The ASTRI-Mini Array software engineering approach and the on-site software system
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for the ASTRI Project
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TETIS Workshop
People involved in ASTRI Mini-Array software

Outline

- The ASTRI Mini-Array project
- System and software engineering approach
- Software functional architecture: context and main drivers
- The SCADA (Supervisory Control and Data Acquisition) software system: technical architecture
The ASTRI Mini-Array project
The ASTRI Mini-Array project

The **ASTRI Mini-Array** is an INAF project aimed to construct, deploy and operate a set of 9 Cherenkov telescopes of the 4-meter class at the **Observatorio del Teide in Tenerife (Spain)** in collaboration with IAC. The project involves more than one 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) and international institutions (University of Sao Paulo – Brazil, North-West University – South Africa, IAC – Spain) Italian and foreign companies are and will be involved in the ASTRI Mini-Array project with important **industrial return**

- **Wide-field stereoscopic observations in the 1 – 300 TeV energy band**
  - Restricted number of targets/deep exposures (>~ 200 h) → strong scientific cases
  - Galactic sources: wide FoV → multi-target fields
  - Extragalactic sources: study of a few promising targets at > ~10 TeV scale
  - Fundamental physics

- **Stellar Hambury-Brown intensity interferometry in the visible band with very long baselines (hundreds of meters)**
The ASTRI Mini-Array architecture

- **Infrastructure**: parts to make the observational site suitable to host the telescopes of the ASTRI Mini-Array.
- **Safety & Security**: for the protection of people and site assets
- **Telescopes**
- **ICT**: computing/storage hardware, networking infrastructure, system services on-site and off-site.
- **Software**
- **Monitoring, Characterization and Calibration**: devices that allow the environmental monitoring the atmospheric characterization and the array calibration.
- **Logistics Support**: hardware & software necessary for the preventive and corrective maintenance of the ASTRI Mini-Array.
ASTRI-MA Layout

Figure 19: Physical Architecture of the Mini-Array System at the AOS, including the AOS Data Center. The black lines represent standard network cables or optical fibers; the yellow lines represent safety certified cables or optical fibers; the red lines represent white-rabbit certified cables or optical fibers.

ASTRI Mini-Array Layout

Observatorio del Teide in Tenerife
System Engineering and Software Engineering: a common and integrated approach
ASTRI-MA as a System of Systems

Model Based System Engineering:
- SysML modelling with block diagrams of the PBS.
- Internal block diagram modelling for interface management

Figure 3. System of Systems Building Blocks
The logical model of the MA hardware system

Description of the HW components and their relationship

HIRERARCHICAL view of the controlled HW
Dynamic View of the controlled HW

Each level of the hierarchy of **control software** manages a state machine.
Software functional architecture: context and main drivers
Drivers

➔ no human presence at the site during the observing nights.
➔ The Mini-Array shall be operated remotely, from the Array Operation Centers (AOCs) available from different locations, including one at the Array Observing Site.
➔ Only one AOC shall control the array, while any others shall be restricted to a read-only mode, suitable for monitoring.
Drivers/2

➔ The **observation plan** (a set of Scheduling Blocks) shall be **prepared and validated in advance** by the Science User.

➔ The Software System shall be able to:
  ◆ **automatically** execute the whole sequence of operations needed to perform an **observation**.
  ◆ react to environmental critical and survival conditions in an automatic way to put the array system in **safe state**.

➔ All data (scientific and technical) shall be **transferred to a remote data centre located in Rome** (Italy) at the end of each run, where they will be permanently archived.
  ◆ Any search for Cherenkov events detected in coincidence by more than one telescope (**stereo trigger**) shall be performed via software **off-line** at the Rome Data Center.
  ◆ **Data processing** shall be carried out off-line at the Rome Data Center, including the historical analysis of monitoring and logging data.
• Acquired data for one night:
  ○ ~3 TB of scientific Cherenkov RAW data
  ○ ~30 TB of scientific Intensity Interferometry RAW data but only for 3 nights/month
• The system shall monitor at least 20000 distinct sensors ("monitoring points"), at a rate of 1 Hz per sensor.
Software System Requirements and External Review

- ASTRI-MA Top Level Software Architecture:
  - **functional architecture** and quality requirements
- ASTRI-MA Top Level Use Cases:
  - behaviour
- ASTRI-MA Data Model:
  - to support functional and behavioural views and support for logical external/internal interfaces
- Derived documents:
  - ASTRI-MA Software Product Breakdown Structure:
  - ASTRI-MA Glossary:

External Concept review of Software System Requirements docs: in March-June 2020, passed

- **198 RIXs**, of which 31 discussed during the review meeting
- Main recommendations:
  - explicitly identify operations that can be automatised
  - provide a short and mid-term plan with clear milestone for external companies
  - complete maintenance use cases in addition to science and operation use cases
  - use ACS concept to the whole architecture

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<tr>
<th>Name</th>
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<tr>
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The data model describes the purpose, structural elements, configuration and how data products relate to one another and the properties of real-world entities.

- describes the configuration of the MA System
- describes the data and data products exchanged
- describes the elements for operations (observing plans, executed runs)
ASTRI MA Software PBS and development approach

See Federico Russo’s talk on ASTRI-Horn heritage

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<td>Array Calibration Control System</td>
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Context and main systems

- **SCADA (Supervisory Control and Data Acquisition)** System controls all operations carried out at the Mini-Array site and data acquisition, monitoring and alarms.

- **Data Processing System** to calibrate, reduce and analyse the data, and checks the quality of the final data products. For Cherenkov and Intensity Interferometry data.

- **Science Support System** for Observing Projects and observation plans preparation, dissemination of scientific data and science tools

- **Archive System** provides a central repository for all persistent information of the MA system.

- **Simulation System** plays a central role in configuration and data processing
Deployment in operation

During the AIV phase a subset of the Data Processing system will run on-site
SCADA

- control operations carried out at the Mini-Array site, executing all kinds of Scheduling Blocks;
- startup of the Mini-Array system;
- interfaces and communicates with all equipment;
- acquire data and other information, by means:
  - **Array Data Acquisition** acquires Cherenkov Cameras, Intensity Interferometry modules, and Atmosphere Characterisation system data;
  - **Online Observation Quality** focuses on ongoing problems and status of the observations;
  - **Logging, Monitoring and Alarm systems** 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**;
The SCADA software system: technical architecture
SCADA control software, ACS and OPC-UA

- SCADA system interacts with Local Control Systems that provide OPC-UA server interfaces.
- **SCADA** has only OPC-UA clients: Alma Common Software (ACS) is the general framework for the Control Software “OPC-UA client side” and to monitor all software sub-systems.

**ACS**

- ACS monitor all running software components.

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A. Bulgarelli, 1\textsuperscript{st} TETIS workshop, Oct 2\textsuperscript{nd}
System Configuration DB (SCDB)

- The controlled system and all interfaces are described in a System Configuration DB common to all Mini-Array Software System (e.g. simulation configuration, configuration for data processing, assemblies to be controlled, all interfaces)
  - A common database schema exists for all the subsystems. This eases operations as the development and maintenance of the database structure can be controlled by a small group of experts all allow to have information and data formats that are standardized across all subsystems.

```
| Product Tree | Interfaces | Location | Serial Number | Software Module | Available |
```

SCDB Runtime

```
| Calibration parameters |
| Monitoring points |
| Alarms conditions |
```
• **Alarm, Monitoring, Logging, Observation Quality System** are producer that publishes on a **Kafka topic**
  - Any subsystem can be a consumer connected a Kafka topic
  - **Alarm** and **Monitoring** are independent from **ACS** but communication with ACS
Development & Quality

Iterative - Incremental Development Approach

SOFTWARE QUALITY ASSURANCE

Development tools:
- git
- Jenkins
- Enterprise Architect for requirement management, system engineering, software engineering

Quality Assurance Management Organization

PRODUCT
- Deliverables (sw / repo / docs)
- test activities (unit, CI, ..)
- Verification
- Validation
- Acceptance
- Maintenance

PROCESS
- Planning and requirements
- Activities monitoring and control
- Problem reporting and corrective actions
- Reviews and Milestones

Software will be developed in an incremental way in different phases, increasing automation and complexity for each phase.
Conclusions
Conclusions

SW project steps:
- Current step: Aug-Oct
  - general project organisation (sw management and development plan)
  - production of templates for WPs
- Next step: Nov 5, kick-off for the design and implementation of sub-WP softwares
  - Prepare industrial contracts for software