The ASTRI Mini-Array at Teide Observatory

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Outline

The ASTRI Mini-Array Project:

- Scope & Organization
- Teide Observatory
- Hardware & Software
- Schedule & Status
- Operations
- Expected performances
- Science

ASTRI Mini-Array project

ASTRI *(**A**strofisica con **S**pecchi a **T**ecnologia **R**eplicante **I**taliana) has started as a* "Progetto Bandiera" funded by MIUR with the initial aim to design, realize and deploy an innovative end-to-end prototype of a dual mirror (Schwarzschild-Couder) 4 meters class Cherenkov telescope in the framework of the CTA observatory. It has been installed at INAF Observatory in Serra La Nave (Catania) on Etna Volcano in 2014 and it observed a gamma source (the Crab nebula) in 2018.

The **ASTRI Mini-Array** is a project aimed 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.

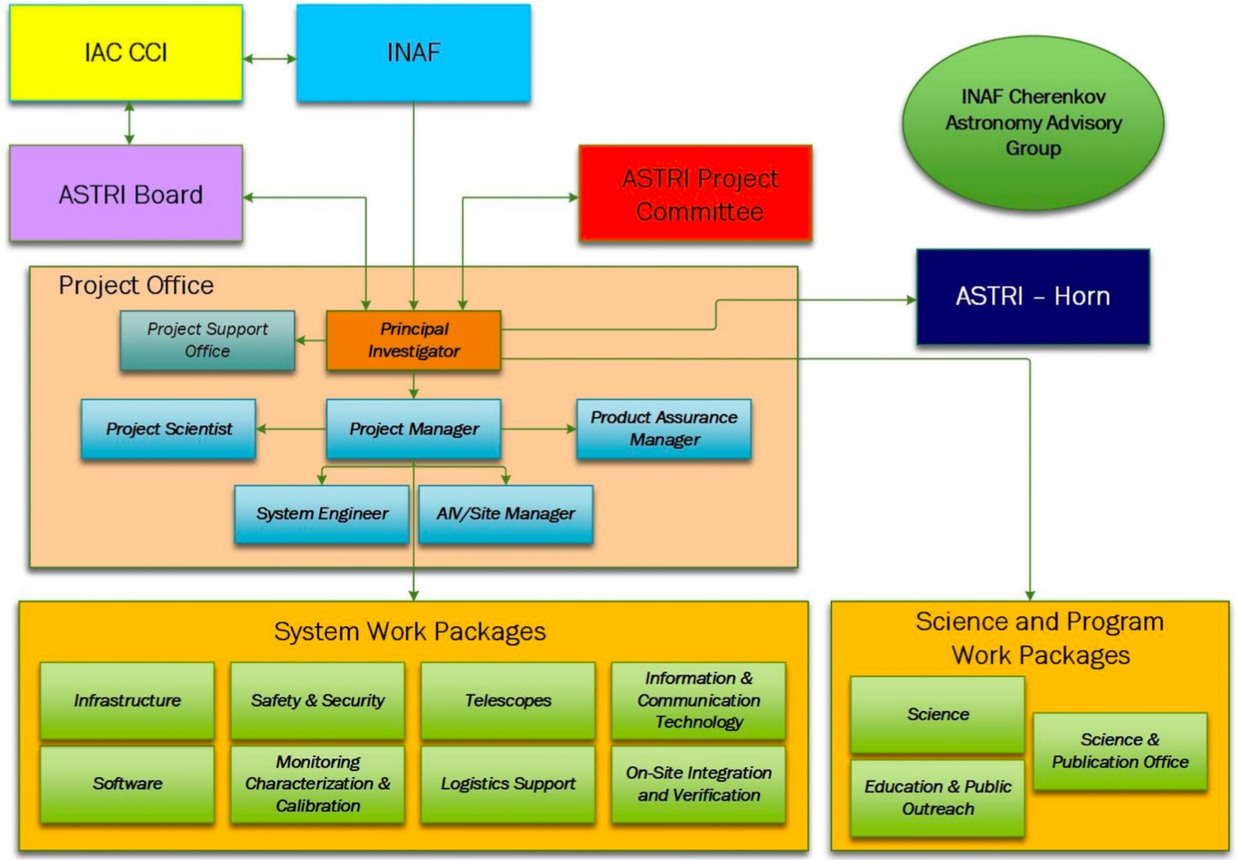
The project is involving more than 150 hundred researchers belonging to:

- INAF institutes (IASF-MI, IASF-PA, OAS, OACT, OAB, OAPD, OAR)
- Italian Universities (Uni-PG, Uni-PD, Uni-CT, Uni-GE, PoliMi)
- Italian Research Institutes (INFN – RM2, ASI – SSDC)
- International institutions (University of Sao Paulo – Brazil, North-West University – South Africa, IAC – Spain).

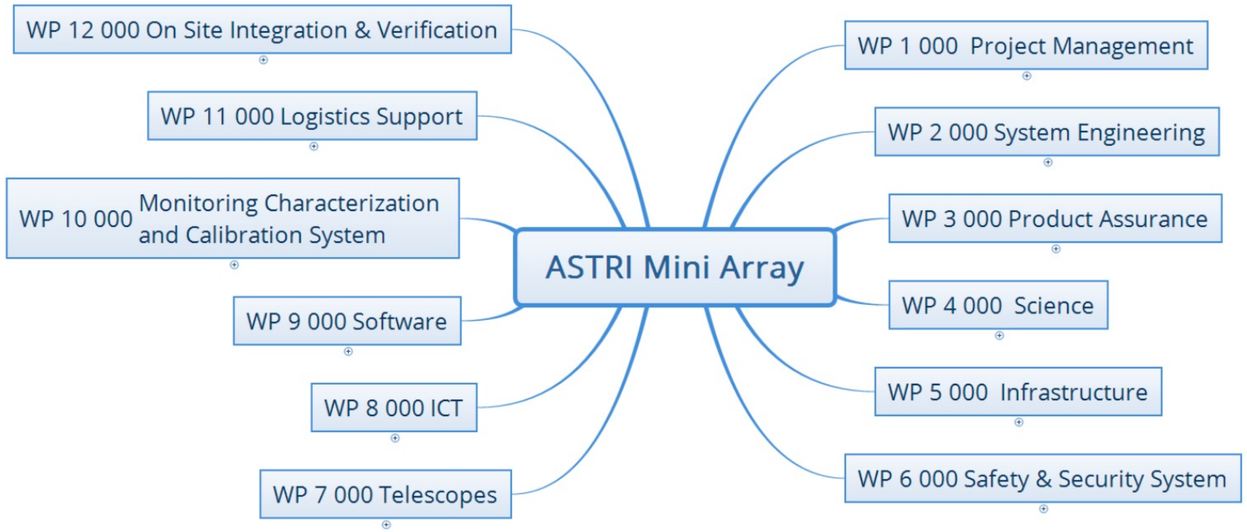
Both Italian and foreign private companies are involved in the ASTRI Mini-Array project providing an important industrial return.

ASTRI Mini-Array Project: organization

Principal Investigator: *Giovanni Pareschi*
Program Manager: *Salvo Scuderi*
Project Scientist: *Andrea Giuliani*



Work Breakdown Structure



ASTRI Mini-Array Project: components

- **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 sci and engineering data.
- **Software**: The Mini-Array software will provide to the user a set of tools from th observing proposal to the execution of the observations, the analysis of th retrieval of all the data products from the archive.
- **Monitoring, Characterization and Calibration**: the set of devices that allows monitoring the atmospheric characterization and the array calibration.
- **Logistics Support**: includes all the hardware & software necessary for the prev maintenance of the ASTRI Mini-Array.

See ASTRI Posters on calibration tools and procedures:

#234 by Compagnino et al.
#243 by Mineo et al.

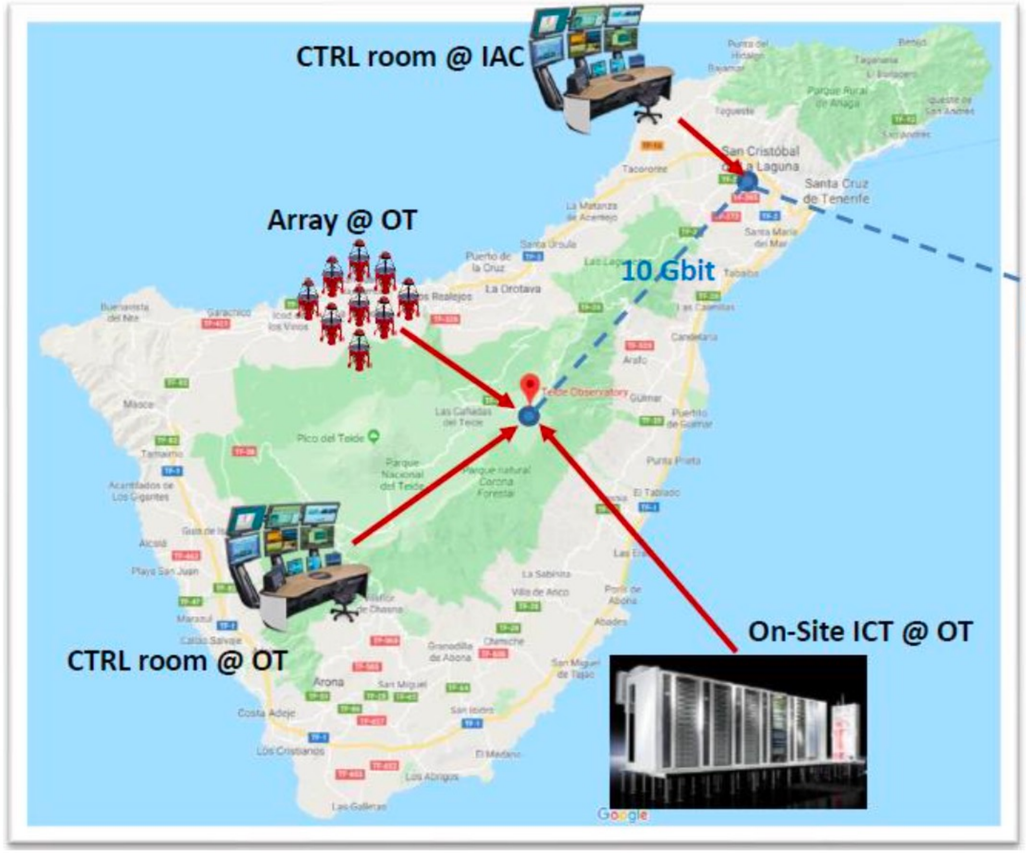
ASTRI Mini-Array

The ASTRI Mini-Array in Tenerife

- Telescope Array & auxiliaries
- Local Control Room @ THEMIS building
- On site Data Centre @ IAC Teide Residencia
- Array operation center, offices and warehouses @IAC in La Laguna

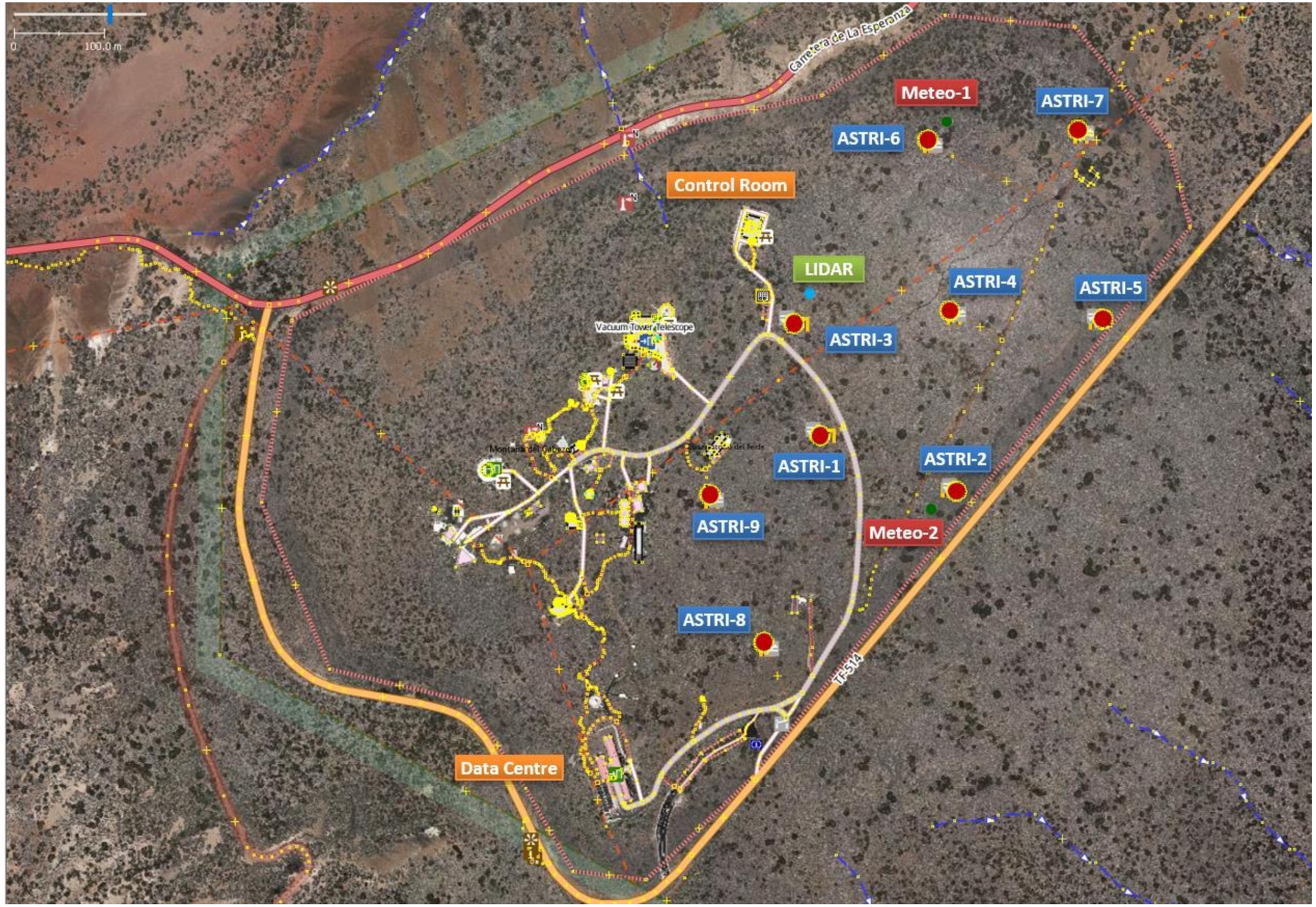
The ASTRI Mini-Array in Italy

- Data Centre in Rome
- Array operation centers (in principle any INAF institute involved)

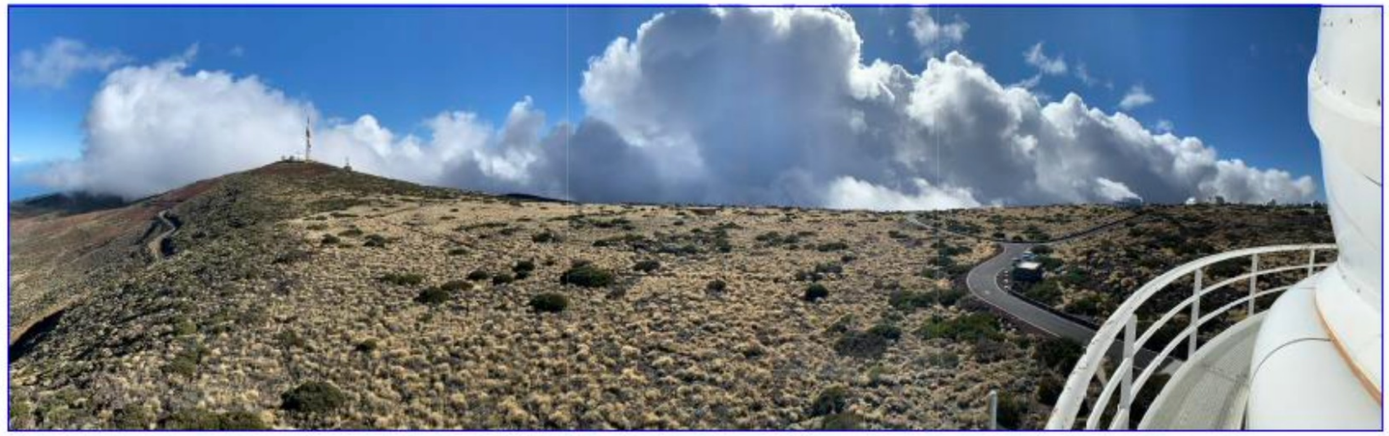


ASTRI Mini-Array @ Teide Observatory

- **9 telescopes** each placed in a dedicated area.
- **A control room** hosted in Themis building.
- **A data center** hosted at the OT Residencia building.
- **A LIDAR** placed in a dome made available by IAC.
- **Two meteo stations** (nearby ASTRI-6 and ASTRI-2).
- Access roads to telescopes.
- Trenches, cable ducts, cable pits for power, data, timing and safety and security networks including electrical cables and optical fibres.
- Medium to low voltage transformer station UPS and diesel generator for power backup placed close to transformer station.
- **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.



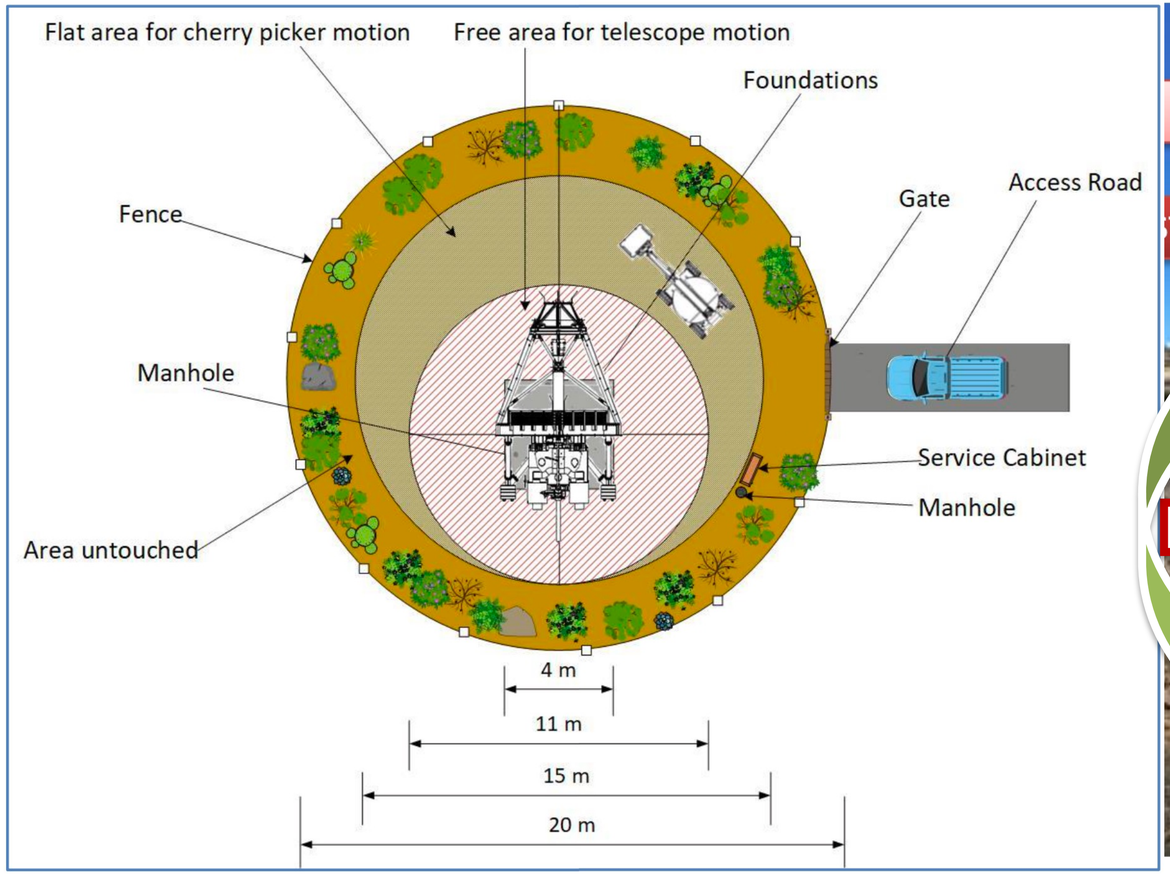
ASTRI Mini-Array @ Teide Observatory

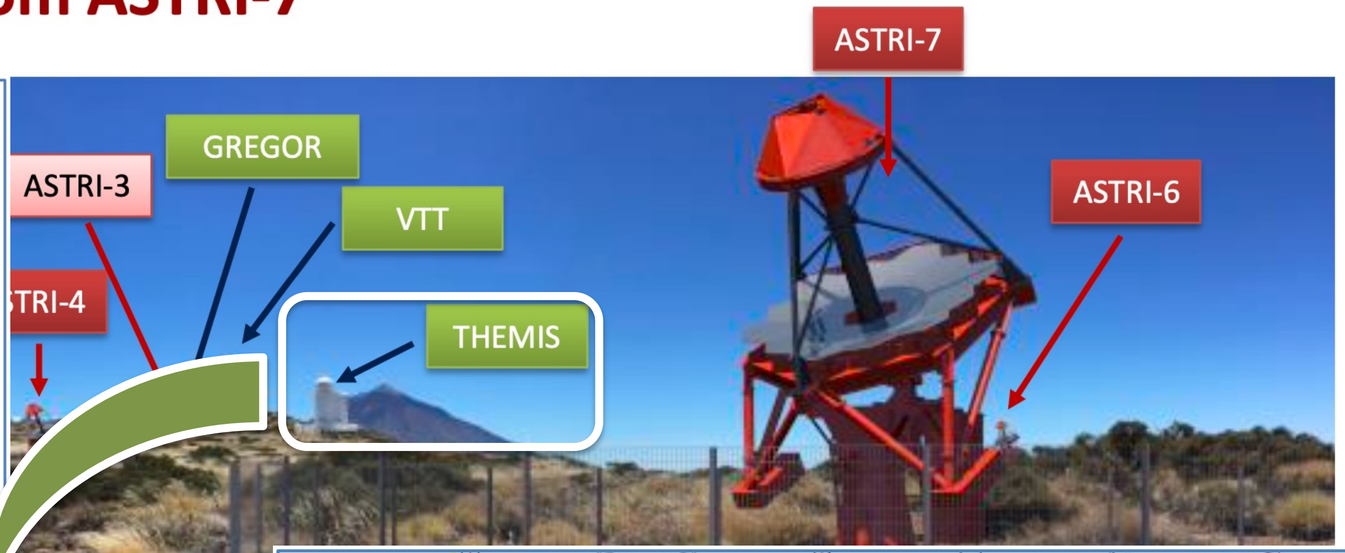


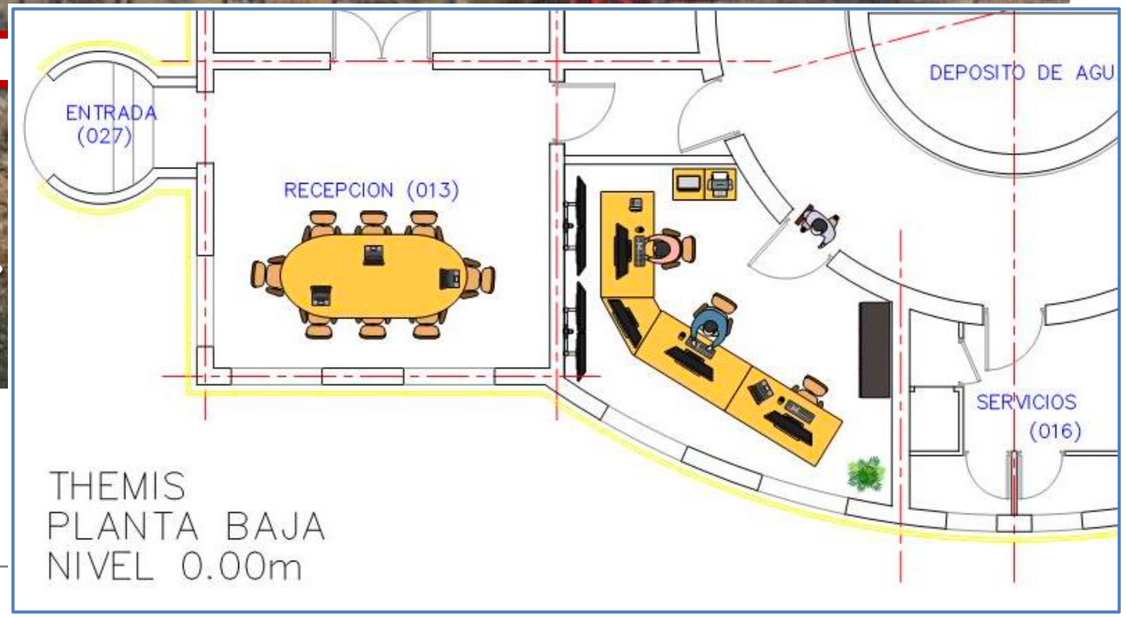
VISTAS DE LA ZONA ASTRIS, DESDE LA TERRAZA DEL THEMIS (5ª PLANTA)

ASTRI Mini-Array @ Teide Observatory

View from ASTRI-7



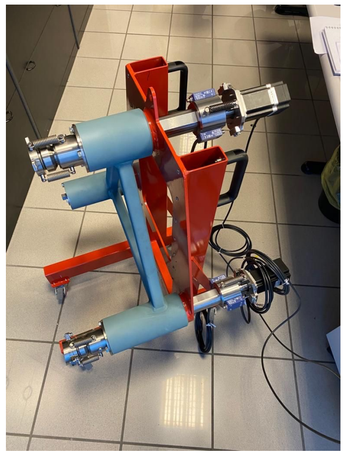




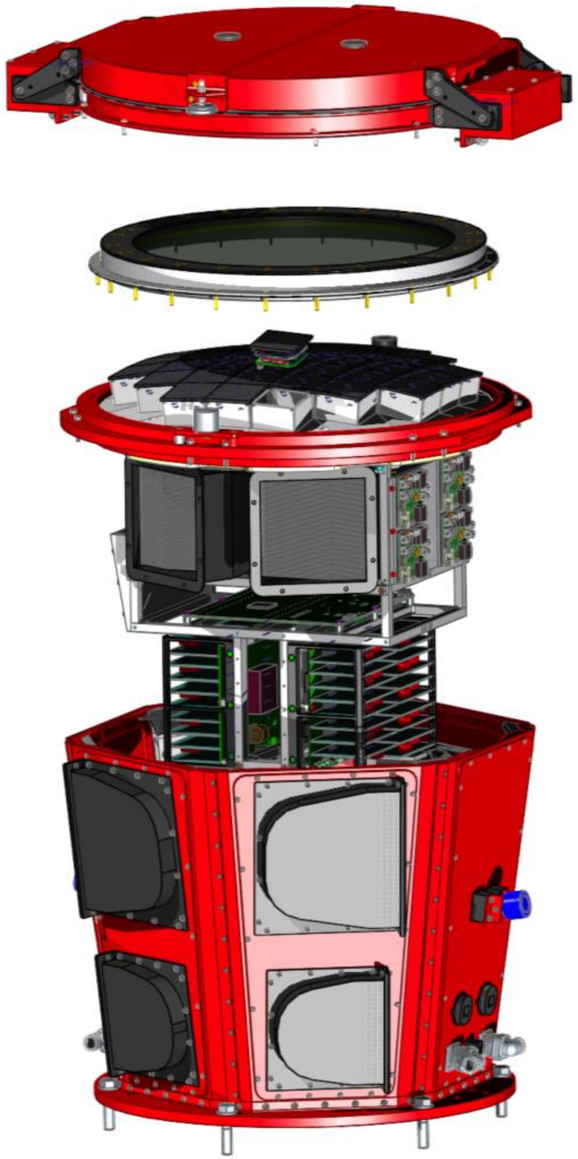
ASTRI Mini-Array Telescopes

Telescope characteristics

Primary mirror = Ø 4.3m
Optical design = Schwarzschild-Couder
M1 type = Segmented (18 exagonal panels, 3 coronae)
Secondary mirror = Ø 1.8m (2.2m RoC)
M2 type = Monolithic
M1-M2 distance = 3m
Optical effective area = ~5 m^2
F/D1 = 0.5, F = 2.15m
Optical PSF ~0.19 deg
Post calibration pointing precision ~7 arcsec

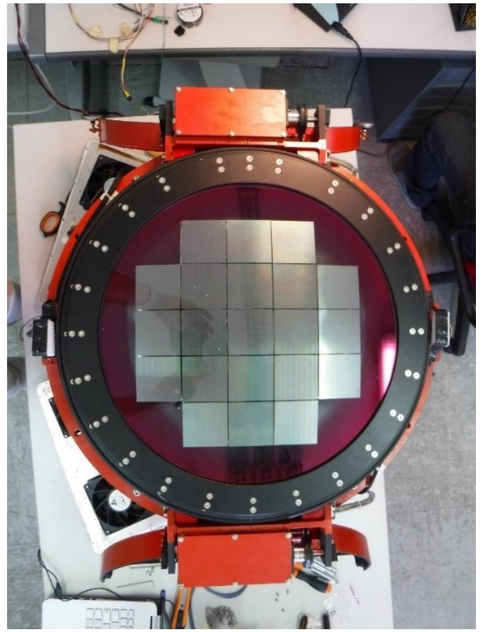


ASTRI Mini-Array Cameras



Cherenkov Camera

- Front End electronics based on CITIROC ASICs
- SiPM sensors
- 2368 pixels (37 matrices, 8x8 pixels, 7x7 mm)
- Field of View: 10.5 deg
- Angular pixel size: 0.19 deg



ASTRI Mini Array Software

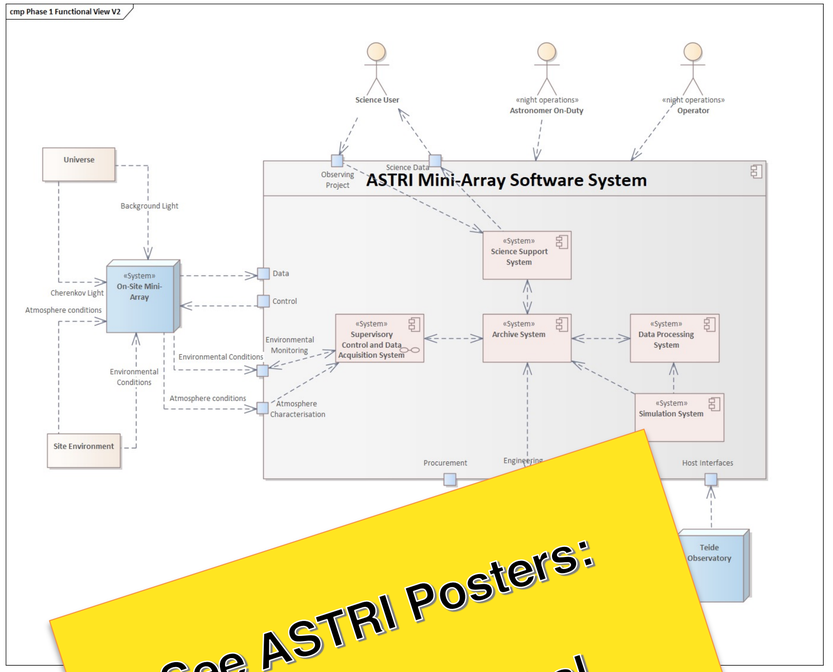
Supervisory Control And Data Acquisition: The software system devoted to control all the operations carried out at the MA site, including the start-up of the MA system. SCADA is a central control system which interfaces and communicate with all equipment and dedicated software installed On-Site.

Archive: The software service that provides storage and organization for all data, data products, and metadata generated for and by the MA, and defined by the MA 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 MA science data products and the corresponding Science Tools to support data analysis.

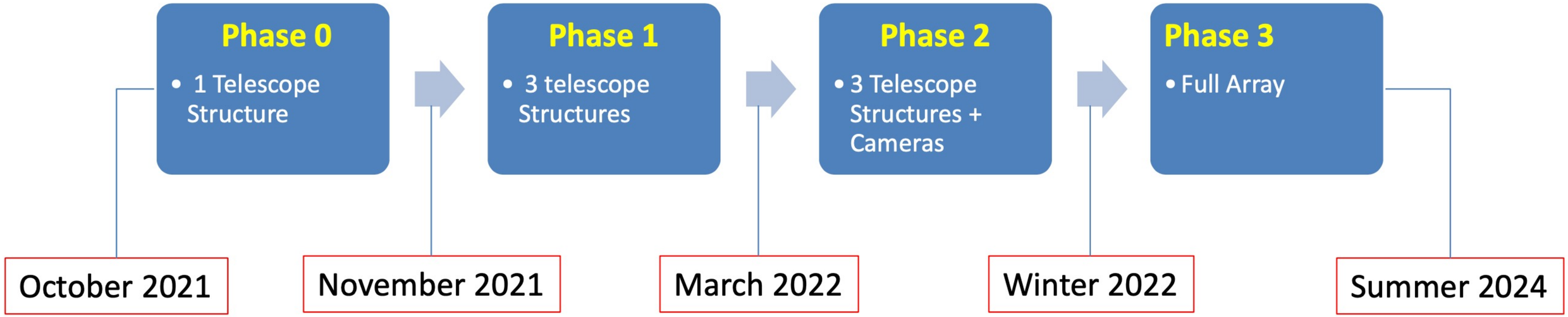
Simulations System: The software system that runs Monte Carlo simulations to provide simulated data for the development of reconstruction algorithms and for the characterization of real observations.



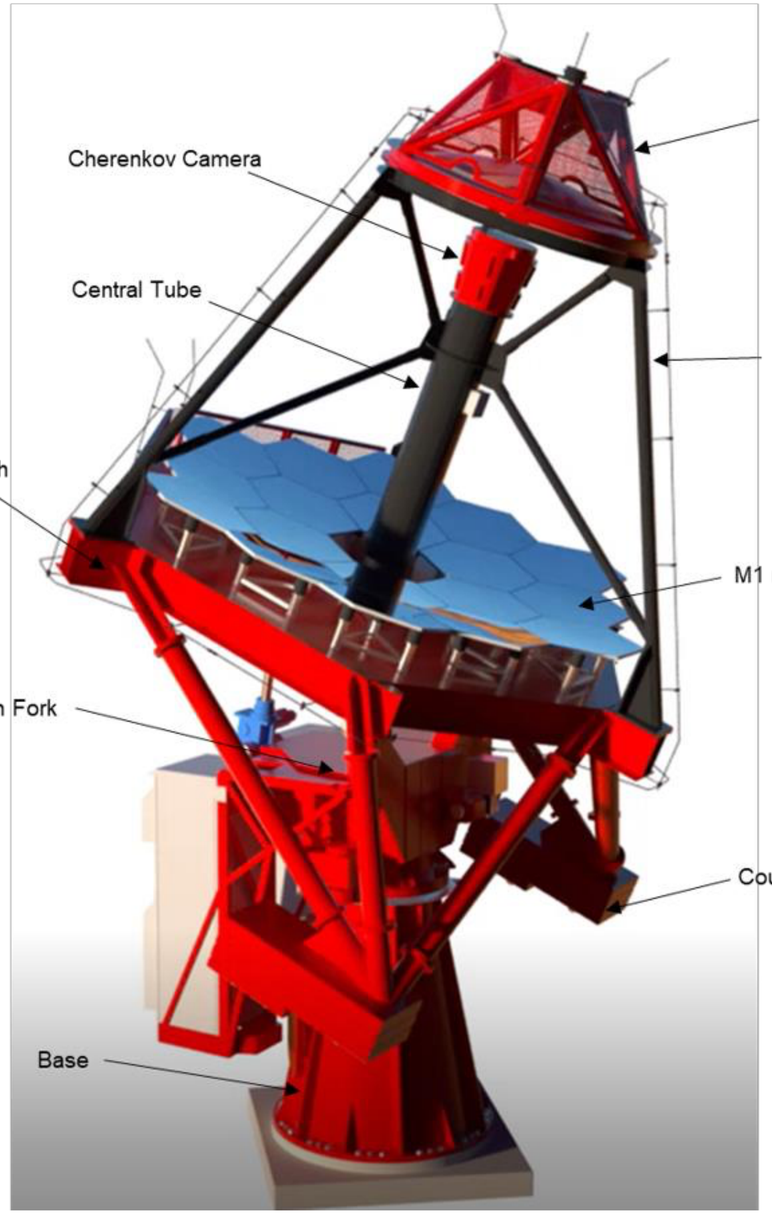
See ASTRI Posters:

#106 by Corpora et al.
#116 by Parmiggiani et al.
#228 by Incardona et al.
#826 by Iovenitti et al.

ASTRI Mini-Array Implementation schedule



Status of ASTRI Mini-Array Hardware



Mechanical structures

- 3 structures in production → Active contract
  - 1st structure ready for test in August → ship in September 2021
  - 2nd and 3rd structures ready for shipping in January 2022
- 6 to go → Tender to be issued shortly

Primary mirrors

- Segments of primary mirrors ready
- First batch delivered for integration on the telescope

Secondary mirrors

- Mirrors ready → 2 delivered for telescope integration

ASICs CITIROC-1A → Delivered

SiPM detectors

- Qualification batch (37 matrices) delivered and accepted
- First production batch (200 matrices) in september

Camera

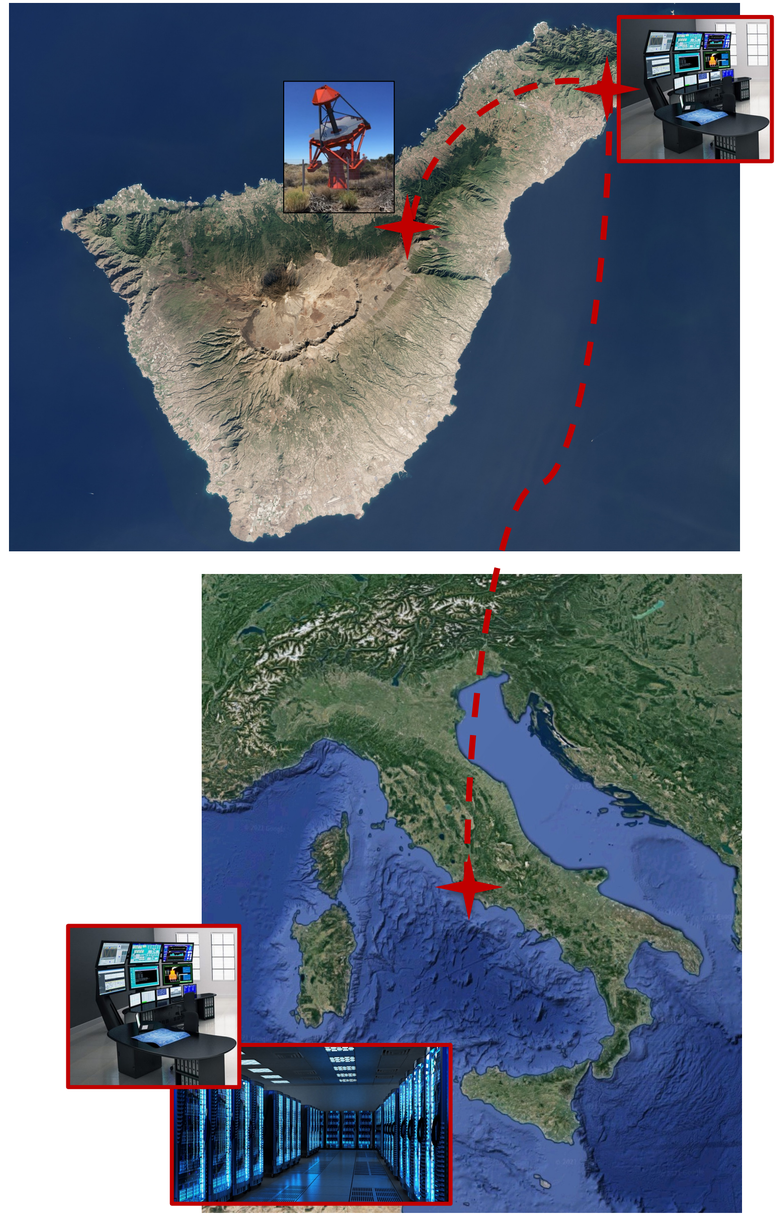
- Contract to be signed by the end of June
- first camera at the site end of summer 2022

Off-site Data Center

- tender already closed, computers and storage to be delivered in september 2021

ASTRI Mini-Array Operations

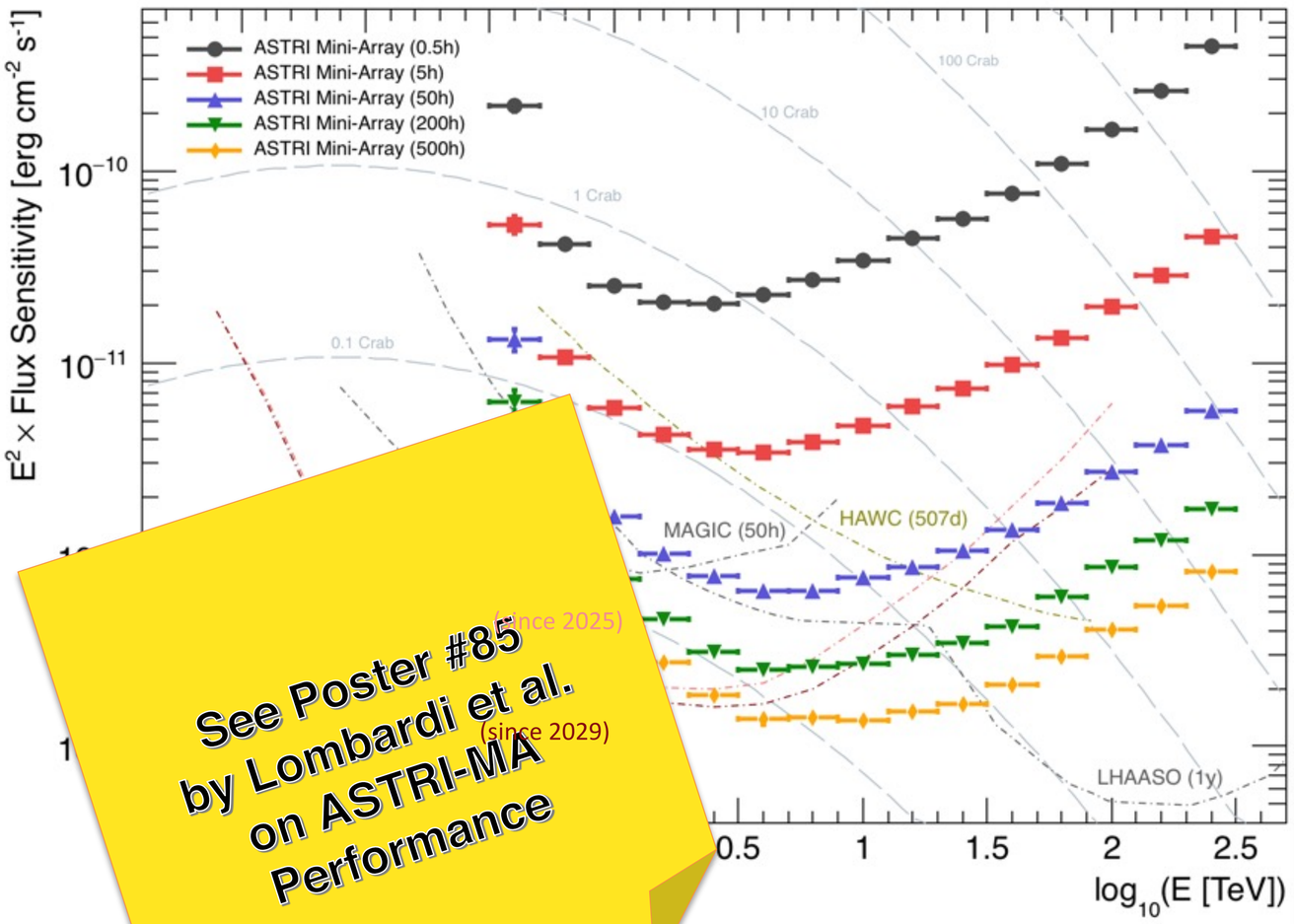
- No real time analysis of the data is foreseen but only a data quality check. Data analysis policy adopted will be *«next day processing».*
- No array trigger (stereo trigger) will be implemented at the site. Any search for Cherenkov events detected in coincidence by more than one telescope will be performed via software off-line at the ASTRI Data Center in Rome.
- Limited Operation modes: Normal observation mode, ToO mode, Coordinated mode, Maintenance mode. No subarray operation is foreseen.
- Night science operations will be controlled remotely from La Laguna @ IAC → no people required at 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 rooms) located in Italy.



ASTRI Mini-Array Operations

- **ASTRI Mini-Array lifetime at least 10 years**
- **During the first 3/4 years of operations the array will be operated as an experiment and not as an observatory.**
- **The ASTRI Science team will develop a strategy to concentrate the observational time on a limited number of programs with clearly identified objectives.**
- **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 going through a Time Allocation Committee procedure.**

ASTRI Mini-Array expected performaces



(since 2025)

(since 2029)

See Poster #85 by Lombardi et al. on ASTRI-MA Performance

Expected performances.

- **Sensitivity: better than current IACTs (E > 5 TeV):**
  - Extend the spectra of already detected sources and/or measure cut-offs
  - Characterize the morphology of extended sources at the highest VHE
- **Energy/Angular resolution: ~10% / ~0.05° (E = 10 TeV)**
- **Wide FoV (≥ 10°)** with homogeneous off-axis acceptance: optimal for multi-target fields, surveys, and extended sources.
  Enhanced chance for serendipity discoveries.

	ASTRI Mini-Array	MAGIC	VERITAS	H.E.S.S.	HAWC	LHAASO
Location	28° 18′ 04″ N 16° 30′ 38″ W	28° 45′ 22″ N 17° 53′ 30″ W	31° 40′ 30″ N 110° 57′ 7.8″ W	23° 16′ 18″ S 16° 30′ 00″ E	18° 59′ 41″ N 97° 18′ 27″ W	29° 21′ 31″ N 100° 08′ 15″ E
Altitude [m]	2,390	2,396	1,268	1,800	4,100	4,410
FoV	~ 10°	~ 3.5°	~ 3.5°	~ 5°	2 sr	2 sr
Angular Res.	0.05° (10 TeV)	0.07° (1 TeV)	0.07° (1 TeV)	0.06° (1 TeV)	0.15°[(a)] (10 TeV)	0.15°[(b)] (1,000 TeV)
Energy Res.	12% (10 TeV)	16% (1 TeV)	17% (1 TeV)	15% (1 TeV)	30% (10 TeV)	(8–20)% (1,000 TeV)[(b)]
Energy Range	(0.3-200) TeV	(0.05-20) TeV	(0.08-30) TeV	(0.02-30) TeV[(c)]	(0.1-100) TeV	(0.1-1,000) TeV

ASTRI Mini-Array Science

- **Wide-field stereoscopic observations in the 1 – 200 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**

See Talk
by S. Vercellone
#574
for the ASTRI Core
Science Program

See Talk
by M. Cardillo
#407
ASTRI & Cosmic Rays

See Talk
by Antonino D'Aì
#976
ASTRI & Galactic
Science

See Posters
#317 by Saturni et al.
ASTRI & Egal. Science
#358 by Stamerra et al.
ASTRI & Transients

SUMMARY

- ASTRI Mini Array is an International project leaded by INAF aimed to observe the northern gamma ray sky in the 1 – 200 TeV energy range.
- ASTRI Mini-Array is composed by 9 dual-mirror Cherenkov telescopes ASTRI-type to be deployed at Observatorio del Teide (Tenerife, Canary Islands) from the end of 2021.
- ASTRI Mini-Array Project is providing all the systems and sub-systems (hardware, software and infrastructures) needed for operating the telescopes, acquiring, archiving, analysing and distributing scientific data.
- Thanks to its sensitivity better than current IACTs (E > 5 TeV), its Energy/Angular resolution: ~10% / ~0.05° (E=10 TeV) and the Wide FoV (>10° - with homogeneous off-axis acceptance), ASTRI Mini-Array is going to play a major role in the observation of the gamma ray sky at the higher energies.
- The ASTRI Mini-Array will start scientific observations in 2024 with a 4 (core science) + 4 (observatory science) year program.