The ASTRI Mini-Array project: control software and status

A.Bulgarelli (INAF / OAS Bologna)

On Behalf of the ASTRI coordination team
for the ASTRI Project

USC-C General Assembly, Trieste, March 11, 2026

ASTRI Mini-Array telescopes

The ASTRI Mini-Array telescopes are an evolution of the ASTRI-Horn prototype telescope

Electromechanical structure

Optimized in terms of mass (reduced by 30%), functionality and maintainability

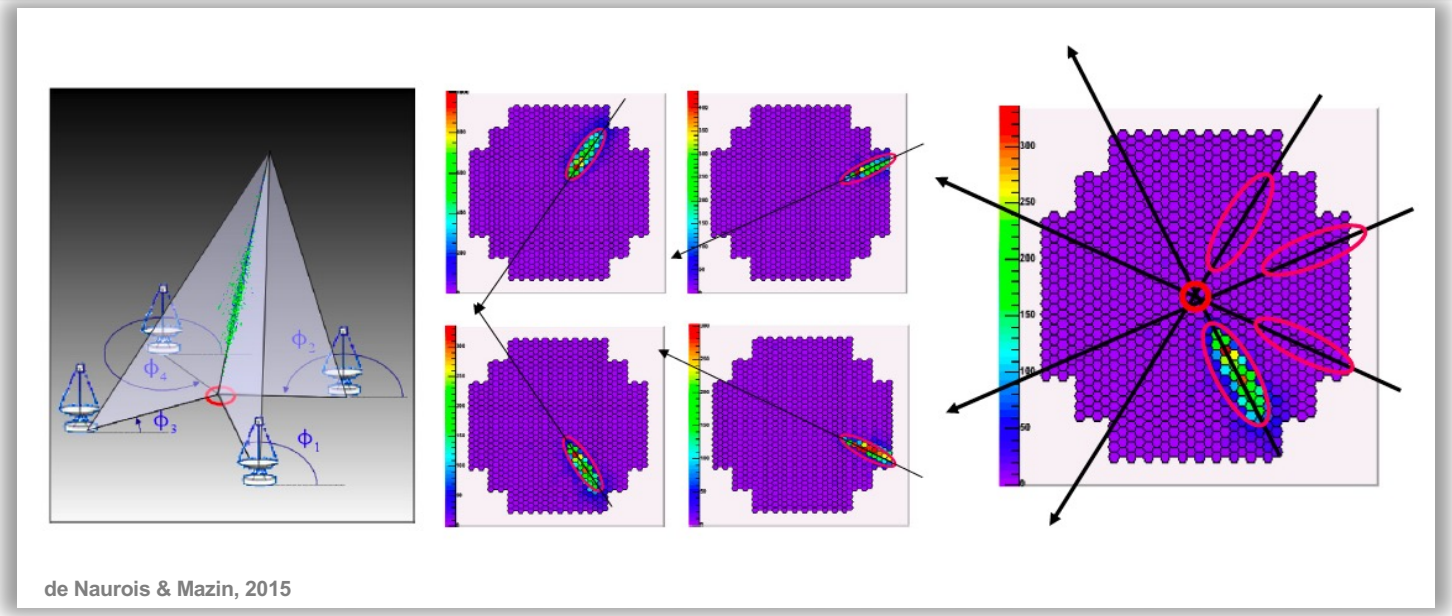
SiPM camera

- 37 (8x8) matrices are arranged to adapt to the curved focal plane of the telescope
- Wide FoV (~10°)
- Small pixel-size (0.19°)

Excellent performance also with moonlight

Sottile et al., 2023

Why building an array of telescopes?



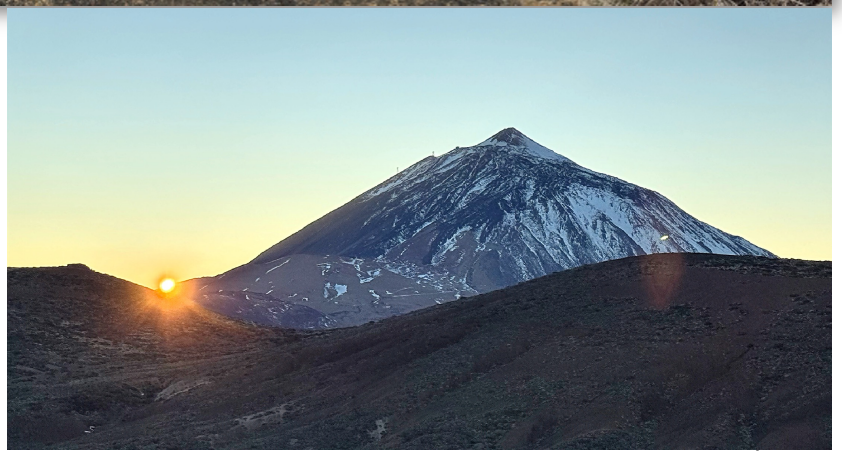
An **imaging atmospheric Cherenkov telescope (IACT) array** will improve

- Effective area
- Background rejection
- Angular resolution
- Energy resolution

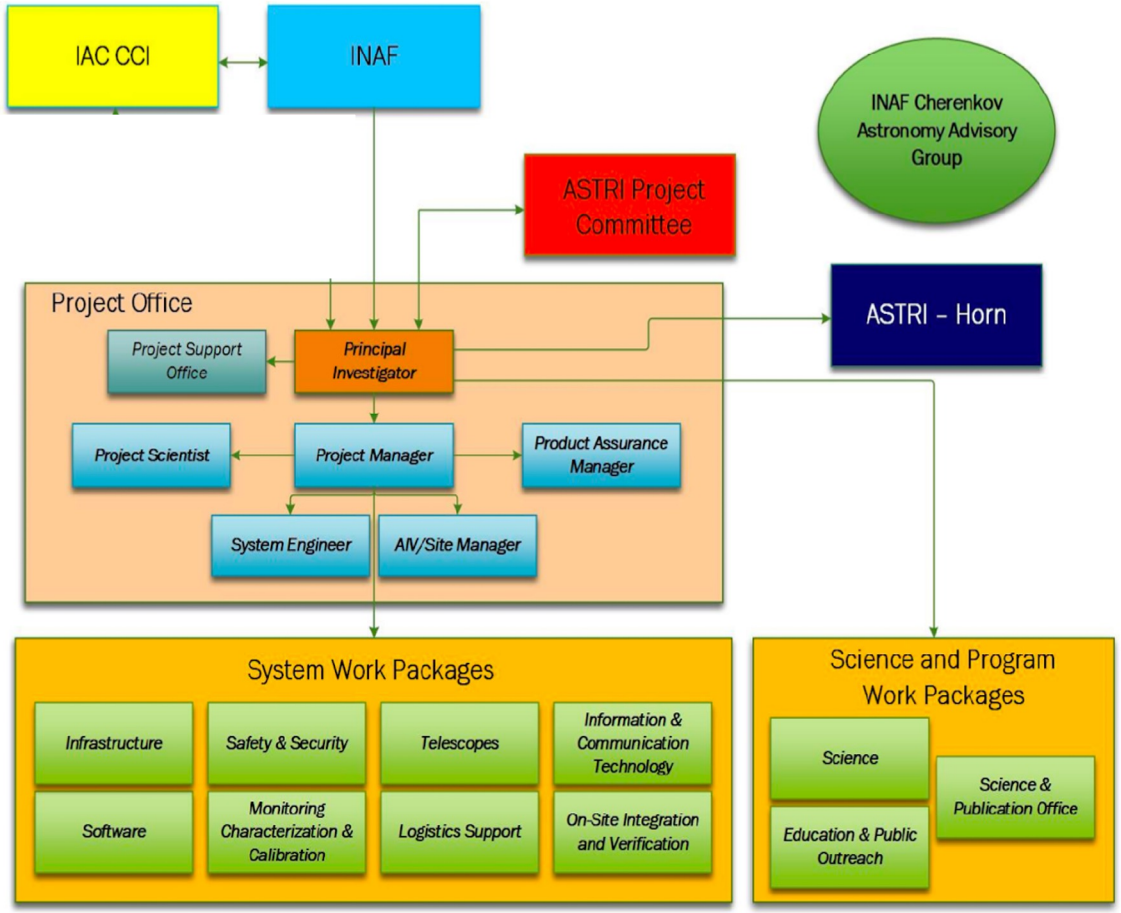
The ASTRI Mini-Array project

- The ASTRI MA is an array of 9 Cherenkov telescopes of the 4 meters class under construction at the **Observatorio del Teide** in Tenerife (Spain)

- About **200 researchers** belonging to **INAF** institutes (IASF-MI, IASF-PA, OAS, OACT, OAB, OAPD, OAR, OAA, IAPS, OATs) **Italian Universities** (Uni-PG, Uni-PD, Uni-TS, Uni-GE), **INFN**, **Fundacion Galileo Galilei**, **IAC** (Spain), **University of Sao Paulo** (Brazil), **North-West University** (South Africa), **Université & Observatoire de Genève** (CH).



ASTRI Mini-Array Project: organization



Principal Investigator: ***Giovanni Pareschi***

Program Manager: ***Salvo Scuderi***

Project Scientist: ***Andrea Giuliani***

System Engineer: ***Gino Tosti***

User Groups Coordinator: ***Stefano Vercellone***

Proj. Committee Coordinator : ***Marco Tavani***

On-site software: ***Andrea Bulgarelli***

Off-site software: ***Fabrizio Lucarelli***

Scientific SW: ***Saverio Lombardi***

ASTRI Mini-Array

End to end approach from design/implementation of all HW/SW components to dissemination of final scientific products.

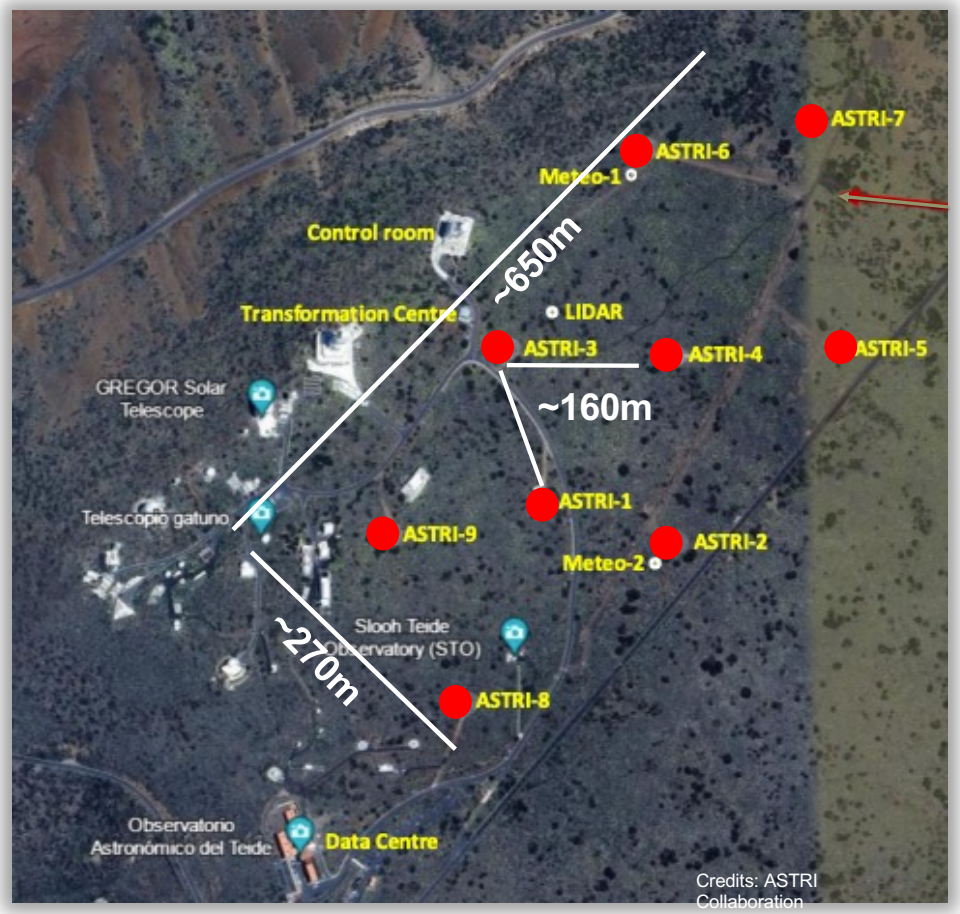
Science Program : 4 year (Core Science Program) + 4 year (Observatory)

Important **synergies** with other Northern ground-based gamma-ray facilities (LHAASO, HAWC, MAGIC, VERITAS, CTAO-N)

ASTRI Mini-Array will be operated remotely.

Unprecedented performance and **wide FoV (~10°) with excellent off-axis performance** for observations at **multi-TeV energies (1-200 TeV)**

- Angular resolution: ~3' (E~10 TeV)
- Energy resolution: ~10% (E~10TeV)



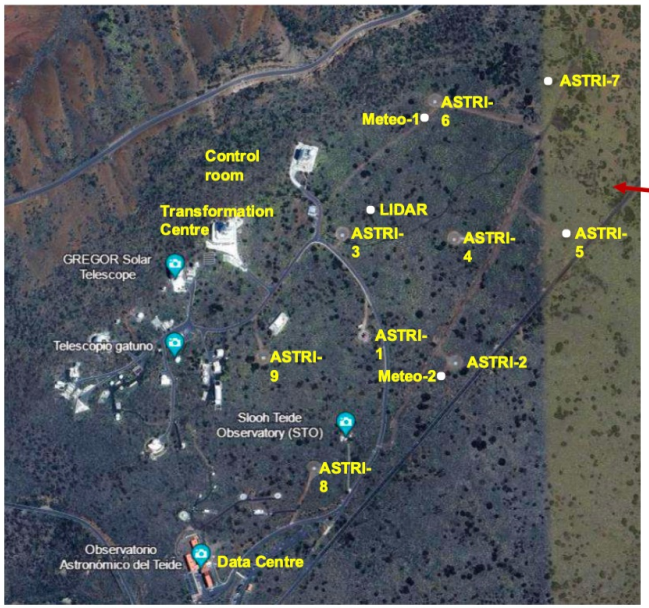
End-to-end approach

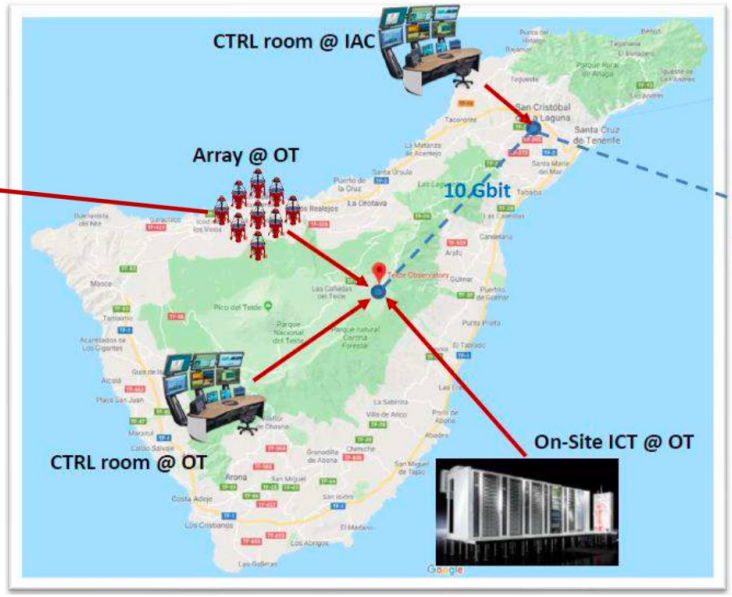
The ASTRI Mini-Array in Tenerife

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

The ASTRI Mini-Array in Italy

- Data Centre in Rome
- Remote Array operation centers





10 Gbit

ASTRI Mini-Array - Schedule

Summer 2021

Site foundation

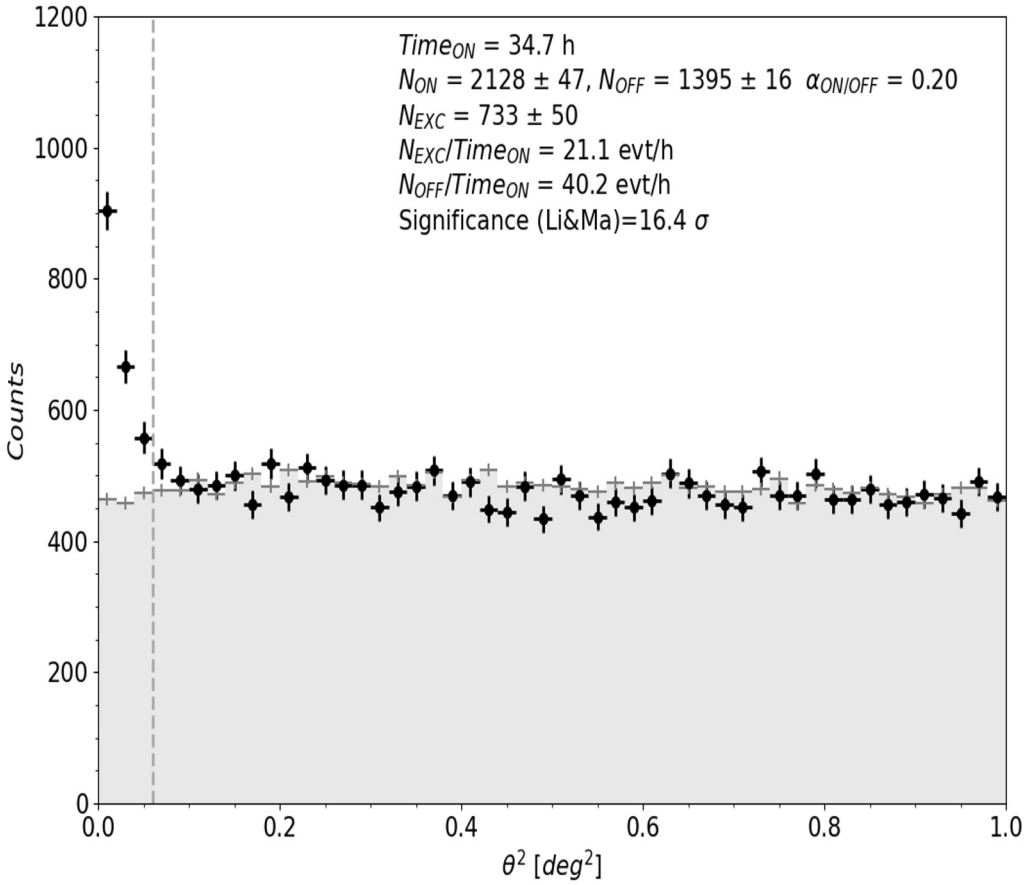
Autumn 2022

ASTRI 1 construction and calibration

Autumn 2024

"Mono" observations

Crab Nebula : november 2024 - february 2025



Crab: from 11/2024 to 02/2025

- Trigger Threshold = 7 pe
- Dark
- Offset: 0.5°
- Low ZD (< 30°)
- Subsample of selected good runs
- 34.7 h of total exposure time
- ASTRI1

ASTRI Mini-Array - Schedule

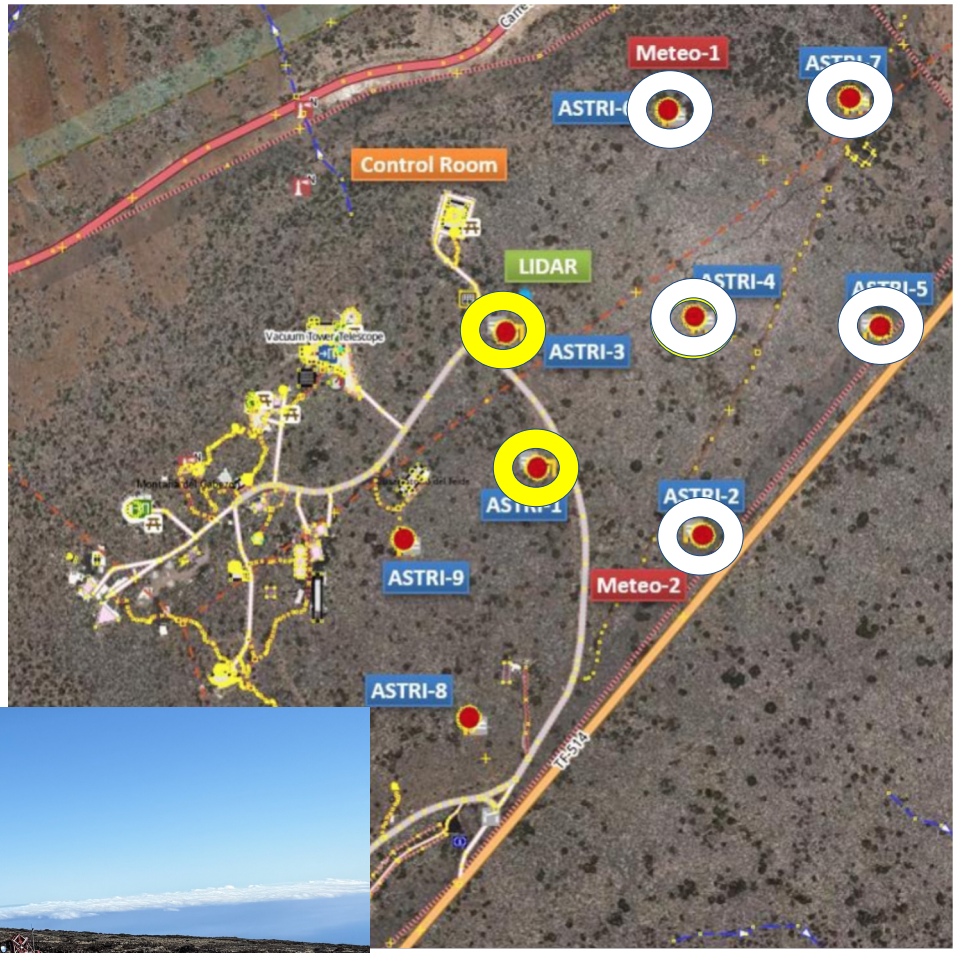
ASTRI 1
construction and
calibration

Autumn 2024

ASTRI-2T
(+ 5 Tels.)

Autumn 2025

Stereoscopic
observations



ASTRI Mini-Array - Schedule

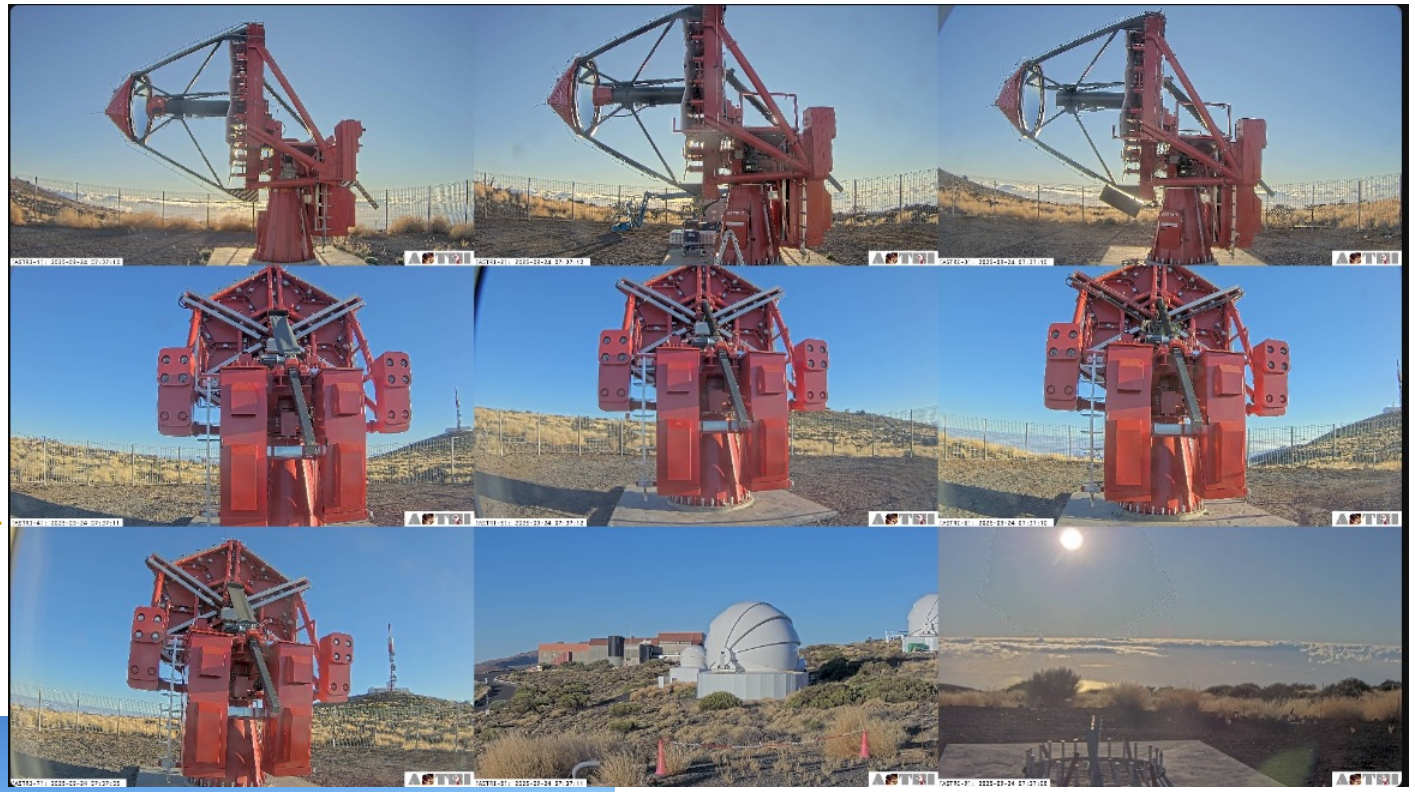
ASTRI 1
construction and
calibration

Autumn 2024

ASTRI-2T
(+ 5 Tels.)

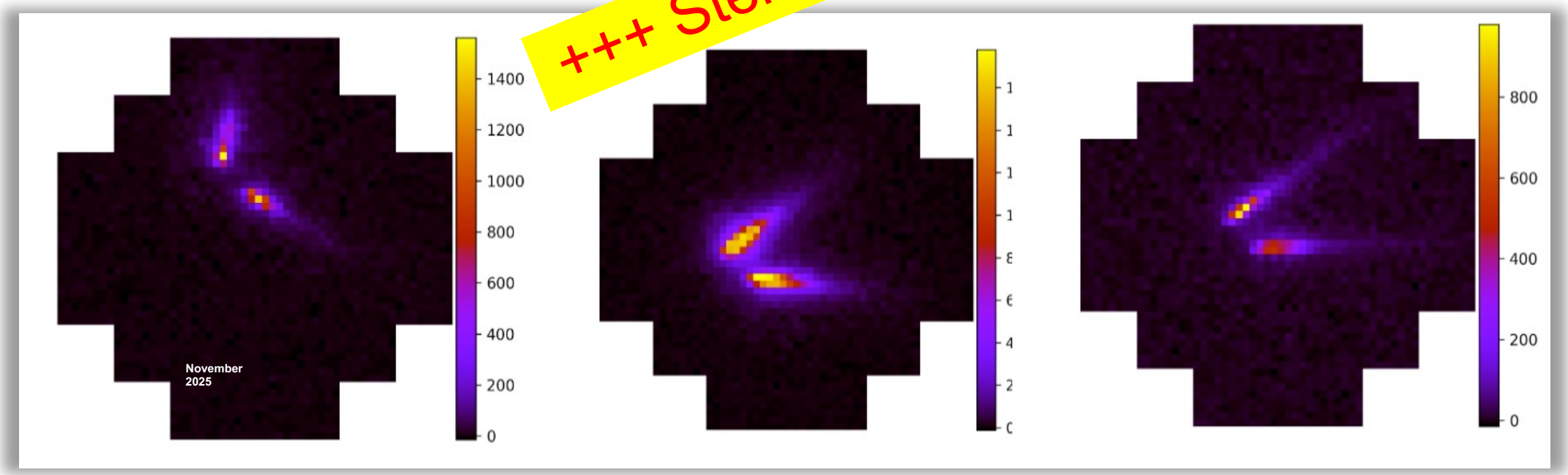
Autumn 2025

Stereoscopic
observations



ASTRI-1 and ASTRI-3 stereo observations!

ASTRI Mini-Array



ASTRI Mini-Array

"Emilia storm" hit hard the Teide Observatory

[Previous | Next]

ASTRI-1 detection of enhanced very high-energy gamma-ray emission from Mrk 421 at TeV energies

ATel #17602; *S. Crestan (INAF/IASF Milano), C. Quartiroli (INAF/IASF Milano), A. Sunny (INAF/IAPS Roma), S. Lombardi (INAF/OAR Roma), F. Lucarelli (INAF/OAR Roma), F. Pintore (INAF/IASF Palermo), for the ASTRI Project*
*on **15 Jan 2026; 17:41 UT***
Credential Certification: Fabio Pintore (fabio.pintore@inaf.it)

Subjects: Gamma Ray, TeV, VHE, AGN, Blazar

Referred to by ATel #: 17622

Related

17622 Mrk 421: Upper limits from a neutrino search with IceCube
17602 ASTRI-1 detection of enhanced very high-energy gamma-ray emission from Mrk 421 at TeV energies
17597 SST-1M detection of increased very-high-energy gamma-ray activity of Mrk 421
17595 SVOM/ECLAIRs Detection of the Current Exceptional Very-High Energy Flare from Mrk 421
17594 An Exceptional Very-High-Energy Gamma-Ray Flare From Mrk 421 Observed with VERITAS
17535 LHAASO detection of Markarian 421 in a TeV-active state

New Year's fireworks

The ASTRI-1 telescope has observed an increase in the very high-energy gamma-ray flux from the blazar Mrk 421 (z = 0.031). Observations were performed between 2026/01/15 - 2:00 UTC (MJD 61055.08) and 04:40 UTC (MJD 61055.20) for a total effective observation time of approximately 2.5 hr. A preliminary analysis of the collected data reveals a significant detection of 11 sigma. The detected gamma-ray flux between 0.8 and 5 TeV is estimated to be 2.3 +/- 0.3 (stat) Crab Units.

ASTRI Mini-Array - Schedule

ASTRI 1
construction and
calibration

Autumn 2024

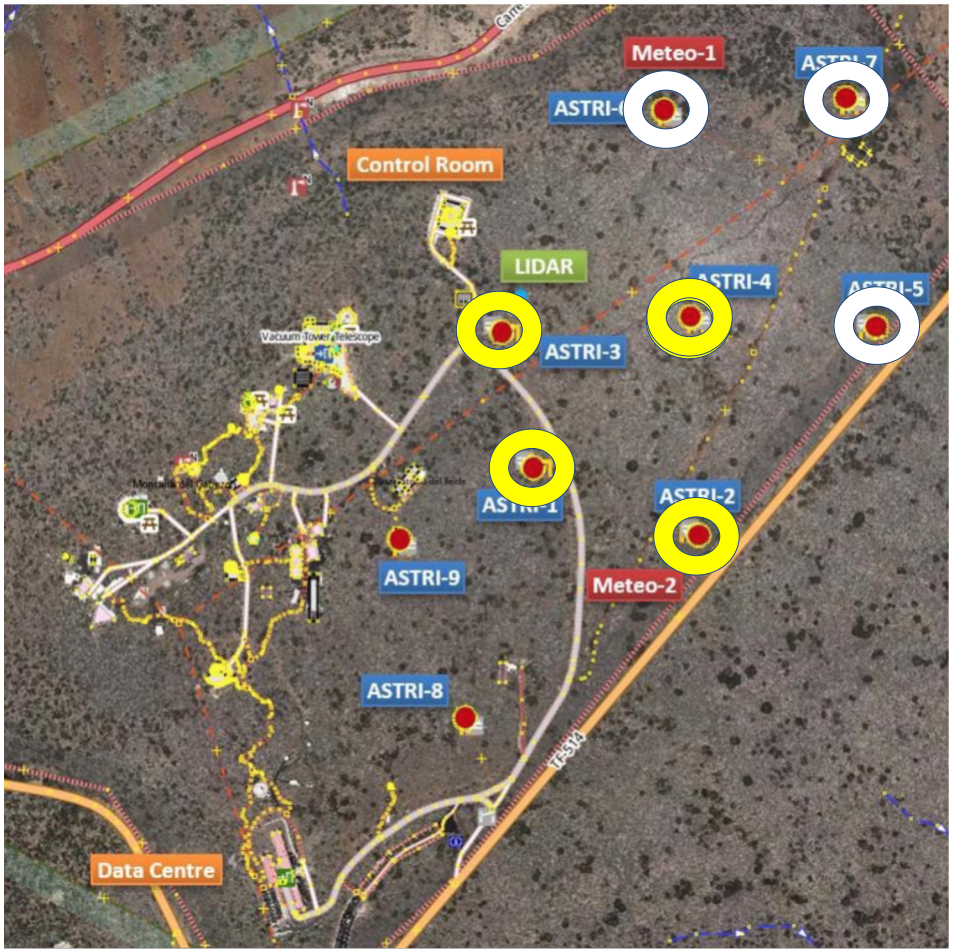
ASTRI-2T
(+ 5 Tels.)

Autumn 2025

ASTRI-4T

Spring 2026

Early
Science



ASTRI Mini-Array - Schedule

ASTRI 1 construction and calibration

Autumn 2024

ASTRI-2T (+ 5 Tels.)

Autumn 2025

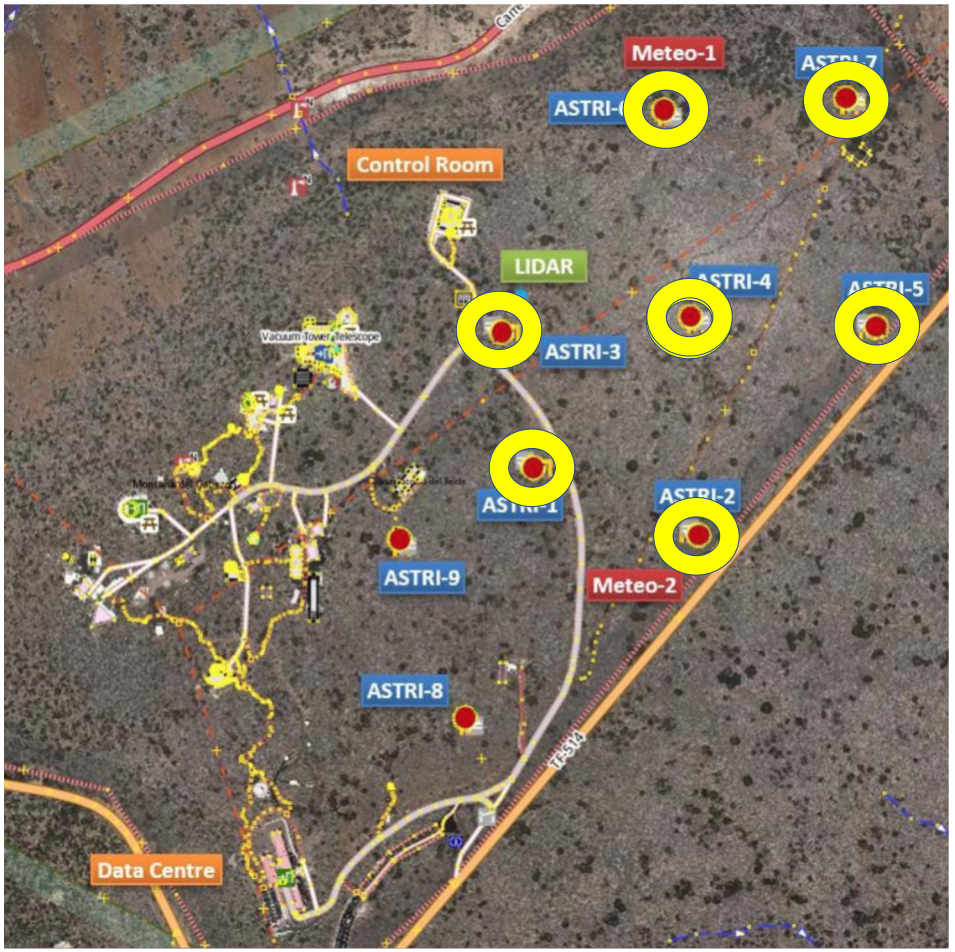
ASTRI-4T

Spring 2026

ASTRI-7T

End 2026

Start Pillar Science



ASTRI Mini-Array - Schedule

ASTRI 1 construction and calibration

Autumn 2024

ASTRI-2T (+ 5 Tels.)

Autumn 2025

ASTRI-4T

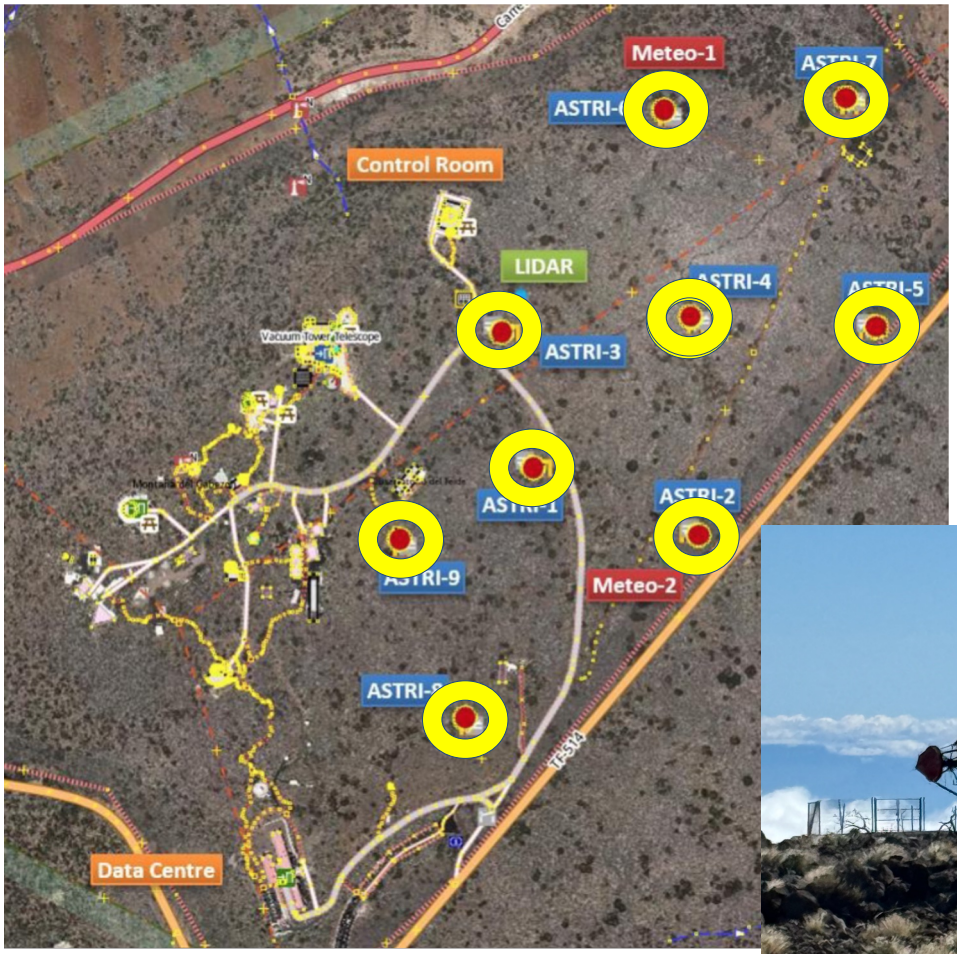
Spring 2026

ASTRI-7T

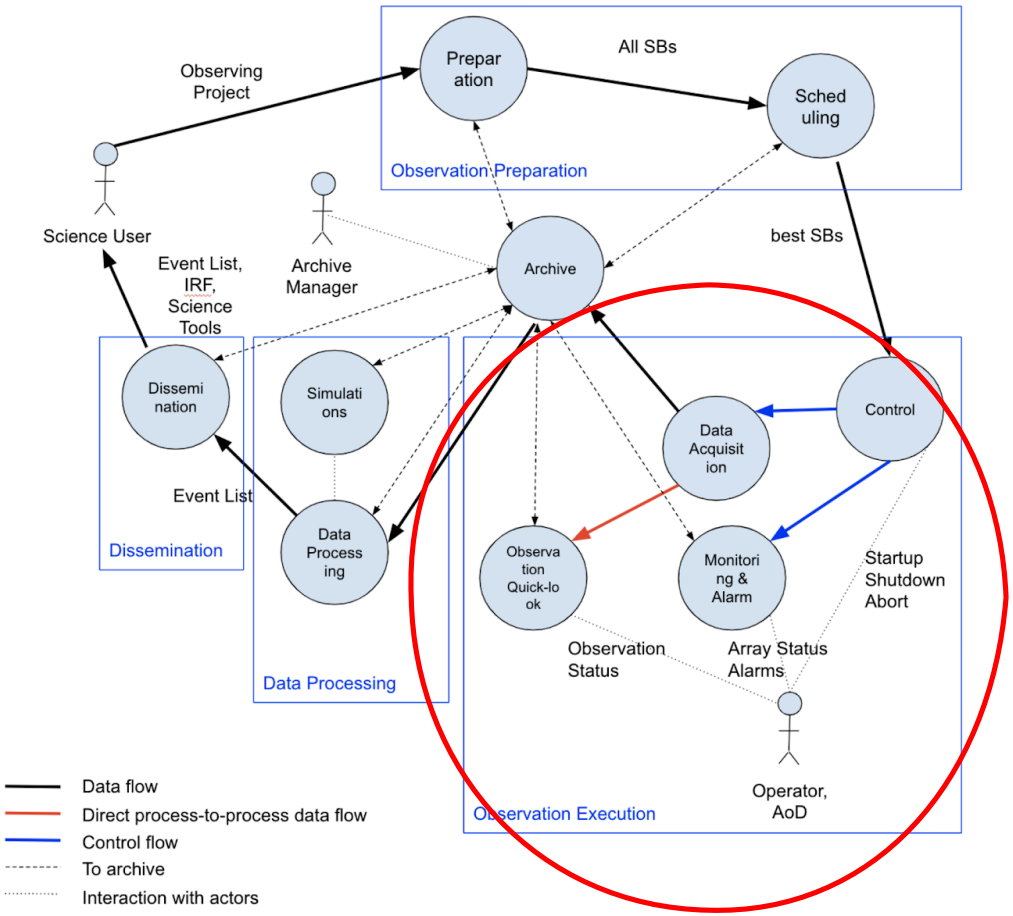
End 2026

ASTRI-9T

2027



Observing cycle

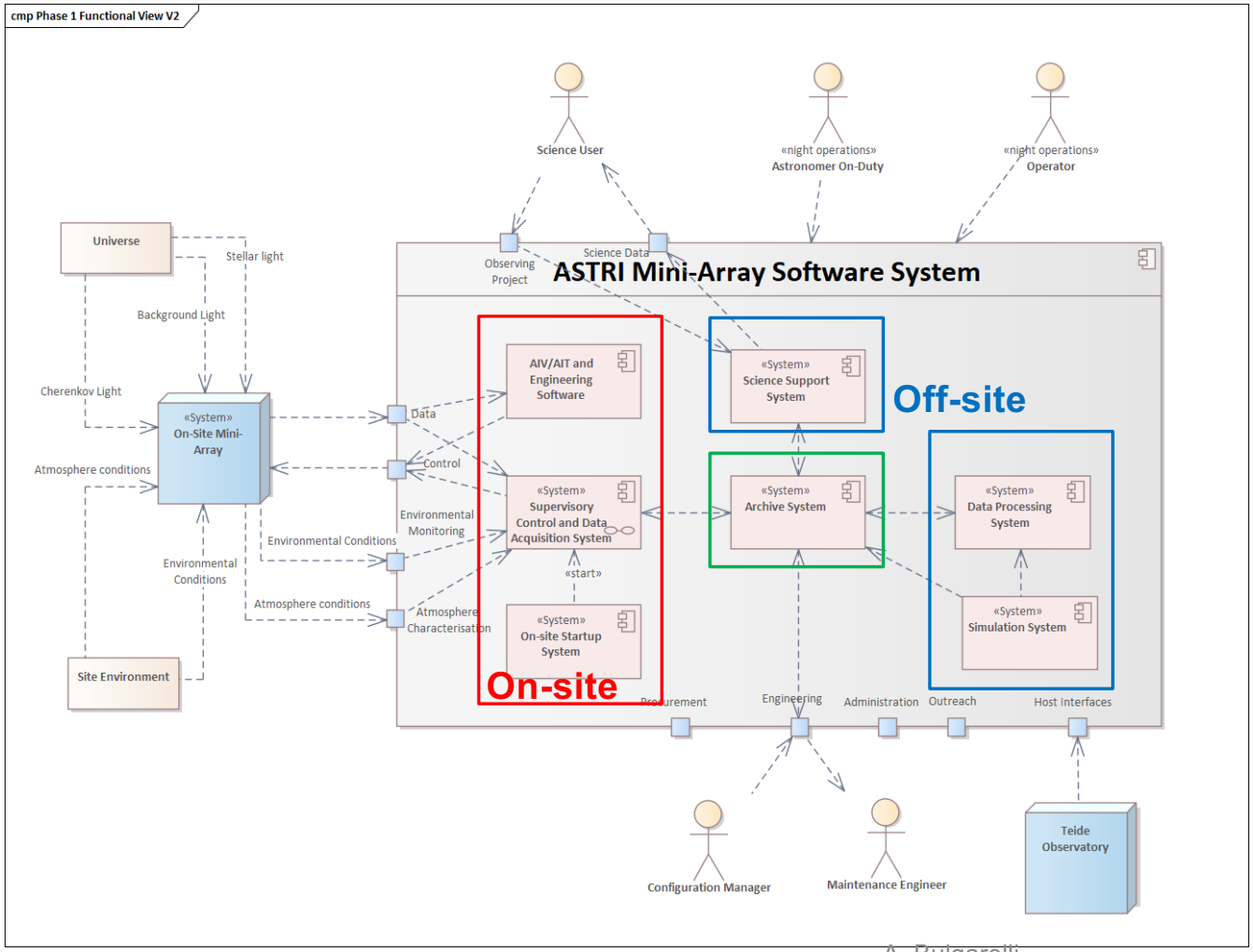


ASTRI software support the full observing cycle

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: submitting an Observing Project that is turned into Scheduling Blocks (SBs) and Observing Blocks (OBs)
2. Observation execution: execution of Observing Blocks
3. Data Processing: produces calibrated and reconstructed data
4. Dissemination: Data and Science Tools are distributed for a scientific analysis of the Observing Projects.

General software architecture

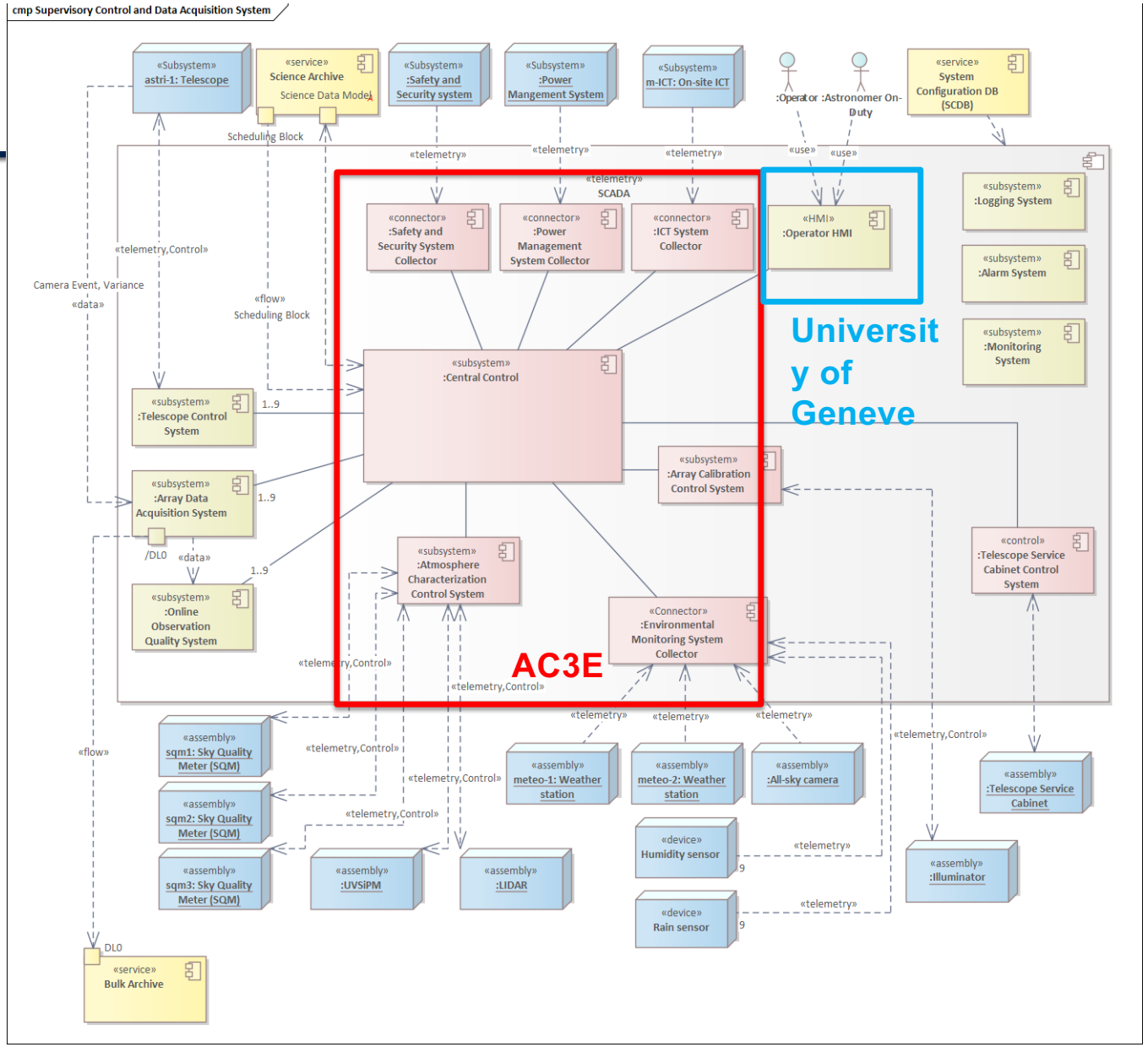


- **Supervisory Control And Data Acquisition (SCADA) System**: *interfaces, controls, monitors, acquires data, manage alarms of all software subsystems and assemblies of the Mini-Array*
- **On-site Startup System**
- **AIV/AIT and Engineering Software**
- **Archive System**
- **Data Processing System**
- **Science Support System**
- **Simulations System**

Supervisory Control and Data Acquisition System (SCADA)

- **SCADA interfaces, controls, monitors, acquires data, manage alarms of all software subsystems and assemblies of the Mini-Array:**
  - automatically execute the whole sequence of operations needed to perform an observation;
  - react to critical conditions in an automatic way to put the array system in a safe state.
- **Software subsystems:**
  - Central Control;
  - Control systems and Collector;
  - Monitoring/Alarm/Logging systems;
  - Data Acquisition and Quality systems;
- Supervised by an Operator with an HMI

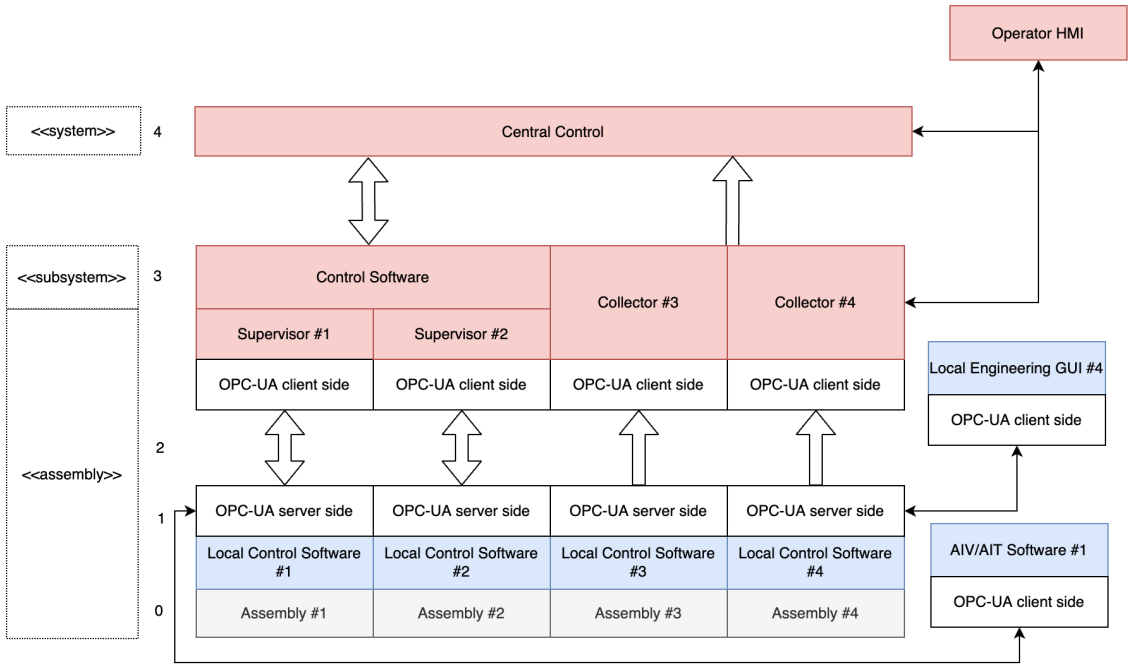
Red and green are SCADA subsystem; blue boxes are the ASTRI Mini-Array assemblies; yellow boxes are part of the Archive System.
The << telemetry >> stereotype represents monitoring points, alarms, errors, logs, and status information, << data >> stereotype represents the data flow. The << control >> stereotype represents the control flow.



Supervisory Control and Data Acquisition System (SCADA)/2

Mini-Array

- **Central Control System** coordinates the sequence of operations, all software components and hardware assemblies, the sequences of the startup, shutdown, configuration and the status.
- Control systems, to control, monitor, and manage alarms and the status of the telescopes (**Telescope Control System**, developed by INAF based on the ASTRI-Horn experience), the assemblies used to characterise the atmosphere (**Atmosphere Characterisation Control System**), the calibration system (**Array Calibration Control System**), the telescope service cabinets **(Telescope Service Cabinet Control System);**
- Collectors, to monitor and determine alarms and the status of environmental devices (**Environmental Monitoring System Collecto**r), of the Information and Communication Technology (ICT) system (**On- site ICT System Collector**), the power system (**Power Management System Collector**), the Safe and Security System (**Safety and Security System Collector**);
- **Operator Human Machine Interface (HMI),** the user interface for the Operator, including an Operator Logbook to save logs of the observations during the night.



Interfaces between hardware assemblies and SCADA: IEC 62541 standard OPC Unified Architecture protocol, plus

- SNMP for the ICT system
- Modbus for Power Management System

Supervisory Control and Data Acquisition System (SCADA)/3

- **Logging System, Monitoring System and Alarm System**, developed by INAF, monitor the overall performance of the systems through the acquisition of environmental, monitoring and logging points and alarms from instruments and generates status reports or notifications to the Operator.
- **Telescope Control System**, to control a single telescope, developed by INAF
- **Array Data Acquisition System**, developed by INAF, acquires Cherenkov Cameras and Stellar Intensity Interferometry Instruments data
- **Online Observation Quality System**, developed by INAF, focuses on ongoing problems and the status of the observations

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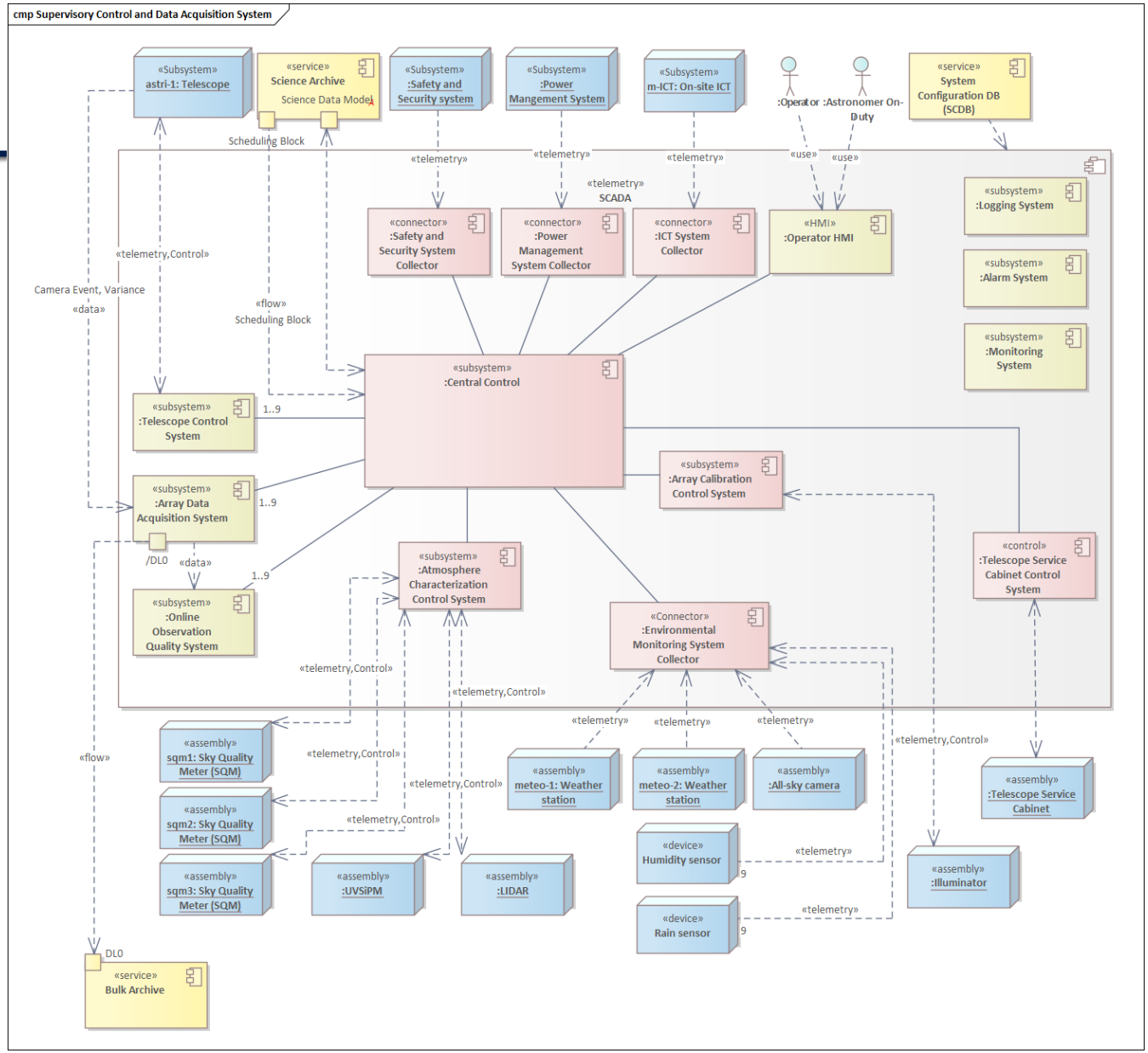
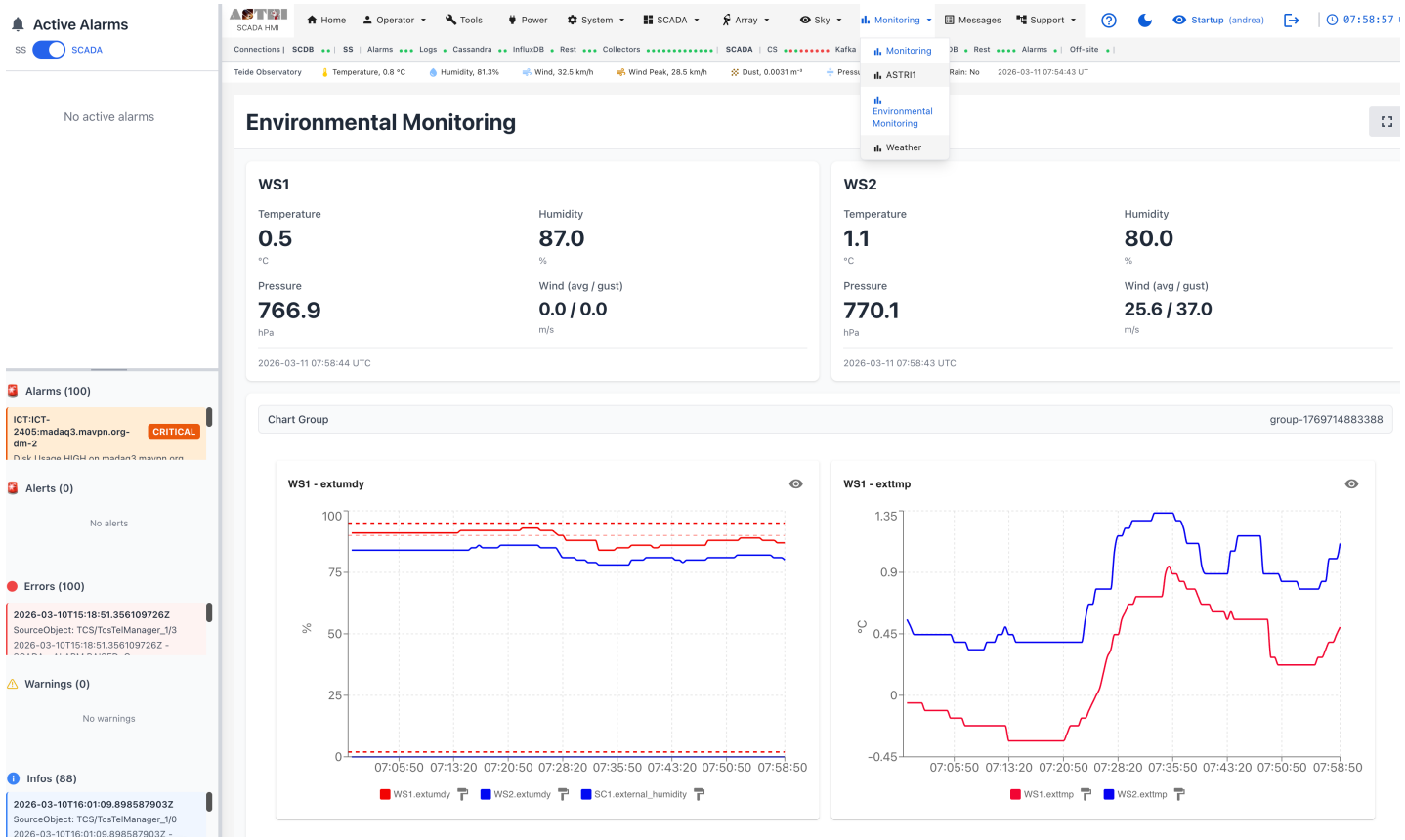


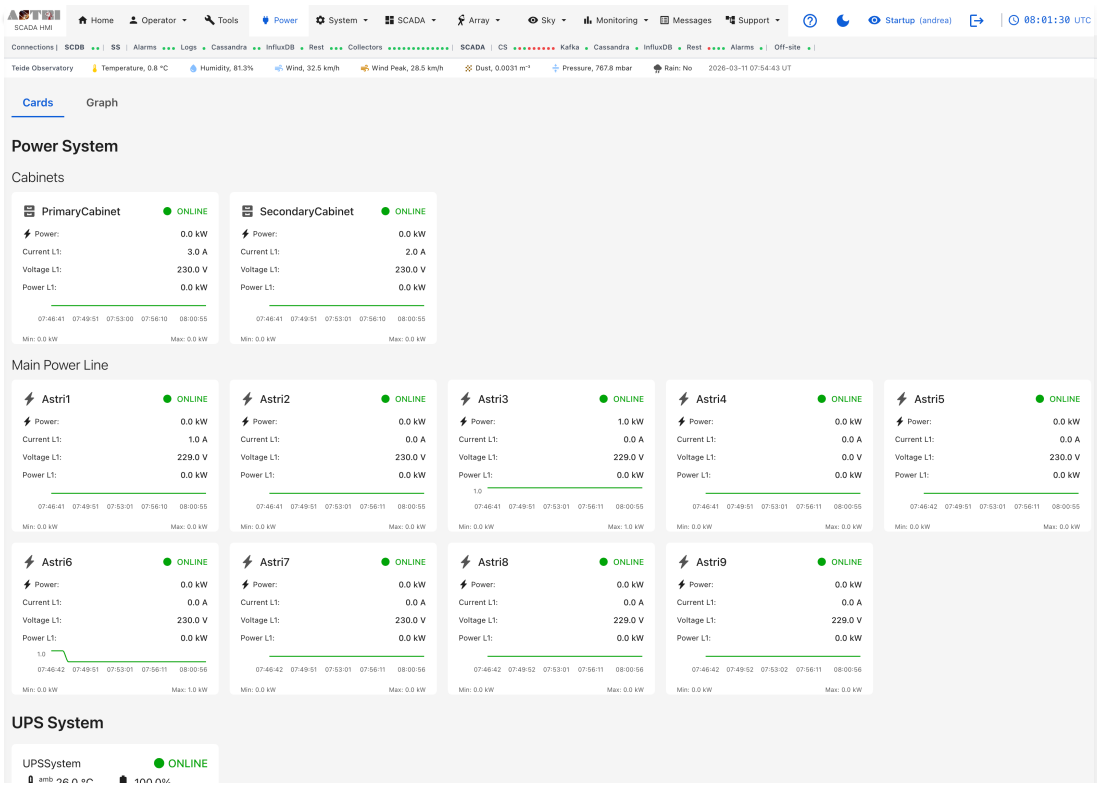
SCADA and software frameworks

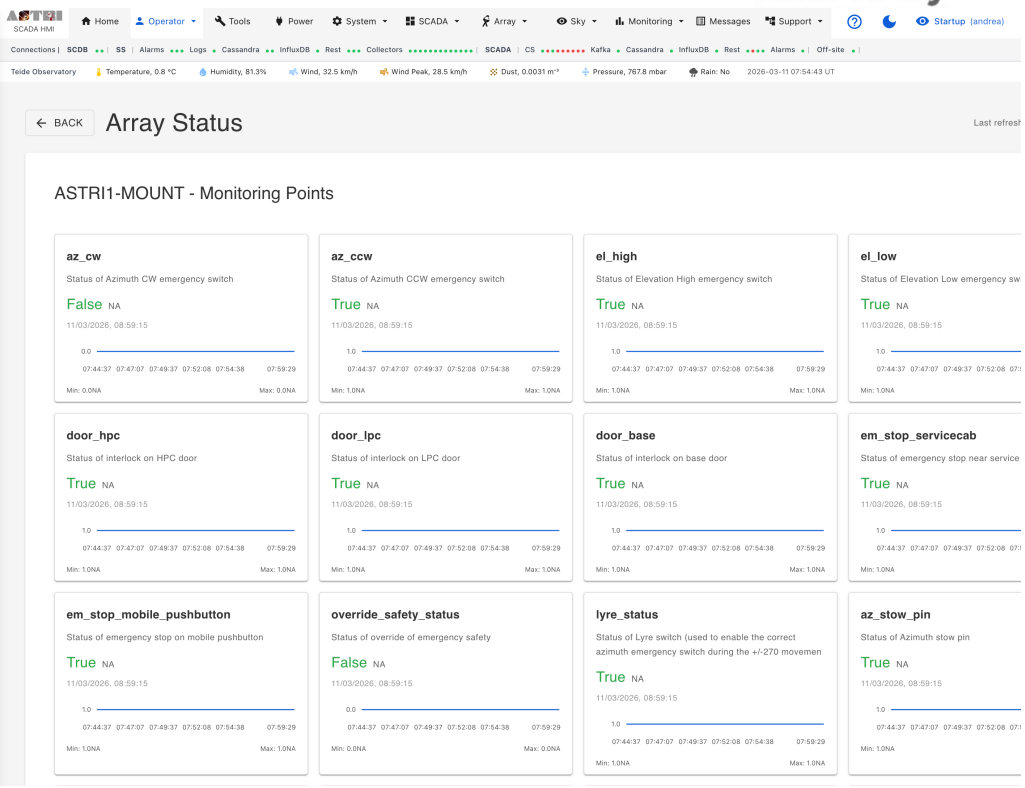
- SCADA is developed using ALMA Common Software (ACS)†, Kafka, Cassandra, MongoDB.
  - ALMA Common Software (ACS): a container component framework, designed for distributed systems, with standardized paradigms for logging, alarms, location transparency, and support for multiple programming languages: Java, C++ and Python.
    - ACS has been used successfully for ALMA, which manages an array of 66 antennas on the Chajnantor plateau in Chile.
    - ACS is used for ASTRI-Horn, Sardinia Radio Telescope, CTAO.
  - Kafka is used as a data backbone for all SCADA subsystems, except for data acquisition that uses TCP/IP.
  - Cassandra is used for the permanent storage of monitoring and data quality information, synchronized with off-site data center
  - MongoDB for observing plans and system configuration

†https://confluence.alma.cl/display/ICTACS/ACS+Documentation


Active Alarms
SS SCADA
No active alarms
SCADA HMI
Home
Operator
Tools
Power
System
SCADA
Array
Sky
Monitoring
Messages
Support
Startup (andrea)
07:58:57
Monitoring
ASTRI1
Environmental Monitoring
Weather
Environmental Monitoring
WS1
Temperature
0.5
°C
Humidity
87.0
%
Pressure
766.9
hPa
Wind (avg / gust)
0.0 / 0.0
m/s
2026-03-11 07:58:44 UTC
WS2
Temperature
1.1
°C
Humidity
80.0
%
Pressure
770.1
hPa
Wind (avg / gust)
25.6 / 37.0
m/s
2026-03-11 07:58:43 UTC
Chart Group
group-1769714883388
WS1 - extumdy
WS1 - exttmp
Alarms (100)
ICT:ICT-2405:madaq3.mavpn.org-dm-2
CRITICAL
Alerts (0)
No alerts
Errors (100)
2026-03-10T15:18:51.356109726Z
SourceObject: TCS/TcsTelManager_1/3
Warnings (0)
No warnings
Infos (88)
2026-03-10T16:01:09.898587903Z
SourceObject: TCS/TcsTelManager_1/0

Mini-Array


SCADA HMI
Home
Operator
Tools
Power
System
SCADA
Array
Sky
Monitoring
Messages
Support
Startup (andrea)
08:01:30 UTC
Connections | SCDB | SS | Alarms Logs Cassandra InfluxDB Rest Collectors | SCADA | CS Kafka Cassandra InfluxDB Rest Alarms | Off-site |
Teide Observatory
Temperature, 0.8 °C
Humidity, 81.3%
Wind, 32.5 km/h
Wind Peak, 28.5 km/h
Dust, 0.0031 m⁻³
Pressure, 767.8 mbar
Rain: No
2026-03-11 07:54:43 UT
Cards
Graph
Power System
Cabinets
PrimaryCabinet
ONLINE
Power: 0.0 kW
Current L1: 3.0 A
Voltage L1: 230.0 V
Power L1: 0.0 kW
SecondaryCabinet
ONLINE
Power: 0.0 kW
Current L1: 2.0 A
Voltage L1: 230.0 V
Power L1: 0.0 kW
Main Power Line
Astri1
ONLINE
Power: 0.0 kW
Current L1: 1.0 A
Voltage L1: 229.0 V
Power L1: 0.0 kW
Astri2
ONLINE
Power: 0.0 kW
Current L1: 0.0 A
Voltage L1: 230.0 V
Power L1: 0.0 kW
Astri3
ONLINE
Power: 1.0 kW
Current L1: 0.0 A
Voltage L1: 229.0 V
Power L1: 0.0 kW
Astri4
ONLINE
Power: 0.0 kW
Current L1: 0.0 A
Voltage L1: 0.0 V
Power L1: 0.0 kW
Astri5
ONLINE
Power: 0.0 kW
Current L1: 0.0 A
Voltage L1: 230.0 V
Power L1: 0.0 kW
Astri6
ONLINE
Power: 0.0 kW
Current L1: 0.0 A
Voltage L1: 230.0 V
Power L1: 0.0 kW
Astri7
ONLINE
Power: 0.0 kW
Current L1: 0.0 A
Voltage L1: 230.0 V
Power L1: 0.0 kW
Astri8
ONLINE
Power: 0.0 kW
Current L1: 0.0 A
Voltage L1: 229.0 V
Power L1: 0.0 kW
Astri9
ONLINE
Power: 0.0 kW
Current L1: 0.0 A
Voltage L1: 229.0 V
Power L1: 0.0 kW
UPS System
UPSSystem
ONLINE


SCADA HMI
Home
Operator
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Messages
Support
Startup (andrea)
Connections | SCDB | SS | Alarms Logs Cassandra InfluxDB Rest Collectors | SCADA | CS Kafka Cassandra InfluxDB Rest Alarms | Off-site |
Teide Observatory
Temperature, 0.8 °C
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Wind, 32.5 km/h
Wind Peak, 28.5 km/h
Dust, 0.0031 m⁻³
Pressure, 767.8 mbar
Rain: No
2026-03-11 07:54:43 UT
BACK
Array Status
ASTRI1-MOUNT - Monitoring Points
az_cw
Status of Azimuth CW emergency switch
False NA
11/03/2026, 08:59:15
az_ccw
Status of Azimuth CCW emergency switch
True NA
11/03/2026, 08:59:15
el_high
Status of Elevation High emergency switch
True NA
11/03/2026, 08:59:15
el_low
Status of Elevation Low emergency sw
True NA
11/03/2026, 08:59:15
door_hpc
Status of interlock on HPC door
True NA
11/03/2026, 08:59:15
door_lpc
Status of interlock on LPC door
True NA
11/03/2026, 08:59:15
door_base
Status of interlock on base door
True NA
11/03/2026, 08:59:15
em_stop_servicecab
Status of emergency stop near service
True NA
11/03/2026, 08:59:15
em_stop_mobile_pushbutton
Status of emergency stop on mobile pushbutton
True NA
11/03/2026, 08:59:15
override_safety_status
Status of override of emergency safety
False NA
11/03/2026, 08:59:15
lyre_status
Status of Lyre switch (used to enable the correct azimuth emergency switch during the +/-270 movemen
True NA
11/03/2026, 08:59:15
az_stow_pin
Status of Azimuth stow pin
True NA
11/03/2026, 08:59:15

SCADA HMI

Home | Operator | Tools | Power | System | SCADA | Array | Sky | Monitoring | Messages | Support | Startup (andrea) | 08:00:4

Connections | SCDB | SS | Alarms | Logs | Cassandra | InfluxDB | Rest | Collectors | SCADA | CS | Kafka | Cassandra | InfluxDB | Rest | Alarms | Off-site |

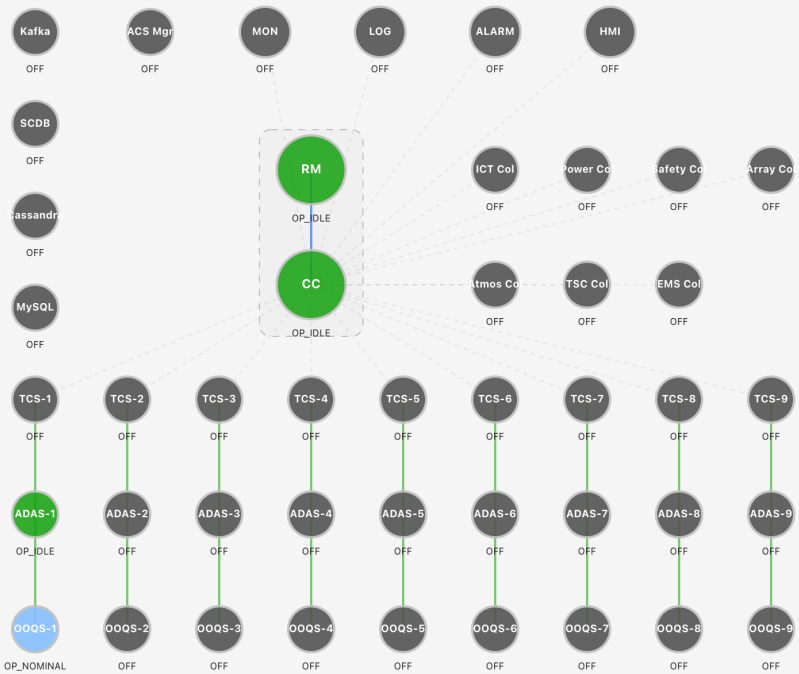
Teide Observatory | Temperature, 0.8 °C | Humidity, 81.3% | Wind, 32.5 km/h | Wind Peak, 28.5 km/h | Dust, 0.0031 m⁻³ | Pressure, 767.8 mbar | Rain: No | 2026-03-11 07:54:43 UT

Mini-Array

SCADA System Status

Live

SCADA Status	AMC Components	TCS Systems	Faults
OP_IDLE	4 / 45	0 / 9	0



Components

CC — Central Control
RM — Resource Manager
TCS — Telescope Control System
ADAS — Array Data Acquisition System
OOQS — Online Observation Quality System

State Legend

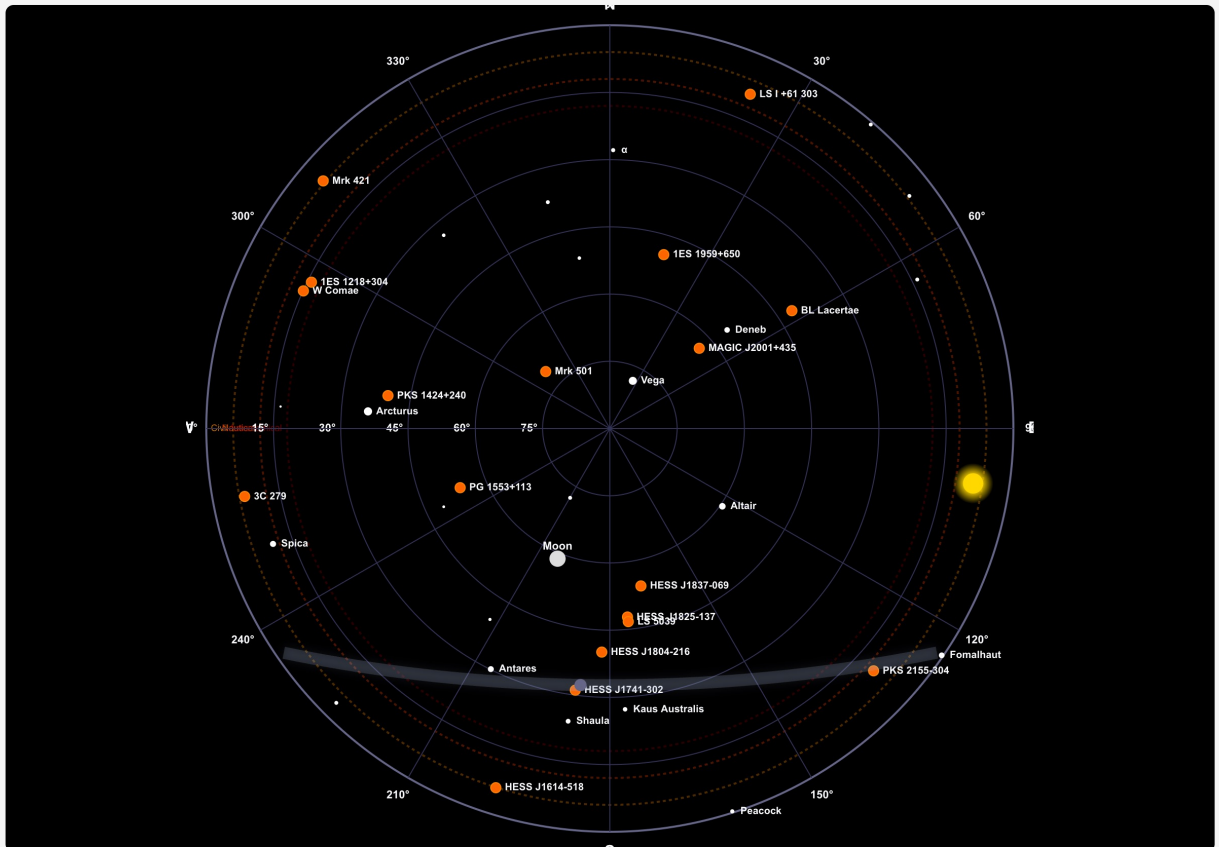
- OFF
- INITIALIZED
- STANDBY
- OP_IDLE
- OP_DEGRADED
- OP_NOMINAL
- SAFE
- ENGINEERING
- FAULT
- UNKNOWN

ASTRI Mini-Array

Sky View

UTC 2026-03-11T08:00 | 1x | SB | Select SB... | CATALOG | (31 objects) | VIEW | ZOOM | 100%

Manual Target:



Moon Phase

Last Quarter
Illumination: 49.7%
Alt: 58.7° | Az: 201.9°

Target Information

Target

Name: N/A
RA: N/A
Dec: N/A
Altitude: 0.00°
Azimuth: 0.00°
FOV Diameter: 8.00°

Twilight Times

Civil: 06:57 UTC / 19:36 UTC
Nautical: 06:30 UTC / 20:04 UTC
Astronomical: 06:03 UTC / 20:31 UTC

Observatory

Lat: 28.2983°
Lon: -16.5097°
Elevation: 2390 m

Interactor Engineering GUI

Light Dark

TCS Debug Status

1 Mocked

ASTRI Mini-Array

> Components with Clients:

Central Control System | Telescope Control System | Short Term Observing Plan

CC/CentralControlManager

STANDBY

Internal subcomponents

No internal state data available

EMSC/EmscManager

OPERATIONAL/NOMINAL

Assemblies

- **WS1** (WeatherStation) ✓ ✓
- **WSStella** (StellaWeatherStation) ✓ ✓
- **WS2** (WeatherStation) ✓ ✓

Environmental monitoring points

EnvConditions: **ENV_SURVIVAL_CONDITION**

General State: **Yes**	Temperature: **1.1 C**
Gradient Temperature: **0.0 C/h**	Relative Humidity: **90.0 %**
Pressure: **770.2 mbar**	Dew Point: **-0.3 C**
Wind Speed: **20.9 km/h**	Wind Speed 10min: **29.0 km/h**
Wind Gust 10min: **17.7 km/h**	Is Raining: **No**
Rain 1h: **0.0 mm**	Rain Daily: **0.1 mm**

Timestamp: **2026-03-11T09:38:26.423613224Z**

Central Control System | Telescope Control System | Short Term Observing Plan

Load JSON | Validate | Execute

cal-stairs done CAL STAIRS
Telescope: ASTRI1 **isToo:** false **Target:** Mrk501 RA: 279.700°, Dec: 36.680° **Max Time:** 20 min
ob1 - calibration.py (~ min, 1 estimated, 1 max)

cal-dark-ped_fixed_01 done CAL DARK-PED
Telescope: ASTRI1 **isToo:** false **Target:** dark-ped RA: 279.700°, Dec: 36.680° **Max Time:** 20 min
ob1 - calibration.py (~ min, 3 estimated, 3 max)

cal-phd_fixed canceled CAL FIBERPEQ
Telescope: ASTRI1 **isToo:** false **Target:** cal-phd RA: 279.700°, Dec: 36.680° **Max Time:** 20 min
ob1 - calibration.py (~ min, 3 estimated, 3 max)

2026-02-24_CrabNebula_SCAD_T9 canceled SCI SWB
Telescope: ASTRI1 **isToo:** false **Target:** CrabNebula RA: 83.633°, Dec: 22.015° **Max Time:** 160 min
CrabNebula_W0.50p000 - autoguider_with_callbacks.py (~ min, 40 estimated, 40 max)
CrabNebula_W0.50p180 - autoguider_with_callbacks.py (~ min, 40 estimated, 40 max)
CrabNebula_W0.50p090 - autoguider_with_callbacks.py (~ min, 40 estimated, 40 max)
CrabNebula_W0.50p270 - autoguider_with_callbacks.py (~ min, 40 estimated, 40 max)

2026-02-24_OffFixed-20-030_SCAD_T7 done SCI FIXED
Telescope: ASTRI1 **isToo:** false **Target:** OffFixed-20-030 Az: 30.000°, Alt: 70.000° **Max Time:** 40 min
OffFixed-20-030_Fixed - fixed_observation.py (~ min, 40 estimated, 40 max)

Telescope Name:	ASTRI1
OPCUA IP:	10.10.1.183
Motion Status:	STOPPED
RA:	0.000
DEC:	0.000
azPosition:	0.000
azVelocity:	0.000
elPosition:	0.000
elVelocity:	0.000

No trajectory data available

Central Control System | Telescope Control System | Short Term Observing Plan

Astri Manager Component state

Initialised → Standby

operational Idle → Movable → operational Nominal

TCS/TcsTelManager_1

STANDBY

INTERNAL: TEL_STANDBY MCS: ASSEMBLY_INITIALIZED PMC: ON CAM: ON
CC_CAMERA_STATUS: ASSEMBLY_STANDBY

TEC Temperatures

OOQS/OOQSManager_1

STANDBY

ADAS/ADASManager_1

STANDBY

State internally managed by TCS (not controlled by buttons above).

TCS/TcsTelManager_2

OFFLINE

OOQS/OOQSManager_2

OFFLINE

ADAS/ADASManager_2

OFFLINE

TCS/TcsTelManager_3

INITIALISED

INTERNAL: TEL_INITIALISED MCS: ASSEMBLY_INITIALIZED PMC: OFF
CAM: OFF CC_CAMERA_STATUS: ASSEMBLY_UNKNOWN

TEC Temperatures

OOQS/OOQSManager_3

INITIALISED

ADAS/ADASManager_3

INITIALISED

State internally managed by TCS (not controlled by buttons above).

ASTRI Mini-Array as precursor of SST-CTAO

SST-1 in DAL BEN SpA integration hall ready for qualification tests

SST-2 to 10 being assembled in a second integration hall

Conclusions

- For the first 4 years the ASTRI Mini-Array will be run as an experiment dedicated to the Core Science Topics but with followup of some transients.
- Detection of Crab, Mrk 501 and Mrk 421.
- The Early Science phase will begin next summer.
- The ASTRI Mini-Array will start scientific observations in Fall 2026 with at least 7 telescopes

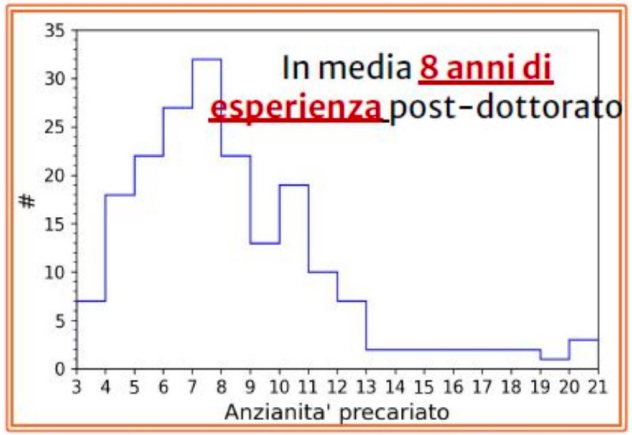
- **If you are interested in joining, please let us know, with the understanding that this would involve a commitment to concrete work.**
- **Transition towards an Observatory period to open to observational proposals from the scientific community**

More at :

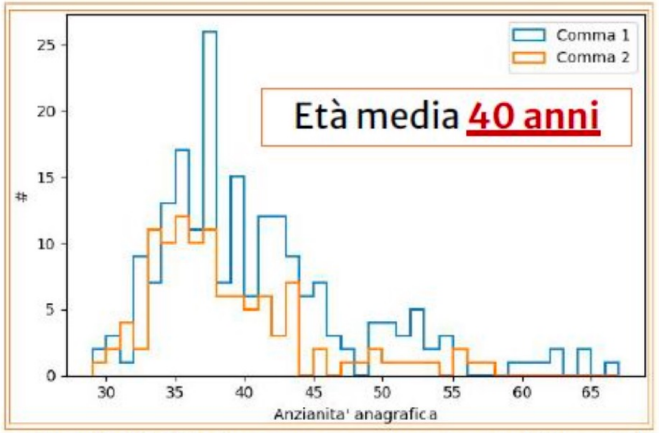
- Astri web site : http://www.astri.inaf.it/
- On socials, search for ASTRIgamma (FB and Instagram)

La situazione del personale precario in INAF è INSOSTENIBILE!

1.200 Tempo Indeterminato Vs **650** precari: più di 1 precario ogni 2 persone di ruolo



Plot di un campione rappresentativo dei precari INAF al 31/12/2024



Dei 650, **287** possono essere stabilizzati:
173 tramite chiamata diretta (comma 1)
114 tramite concorsi riservati (comma 2)

Entro l'anno, l'attuale situazione determinerà l'esodo di > 100 lavoratori altamente qualificati e il MUR se ne lava le mani

È **URGENTE** che INAF **PROCEDA ORA** con le **STABILIZZAZIONI TRAMITE MADIA:** unica soluzione per questa emergenza

Molti colleghi (972) hanno già firmato, per sostenerci e aggiungere il nome alla lista del QR,
contattaci a retestabilizzandi1.inaf@gmail.com