cherenkov Cameras

Mini-Array

Design & simulation



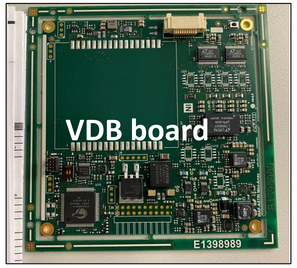
Camera thermal model: evolution of SiPM temperature (T_{env}=25 °C)

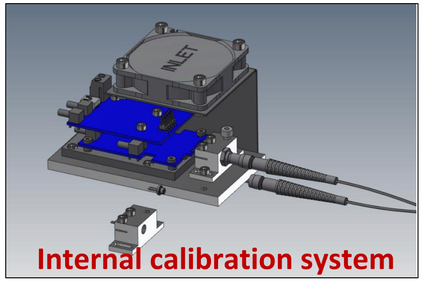


Focal plane support structure

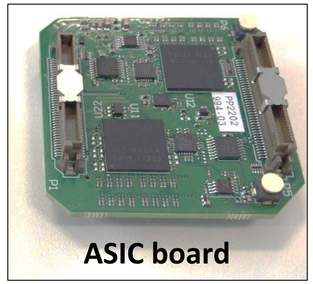
Ongoing contract for the construction of 11 Cherenkov Cameras

Prototyping



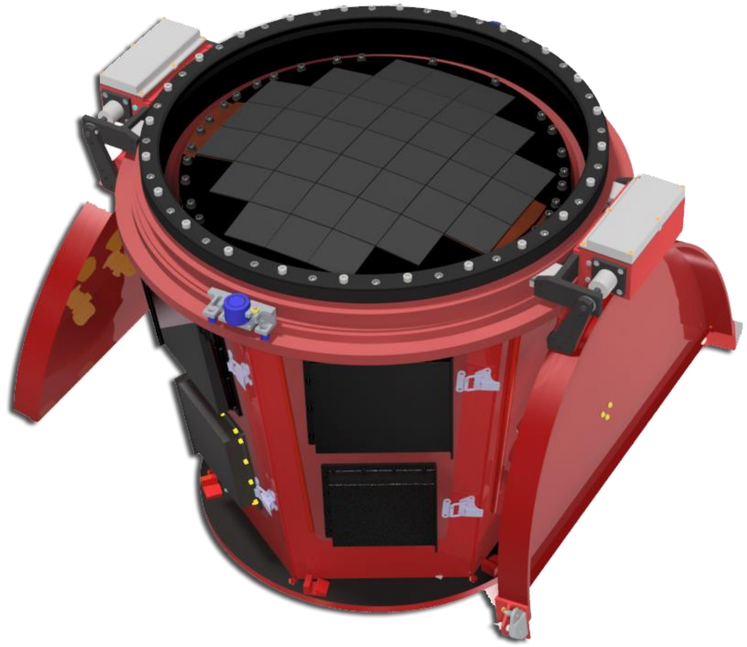


Production



CAEN Tools for Discovery

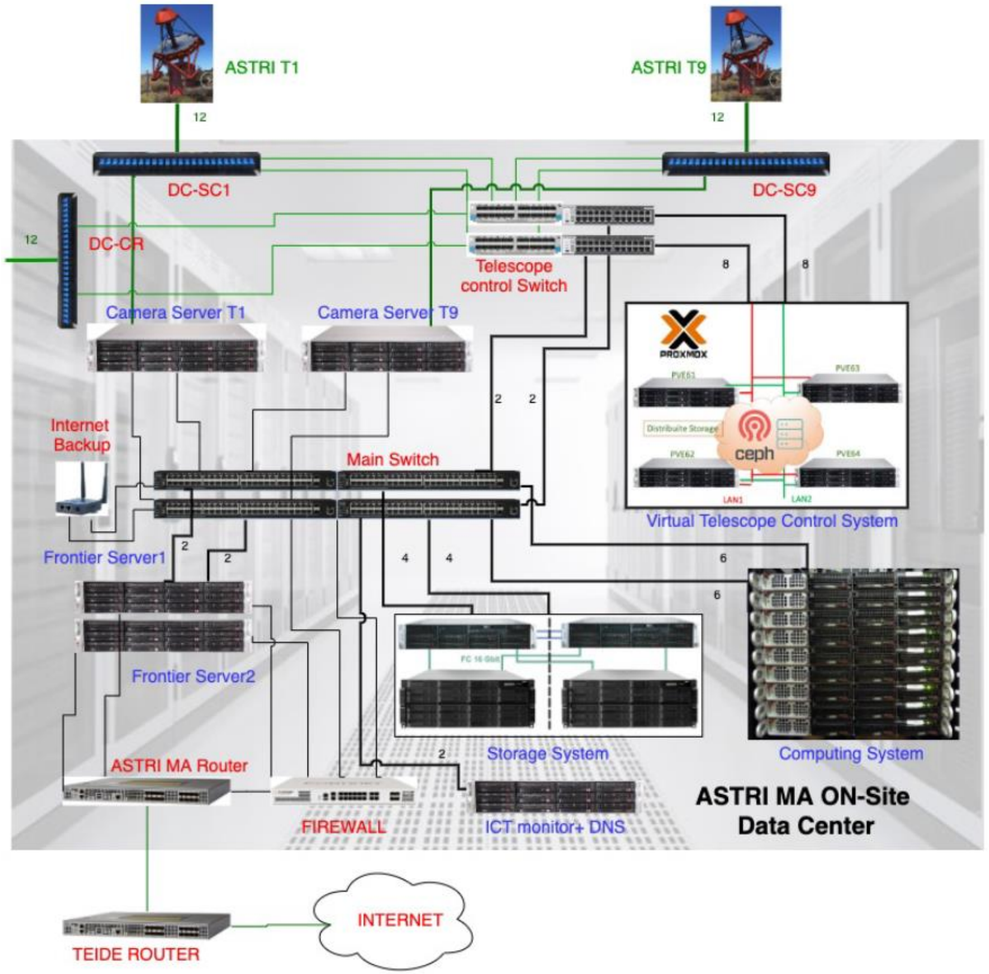
EIE GROUP

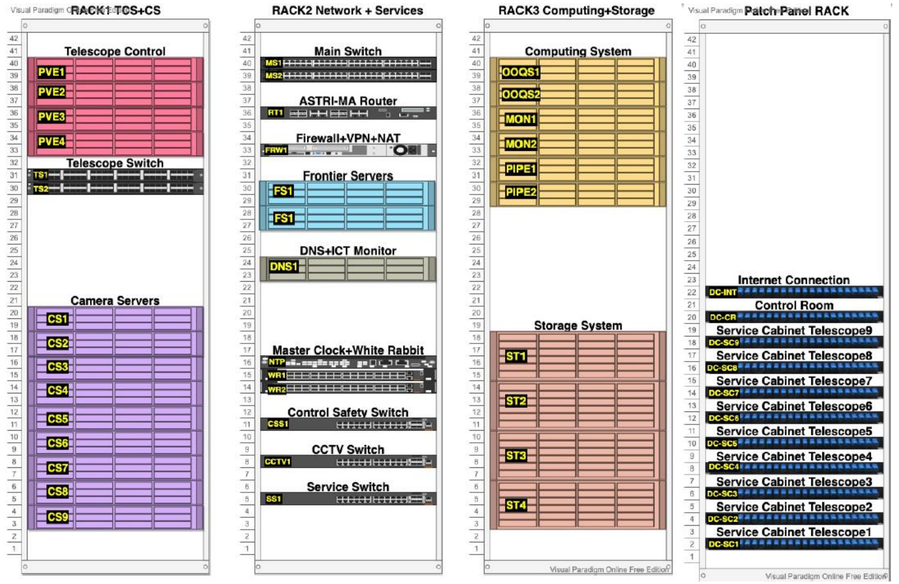


HAMAMATSU PHOTON IS OUR BUSINESS

Delivered 346 out of 450

ICT – On site Data centre





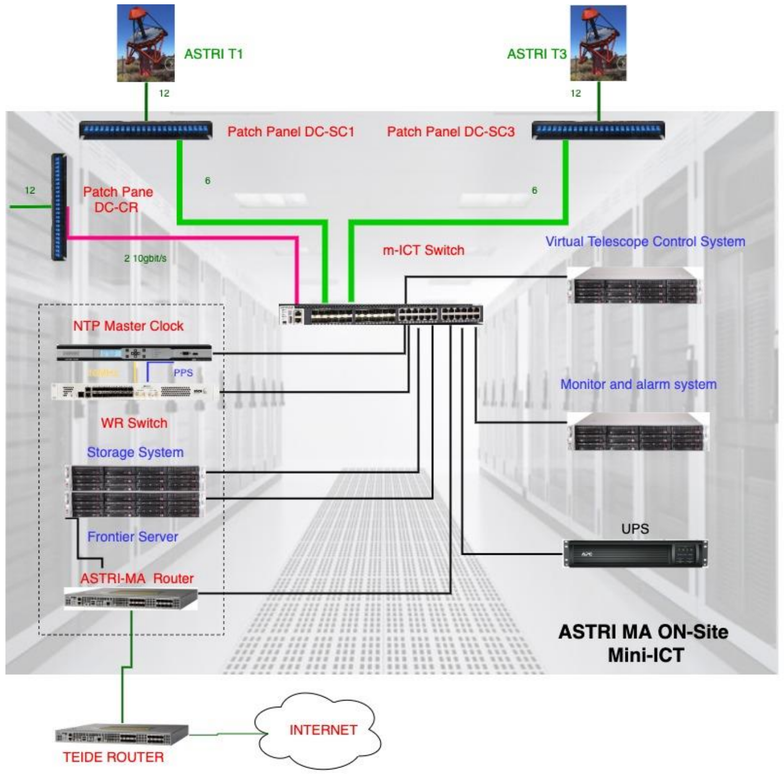
- ***Virtual Telescope Control System***: the system hosting the virtual machines that will be used for the telescopes control.
- ***Camera Servers***: are the physical servers, one for each telescope, for the Cherenkov camera and stellar intensity interferometry data acquisition.
- ***Computing System***: is the set of physical servers dedicated to the on-line analysis of scientific data for quality check and of monitoring data for the alarm management.
- ***Storage System***: is the collection point of the raw scientific data, of the monitoring and of the alarm data. It also the location from where all these data are accessible for remote transfer and for all on-site uses.
- ***Network System***: is the set of devices responsible for internal and external network connections.

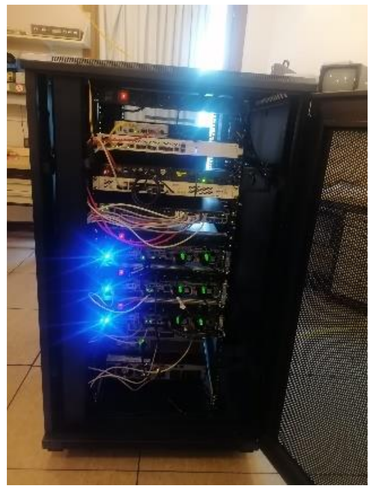
Tender still to be issued → documentation ready

mini-ICT

m-ICT

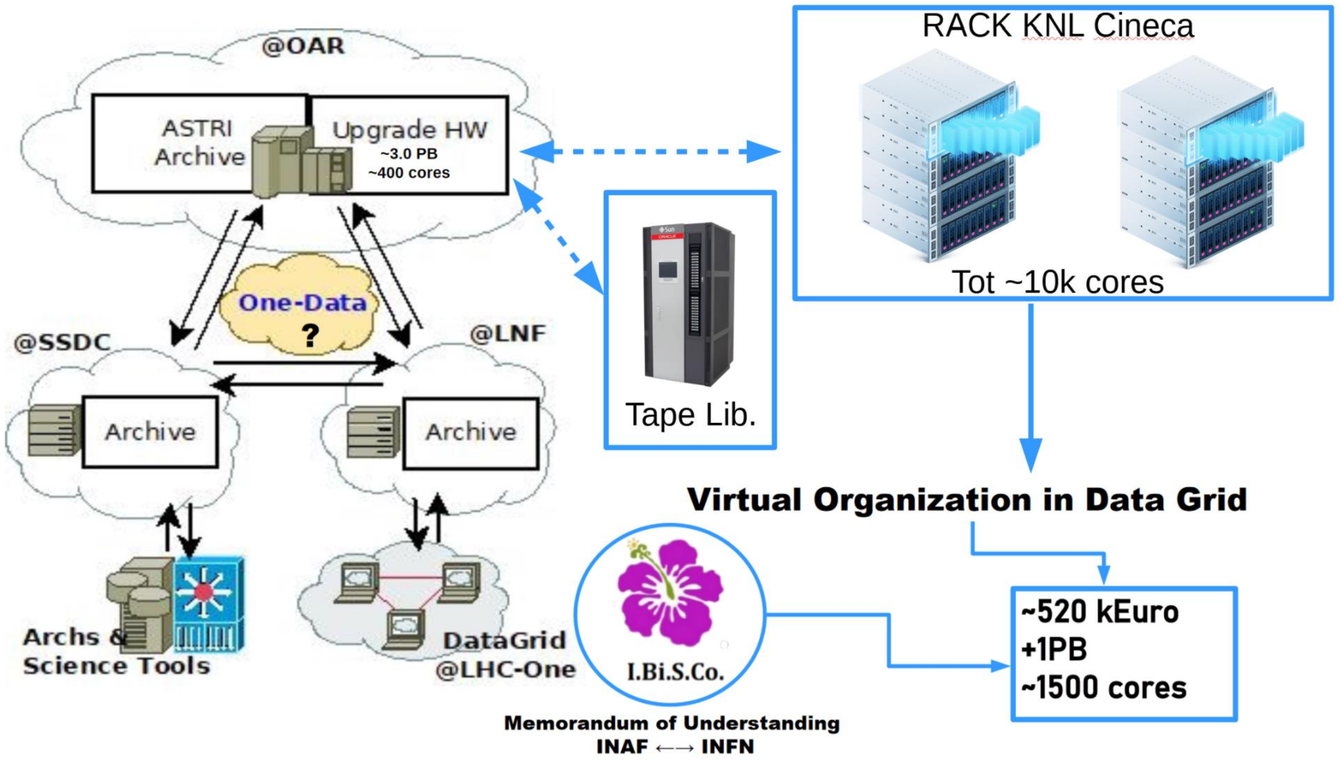
- Reduced version of the onsite ICT
- Allow to run single telescopes
- Preliminary installation @ Themis completed (F. Gianotti & coll.)
- Final installation @ data centre → week of 13th of June





Control room ICT architecture

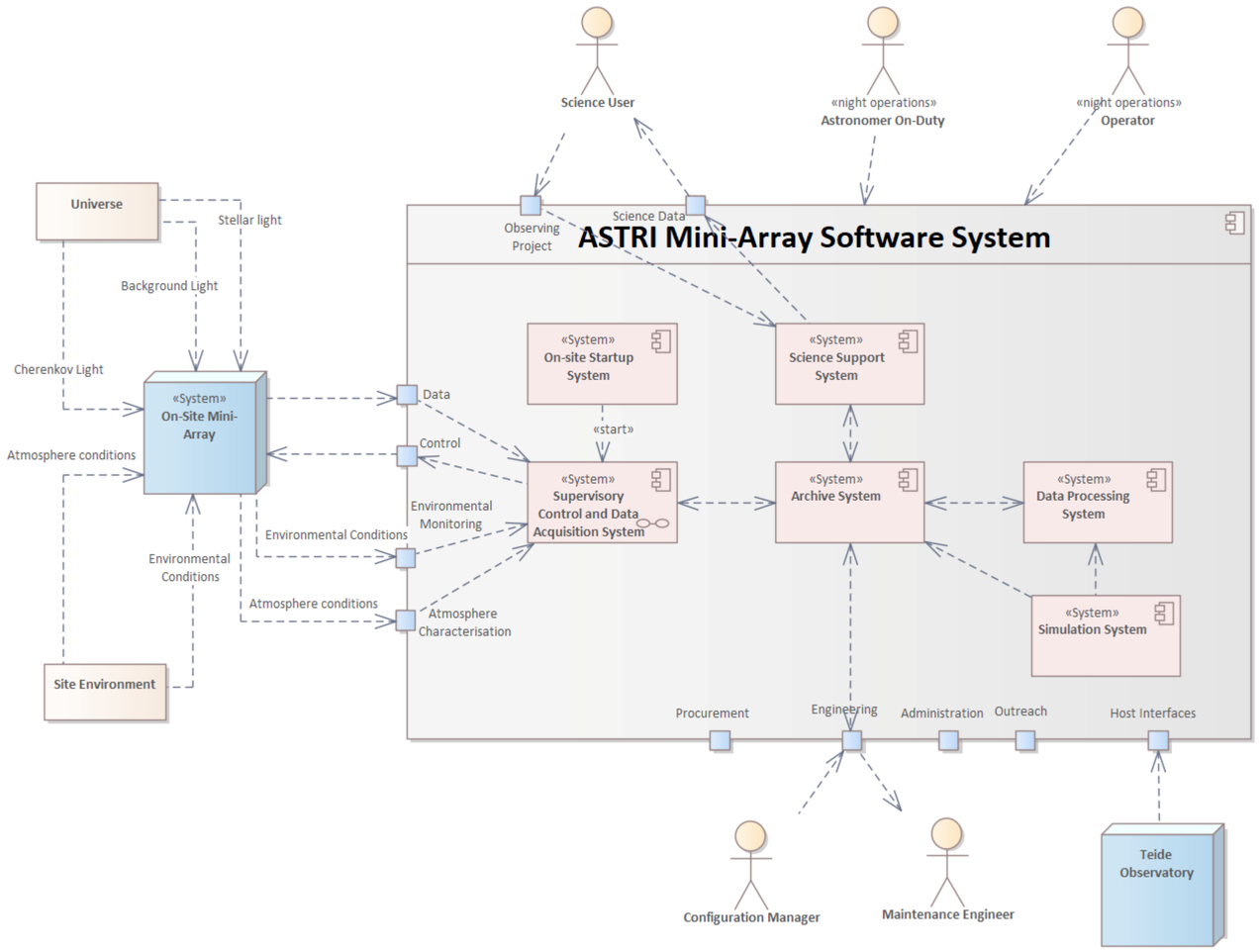
ICT – Offsite data centre



A distributed archive solution will be adopted for the ASTRI Mini-Array archive with three main nodes

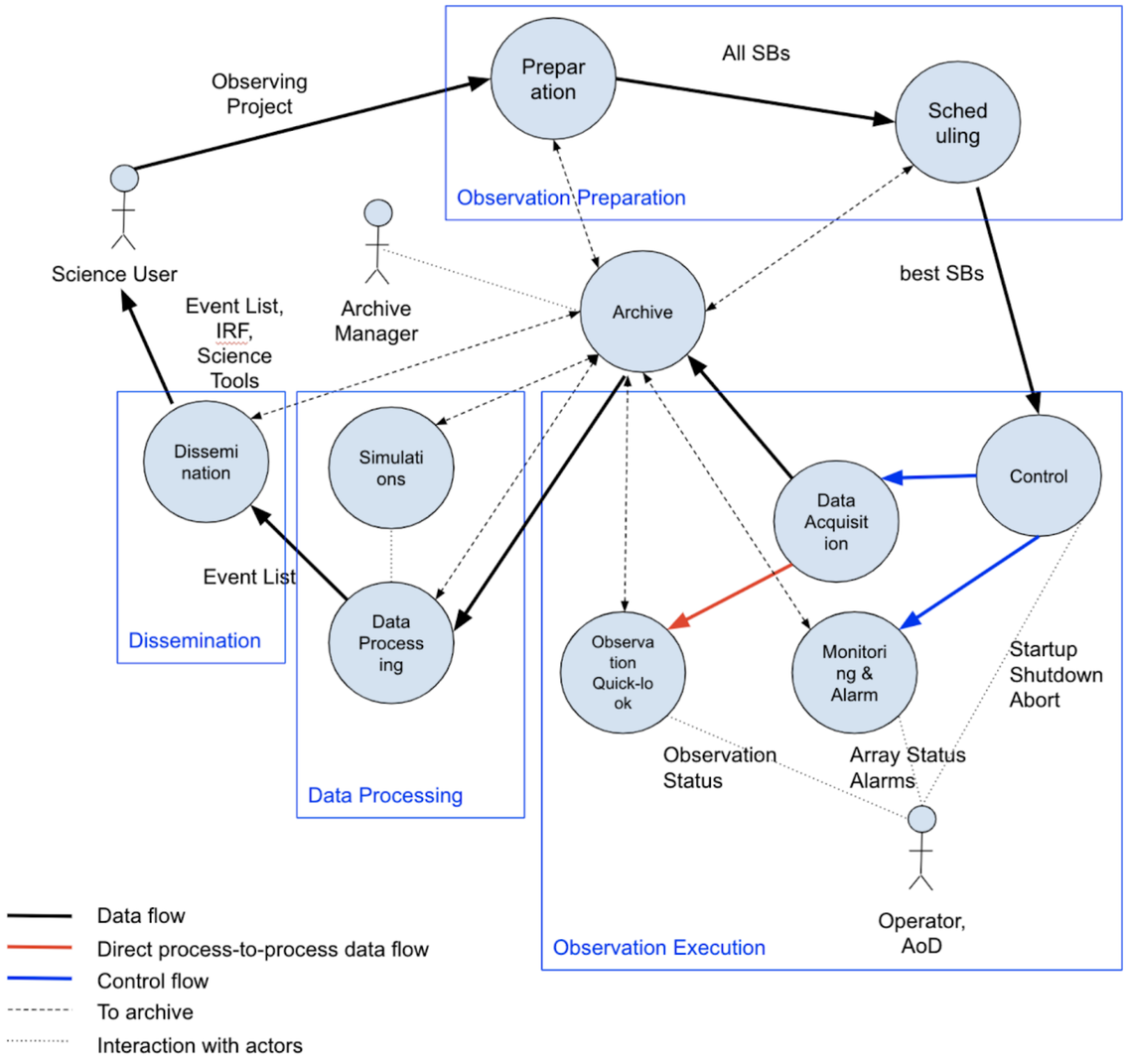
1. INAF – OAR: central storage and computing nodes
2. INFN – LNF: for access to Data Grid infrastructure
3. ASI – SCDC: to interface high level ASTRI Mini-Array science archive with multiwavelength SCDC facilities and science tool services

Software: architecture



- ***Supervisory Control And Data Acquisition (SCADA) System*** The software system devoted to control all the operations carried out at the Mini-Array site, including the startup of the Mini-Array system. SCADA is a central control system which interfaces and communicate with all equipment and dedicated software installed On-Site.
- ***Archive System*** The software service that provides storage and organization for all data, data products, and metadata generated for and by the Mini-Array, and defined by the Mini-Array Data Models.
- *Data Processing System* The software system used to calibrate and reduce the data acquired. This software is also used to check the quality of the final data products.
- ***Science Support System*** The software system which provides the main point of access for the exchange of science-related data and information with the ASTRI Science Users, and which supports the whole science-related workflow, from the Observing Project submission to the access to the archived high-level Mini-Array science data products and the corresponding Science Tools to support data analysis.
- ***Simulations System*** The software system that runs Monte Carlo simulations to provide simulated data for the development of reconstruction algorithms and for the characterization of real observations.
- ***Local Control Software*** Firmware and low-level software dedicated to the low-level hardware control operations.

Software: data & information flow



The ASTRI Mini-Array software is envisioned to handle an observing cycle, i.e. the end-to-end control and data flow system. The observing cycle can be divided into the following main phases:

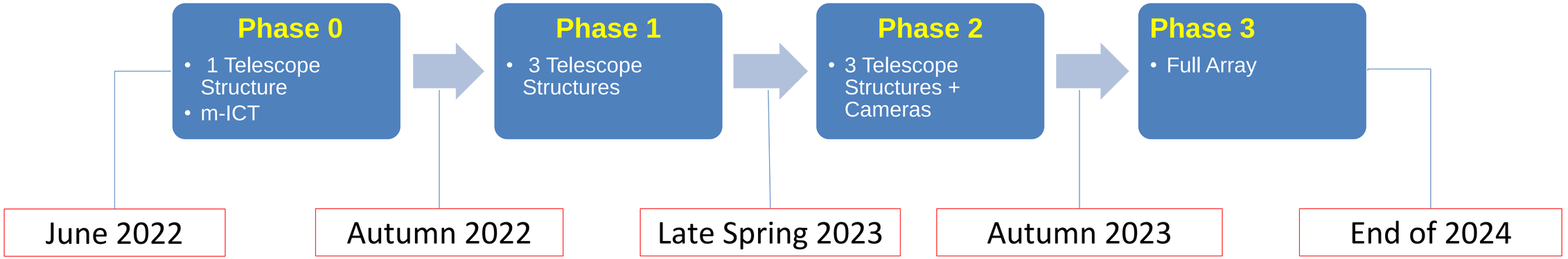
1. Observation preparation
2. Observation execution
3. Data Processing
4. Dissemination

Software development mainly by INAF

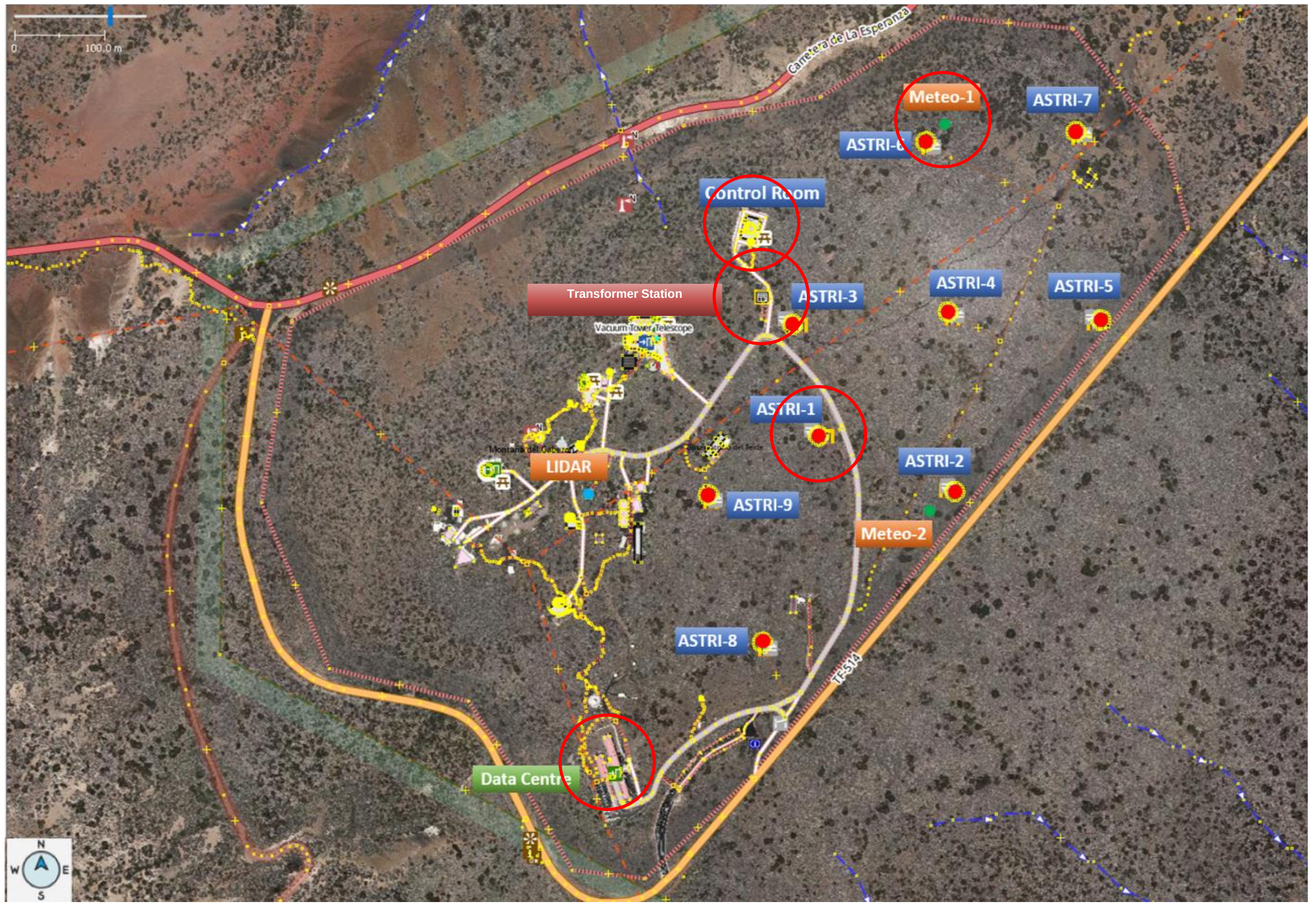
Support by external companies/research institutions on specific aspects as for example:

- Central Control System by Universidad Tecnica Federico Santa Maria (SCADA)
- Operator Human Machine Interface by University of Geneve (SCADA)

Implementation phases: schedule

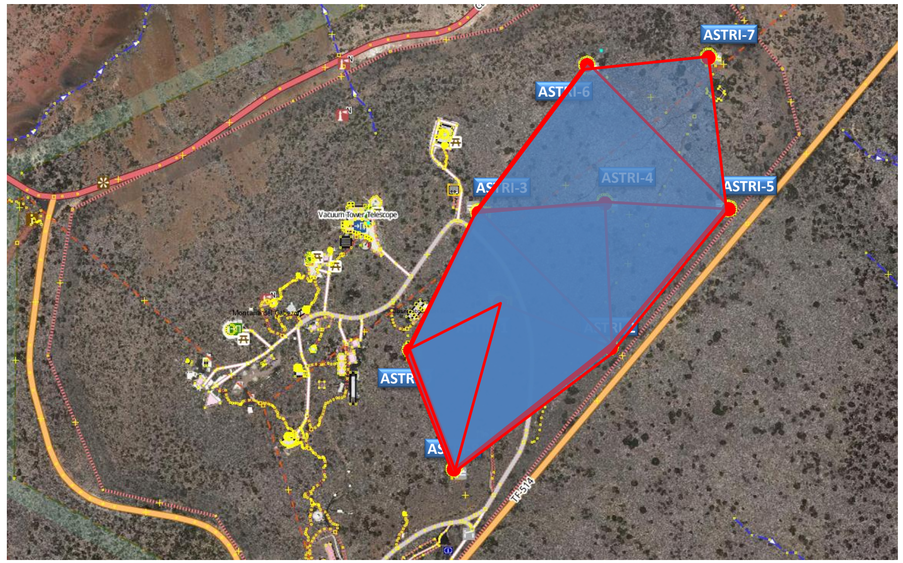


Implementation phase 0 - Summer 2022



- ASTRI-1
- Transformer Station
- Control Room
- Data Center (m-ICT)
- Meteo station 1
- Power & Telecommunication Network

Implementation: populating the array



ASTRI Mini-Array

View from Vacuum Tower Telescope