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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

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Outline

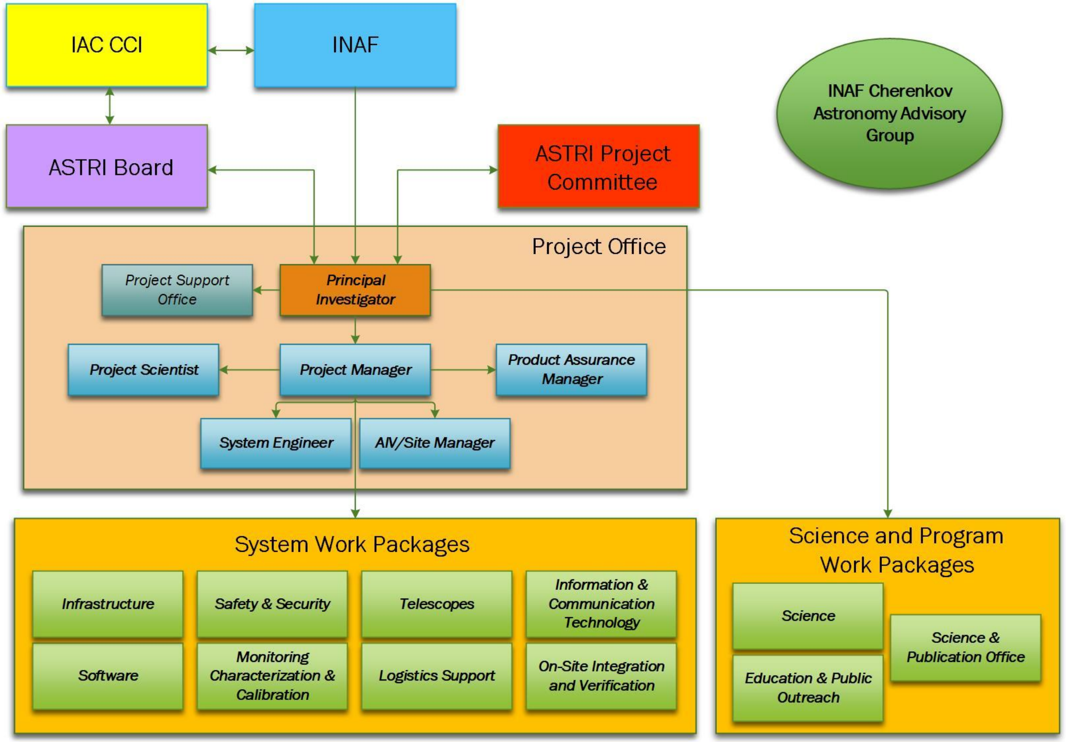
- The ASTRI Mini-Array project
- System and software engineering approach
- Software functional architecture: context and main drivers
- The SCADA (Supervisory Control and Data Acquisition) software system: technical architecture

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.

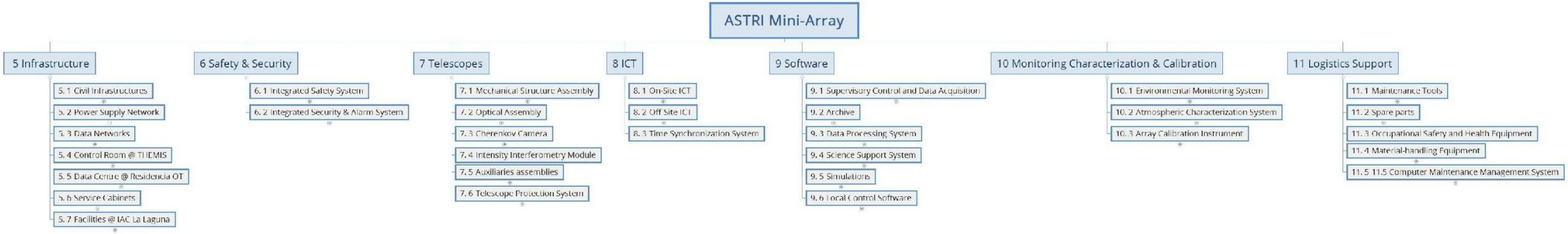
The project involves more than one hundred researchers belonging to INAF institutes (IASF-MI, IASF-PA, OAS, OACT, OAB, OAPD, OAR) Italian Universities (Uni-PG, Uni-PD, Uni-CT, Uni-GE, PoliMi) and international institutions (University of Sao Paulo – Brazil, North-West University – South Africa, IAC – Spain)



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

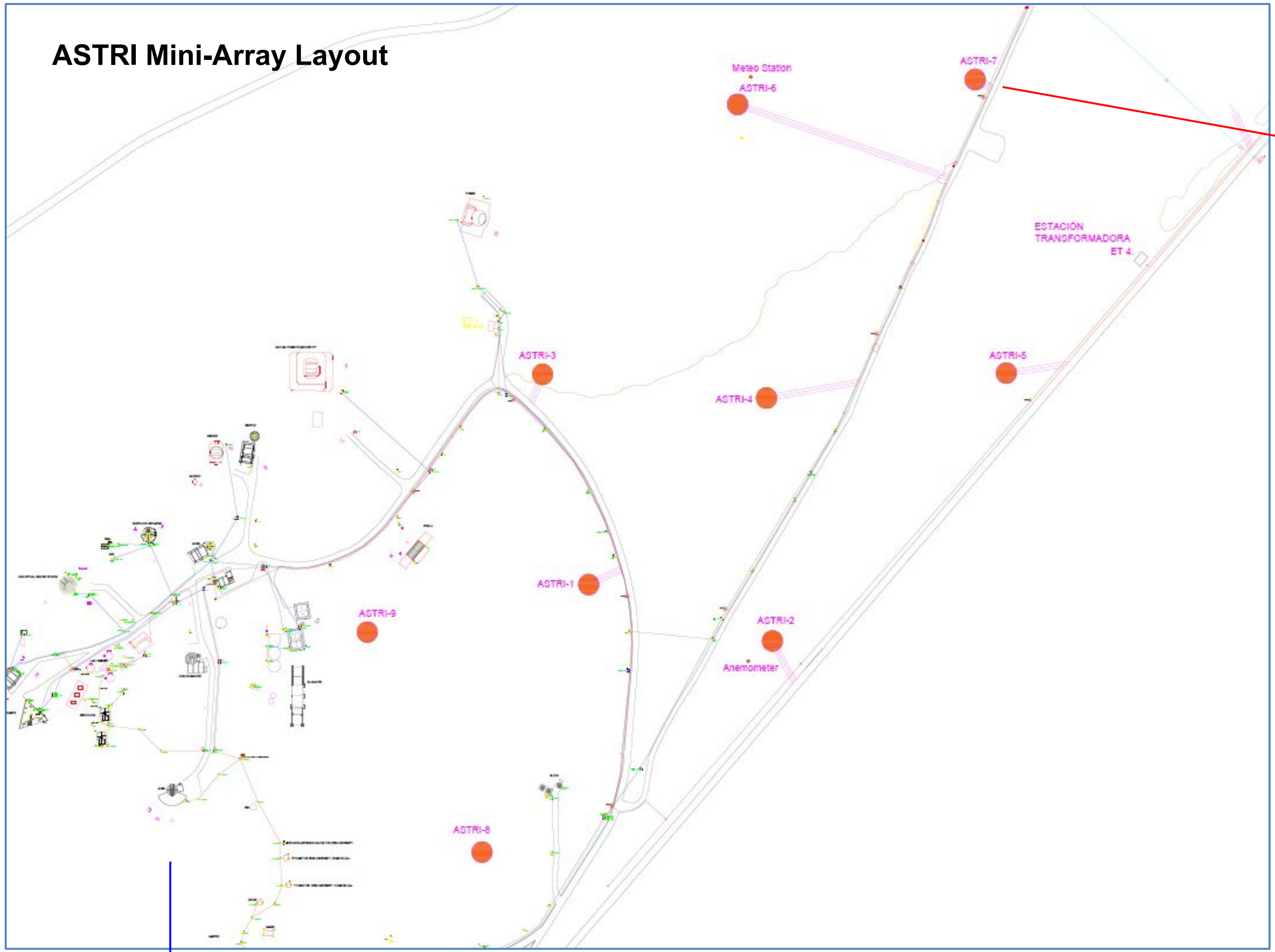
- **Wide-field stereoscopic observations in the 1 – 300 TeV energy band**
  - Restricted number of targets/deep exposures (>~ 200 h) → strong scientific cases
  - Galactic sources: wide FoV → multi-target fields
  - Extragalactic sources: study of a few promising targets at > ~10 TeV scale
  - Fundamental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



Observatorio del Teide in Tenerife

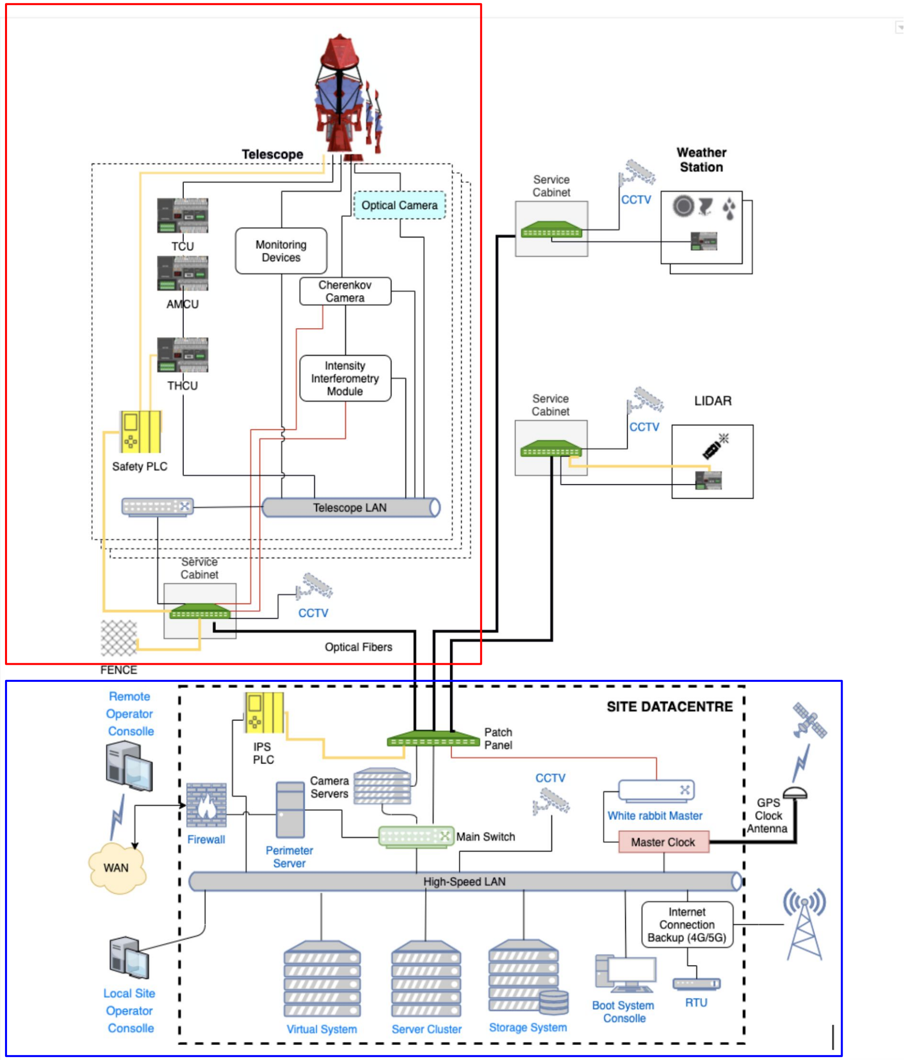


Figure 19: Physical Architecture of the Mini-Array System at the AOS, including the AOS Data Center. The black lines represent standard network cables or optical fibers; the yellow lines represent safety certified cables or optical fibers; the red lines represent white-rabbit certified cables or optical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

System Engineering and Software Engineering: a common and integrated approach

ASTRI-MA as a System of Systems

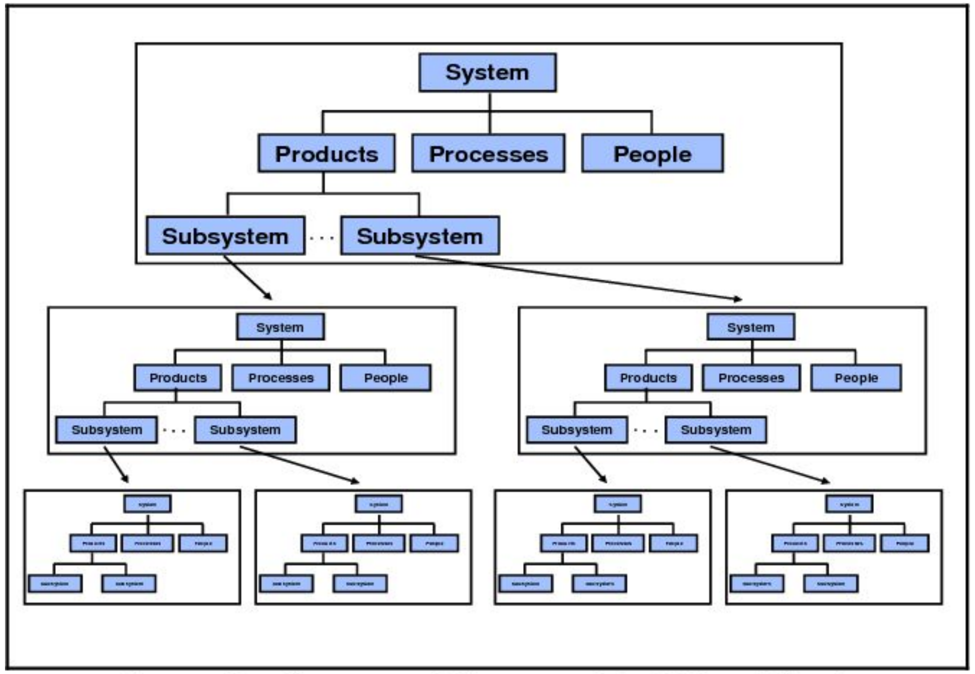
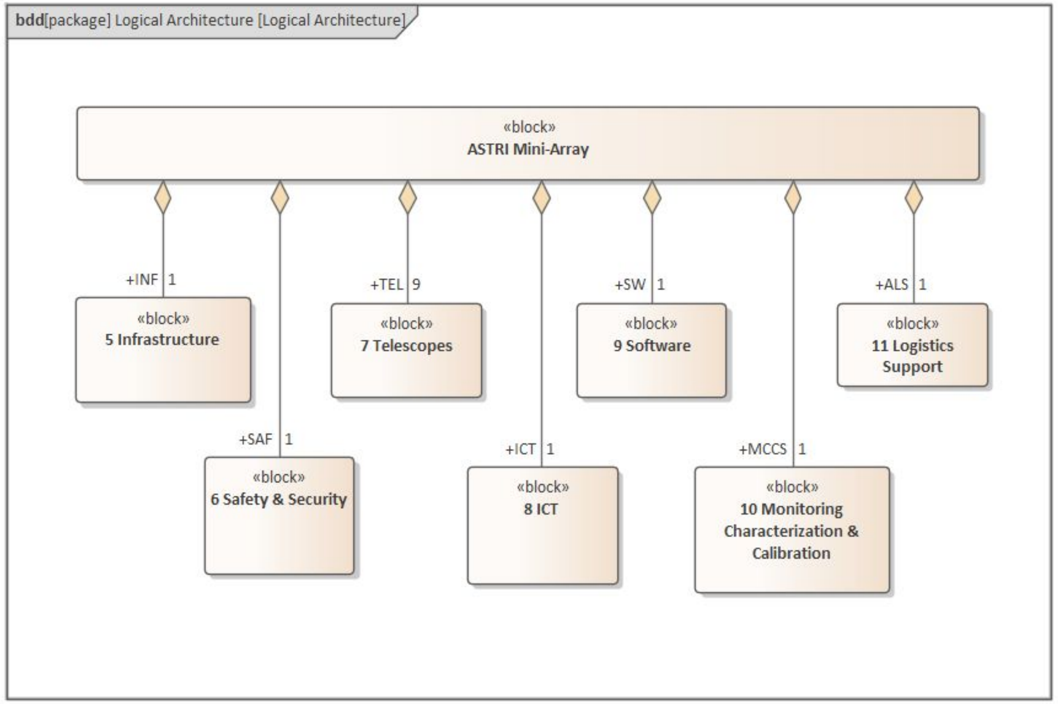


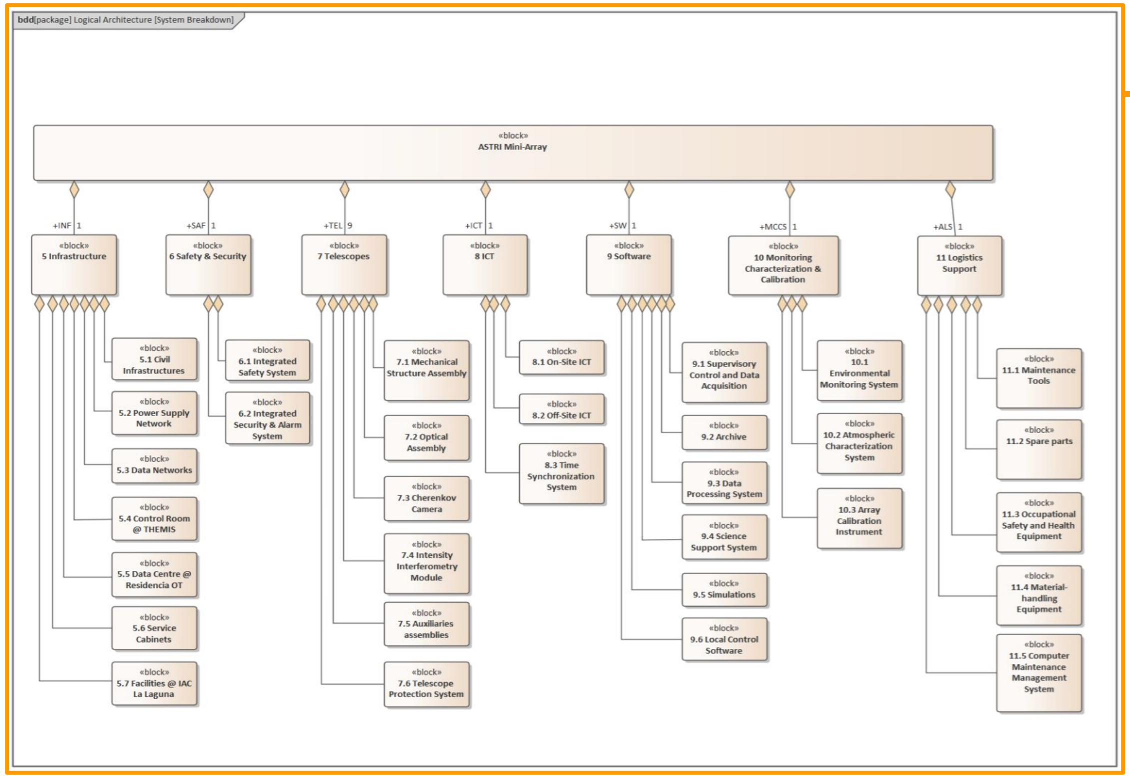
Figure 3. System of Systems Building Blocks



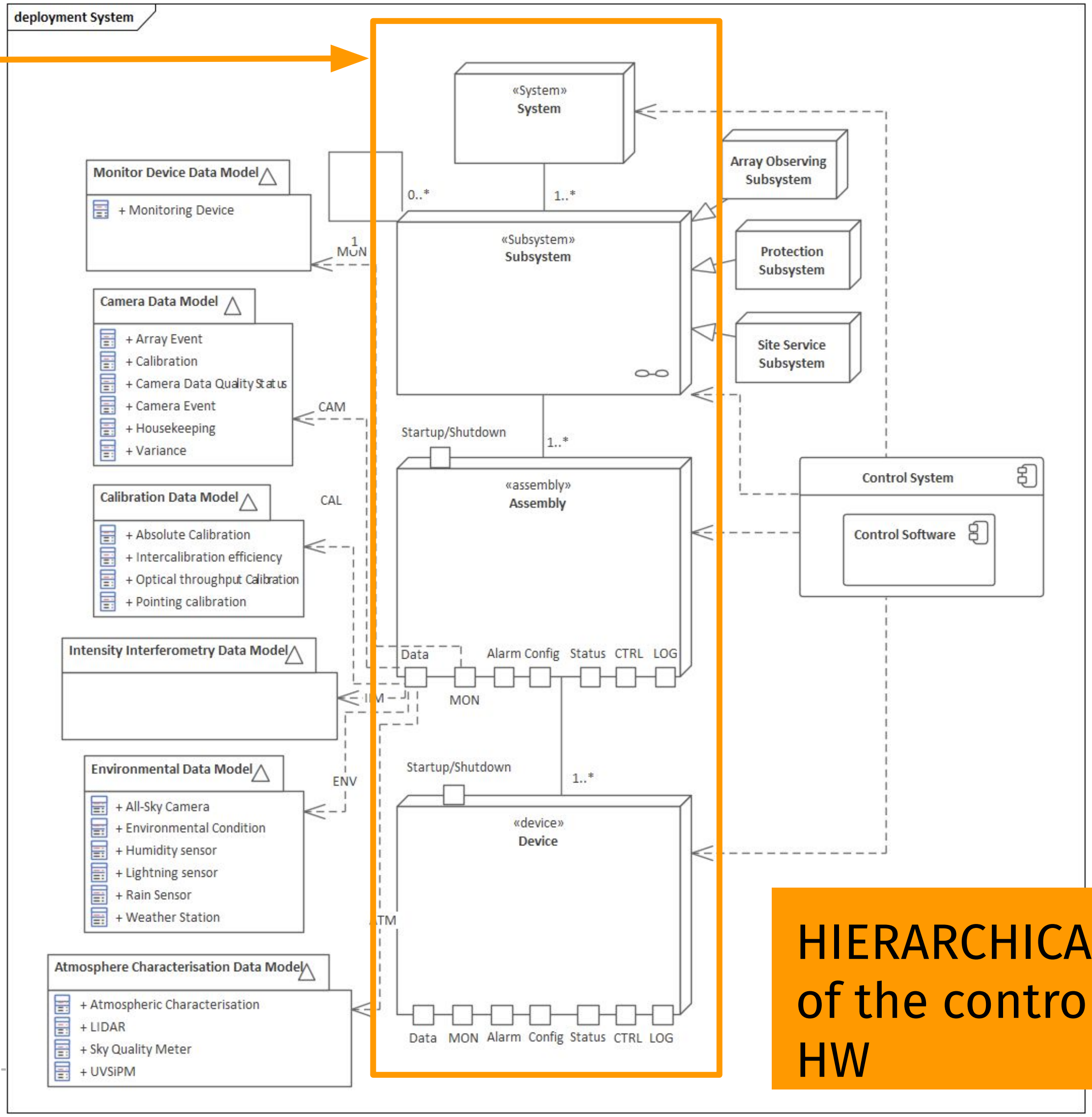
Model Based System Engineering:

- SysML modelling with block diagrams of the PBS.
- Internal block diagram modelling for interface management

The logical model of the MA hardware system

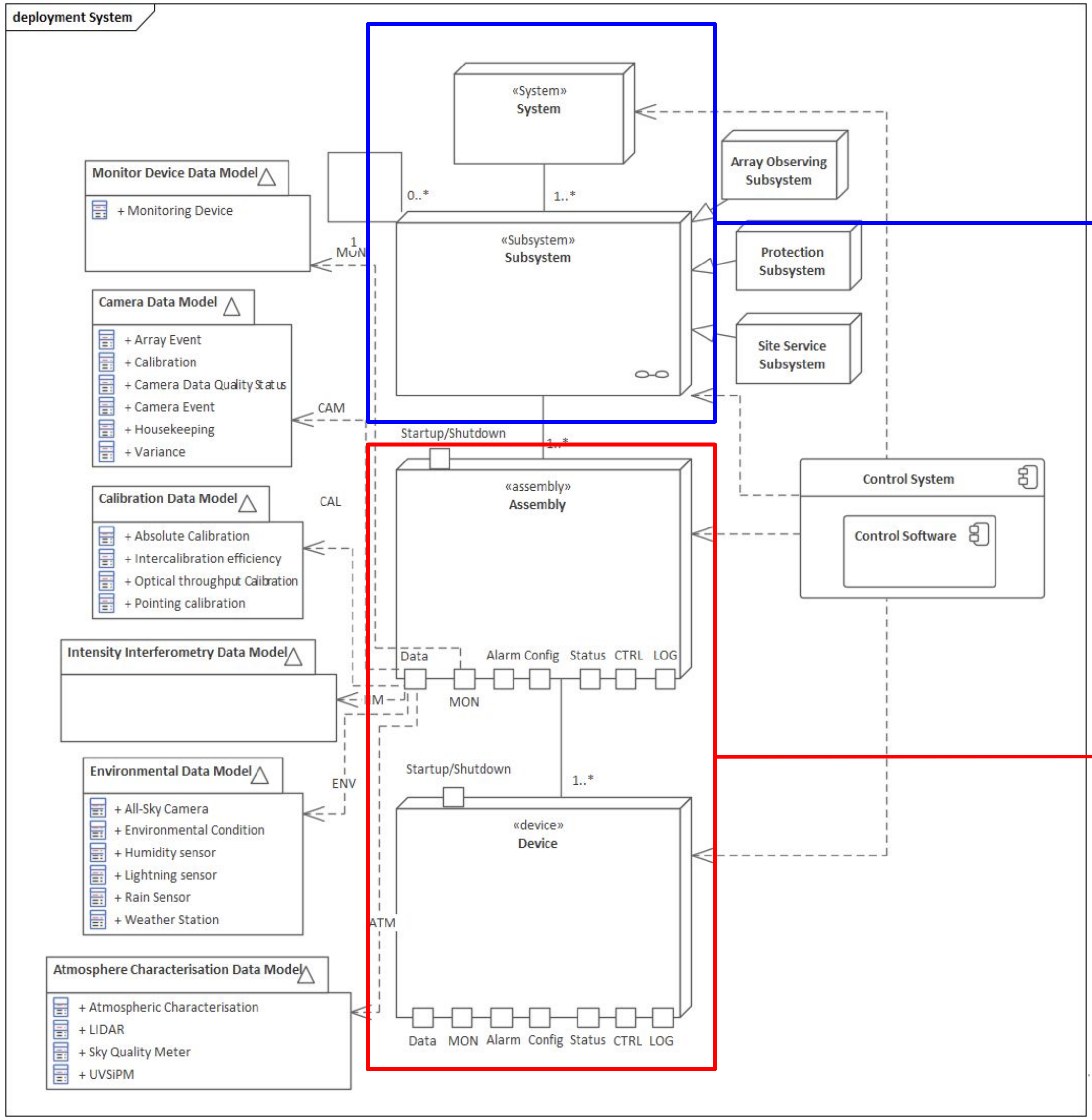


Description of the HW components and their relationship



HIERARCHICAL view of the controlled HW

Dynamic View of the controlled HW



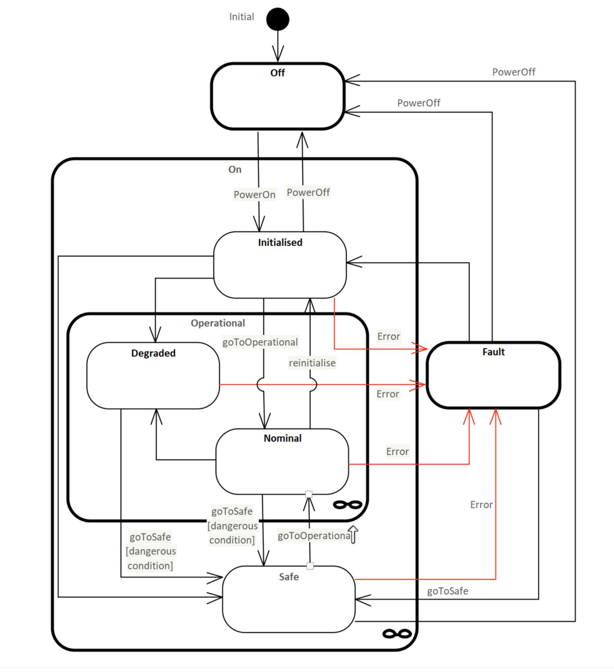


Figure 8: System/subsystem control system state machine

Each level of the hierarchy of **<u>control software</u>** manages a state machine.

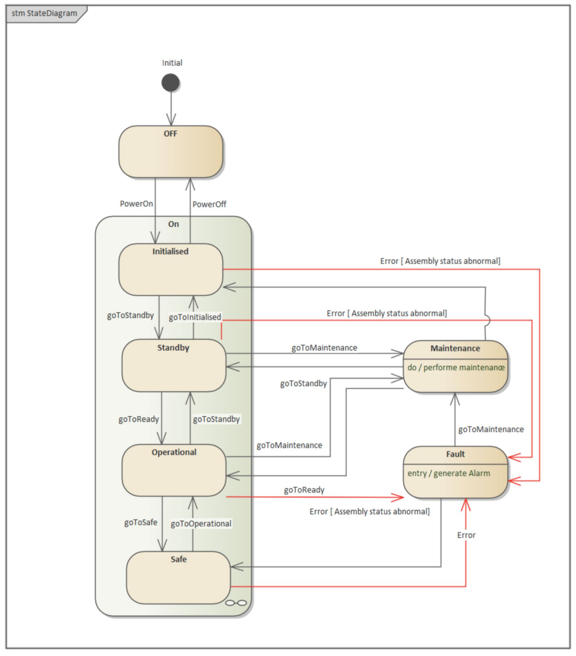
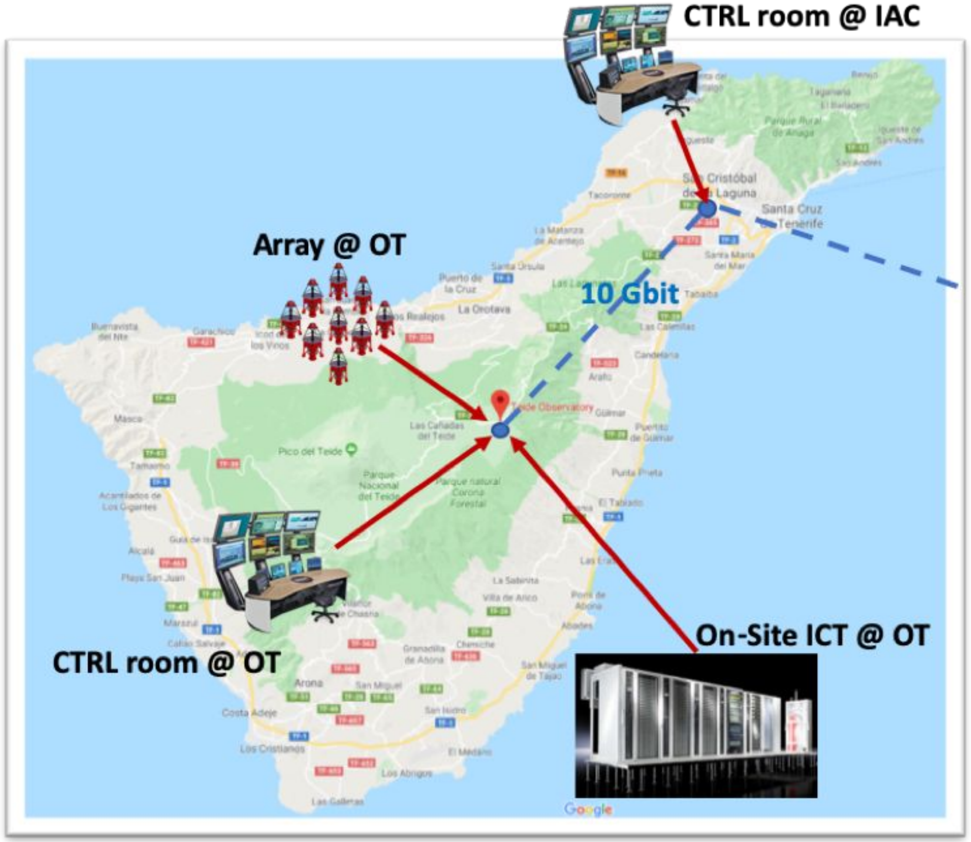


Figure 7: Assembly/device control system state machine

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

Mini-Array

- ➔ The <u>observation plan</u> (a set of Scheduling Blocks) shall be prepared and validated in advance by the Science User
- ➔ The Software System shall be able to
  - ◆ <u>automatically</u> execute the whole sequence of operations needed to perform an <u>observation</u>.
  - ◆ react to environmental critical and survival conditions in an automatic way to put the array system in <u>safe</u> 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.

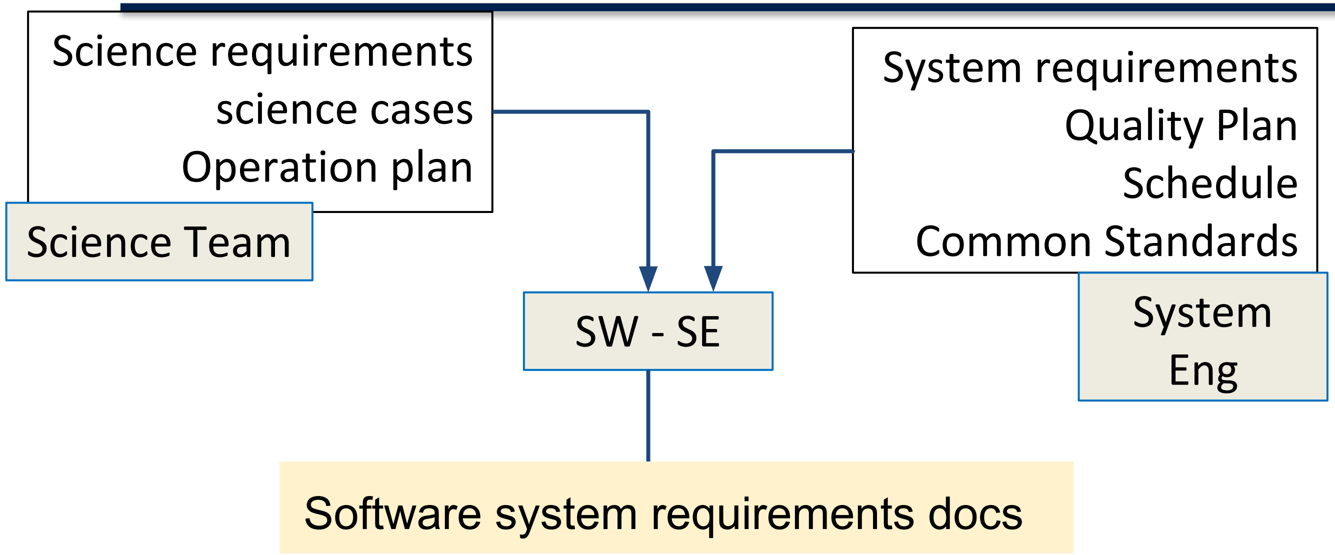
Drivers/3

Mini-Array

- 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

Mini-Array



- 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

Name	Affiliation
Anna Di Giorgio (Chair)	INAF – IAPS Roma
Stefano Covino	INAF – O.A. Brera
Paolo Di Marcantonio	INAF – O.A. Trieste
Marcello Lodi	FGG – TNG
Gianluca Chiozzi	ESO

- **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

Top Level Use cases + Data Model to software architecture

4.1. UC-MA-010: Prepare an Observation

Summary and Scope: The **Science User** submits an Observing Project. The MA Science Team/**Support Astronomer** evaluates the Observing Project, and prepares and schedules it.

Authors: Andrea Bulgarelli, Fabrizio Lucarelli

Version: 1.0

Trigger:

Frequency: Many times

Phase:

Assumptions:

PRE-CONDITION CONSTRAINTS

The ASTRI Mini-Array System is ready for SVP or for nominal observations and engineering runs.

SCENARIOS

Basic Path. Prepare Observing Project for Execution

1. The **Science User** submits an **Observing Project** using the **Science Support System**. The **Science User** specifies the Observing Strategy, that includes:
   1. the Target;
   2. the Observing Mode (e.g. Wobble) strategy;
   3. environmental condition constraints;
   4. atmosphere characterisation constraints (NSB allowed range, Sky Quality allowed range);
   5. time constraints (allowed time range, minimum requested time);
   6. array constraints (e.g. precision pointing, zenith angle range, minimum number of telescopes);
   7. tracking mode.

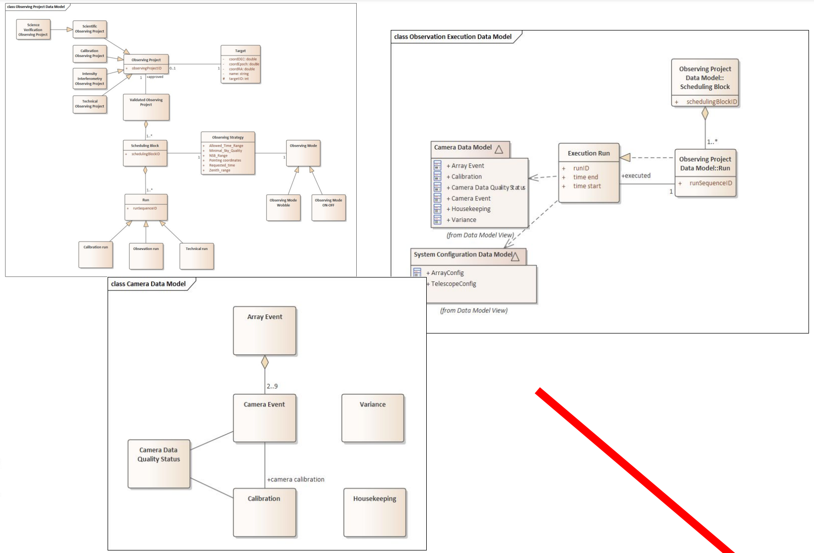
The **Science User** uses a *Visibility Checker* and a *Sensitivity Calculator* for the Observing Project preparation.
The Observing Project is stored in the **Science Archive**.
Observing Project submission.

Exception: 1a. *Errors or problems in the Observing Project* submission (See details below). Rejoins Main Scenario at End.

2. The **MA Science Team** performs a technical and scientific evaluation of the submitted **Observing Project**. The priority of an Observing Project is decided by the **MA Science Team**.
Observing Project evaluation.

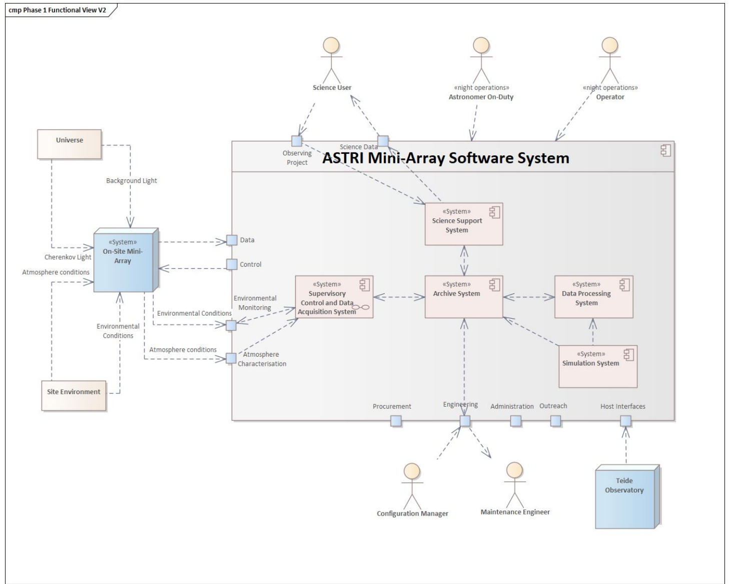
The MA Science Team checks whether the Observing Project is technically feasible, whether there are errors in the submitted information, and decides the priorities.

Exception: 2a. *Errors or problems in the Observing Project* (See details below). Rejoins Main Scenario at End.



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

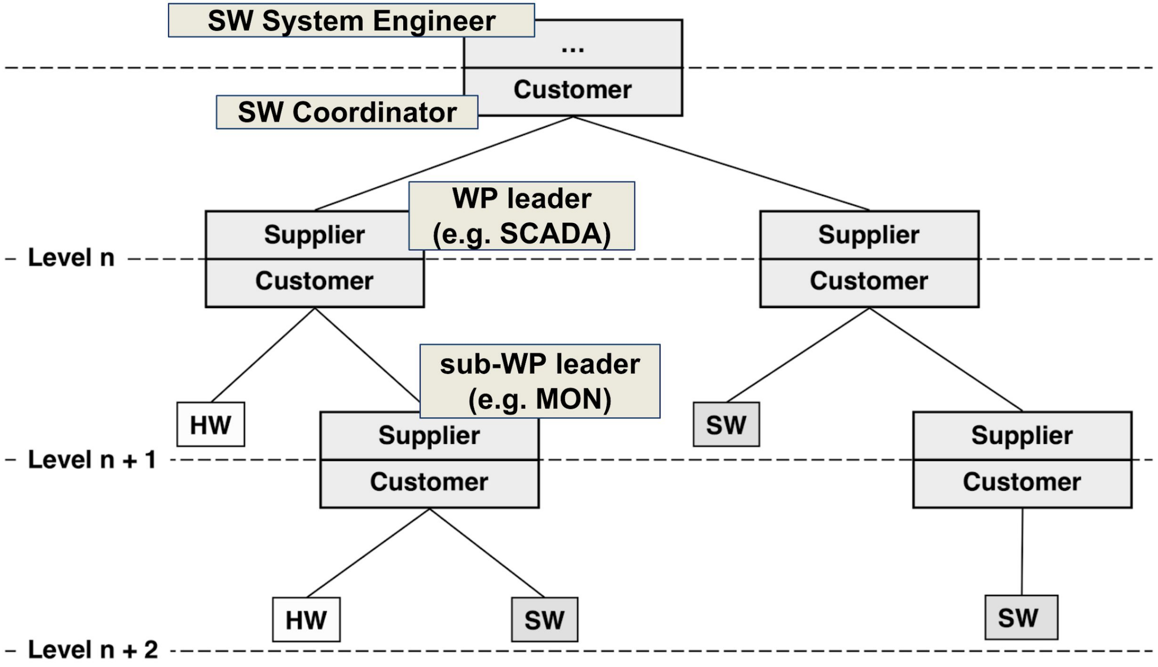
- describes the configuration of the MA System
- describes the data and data products exchanged
- describes the elements for operations (observing plans, executed runs)



ASTRI MA Software PBS and development approach

See Federico Russo's talk on ASTRI-Horn heritage

Software system requirements docs

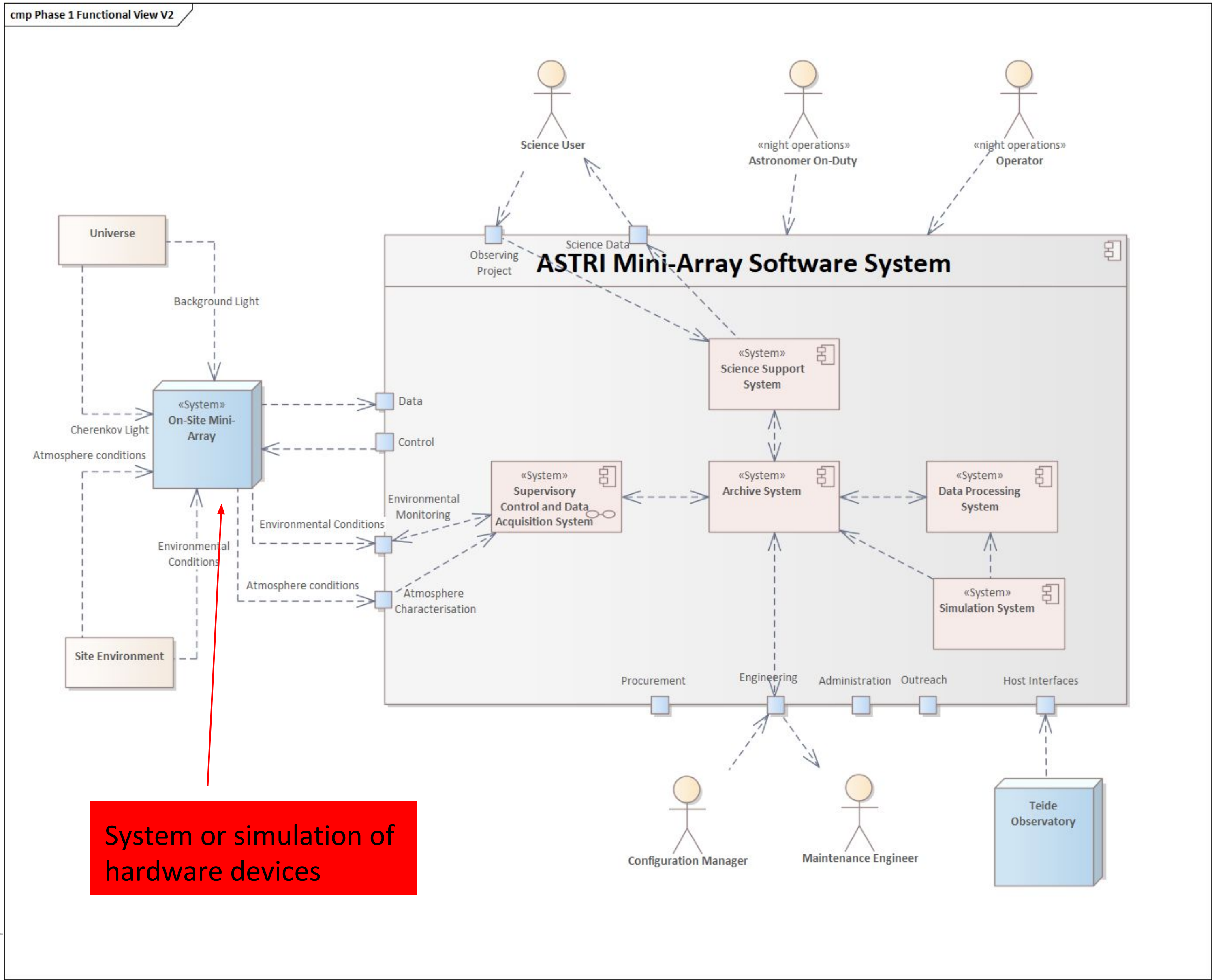


The Customer/Supplier relationship

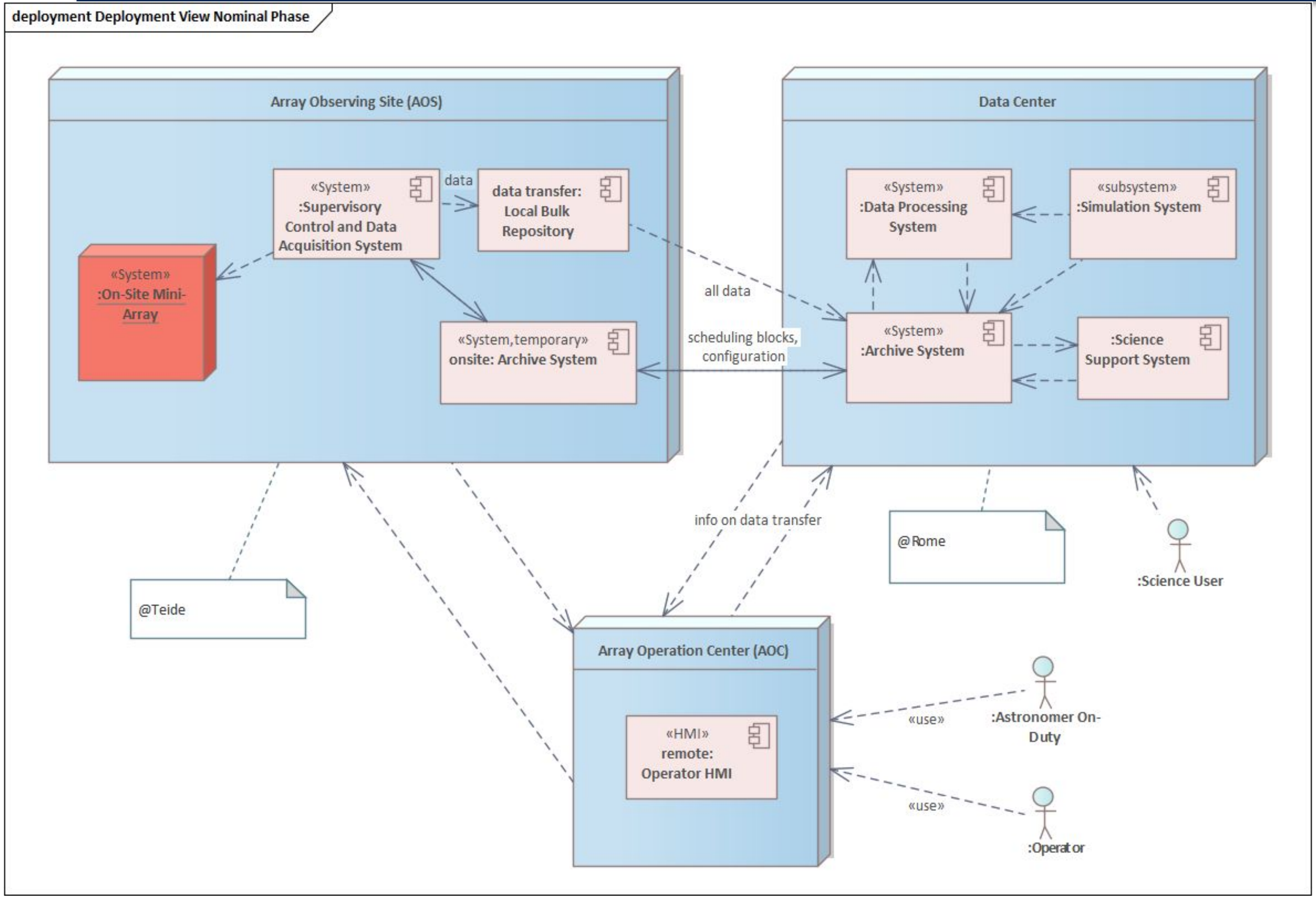
Systems		Supplier	Heritage
SCADA			
	Startup System	external company	
	Master Controller	external company	
	Central Control	external company	
	Array Data Acquisition	INAF	ASTRI-Horn
	Online Observation Quality System	INAF	Under development also for CTA/ACADA
	Alarm System	INAF	ALMA Integrated Alarm System, also used for CTA/ACADA
	Monitoring System	INAF	Under development also for CTA/ACADA
	Logging System	INAF	Under development also for CTA/ACADA
	Operator HMI	external company	
	Telescope Control System	INAF/external company	ASTRI-Horn
	Atmosphere Characterisation Control System	INAF/external company	
	Array Calibration Control System	INAF/external company	
Data Processing System		INAF/consultant	ASTRI-Horn
Science Gateway System		INAF	ASTRI-Horn
Simulation System		INAF	ASTRI-Horn
Archive System		INAF	ASTRI-Horn
Local Control Software		INAF/external company	ASTRI-Horn

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



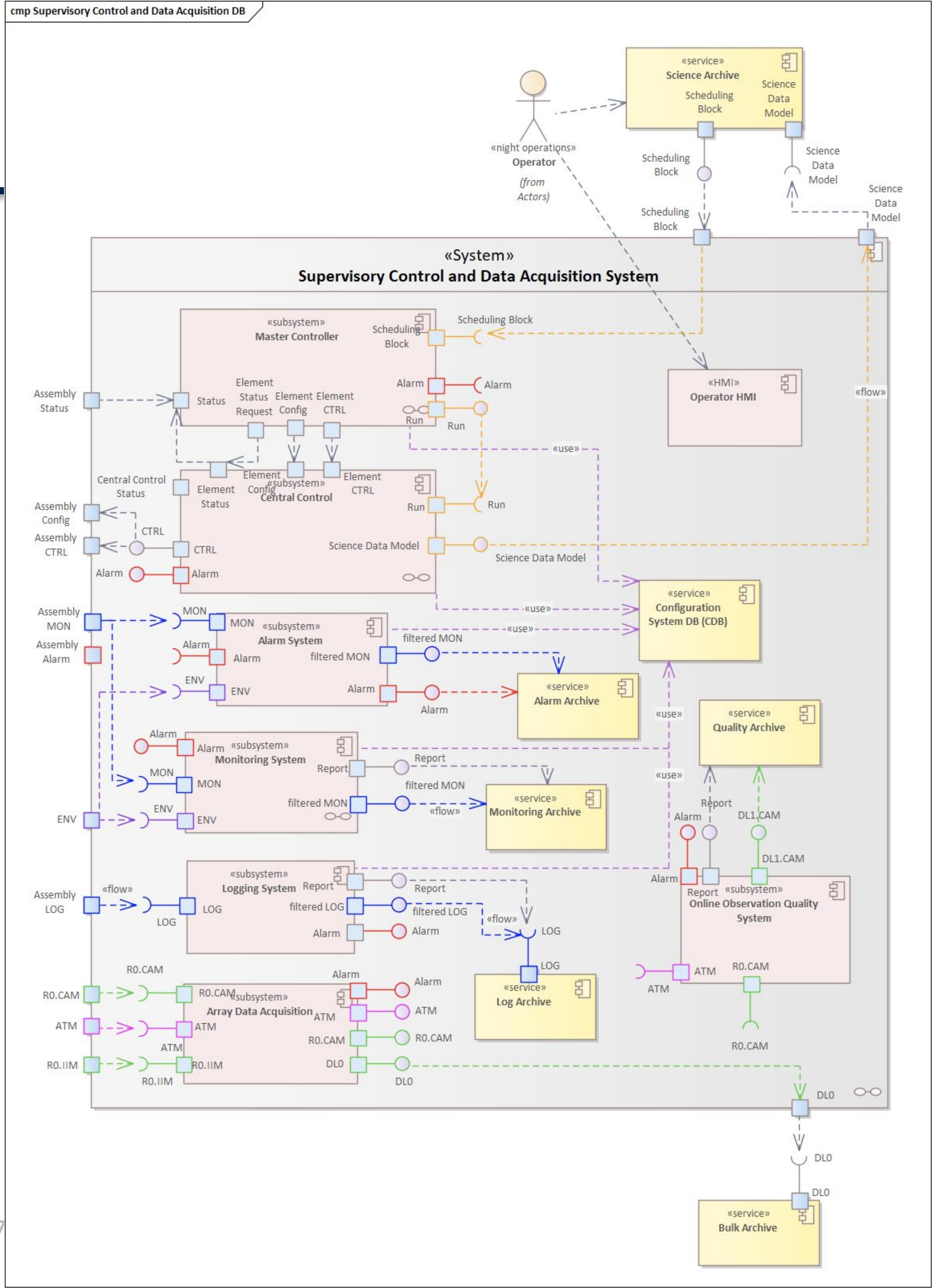
Deployment in operation



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

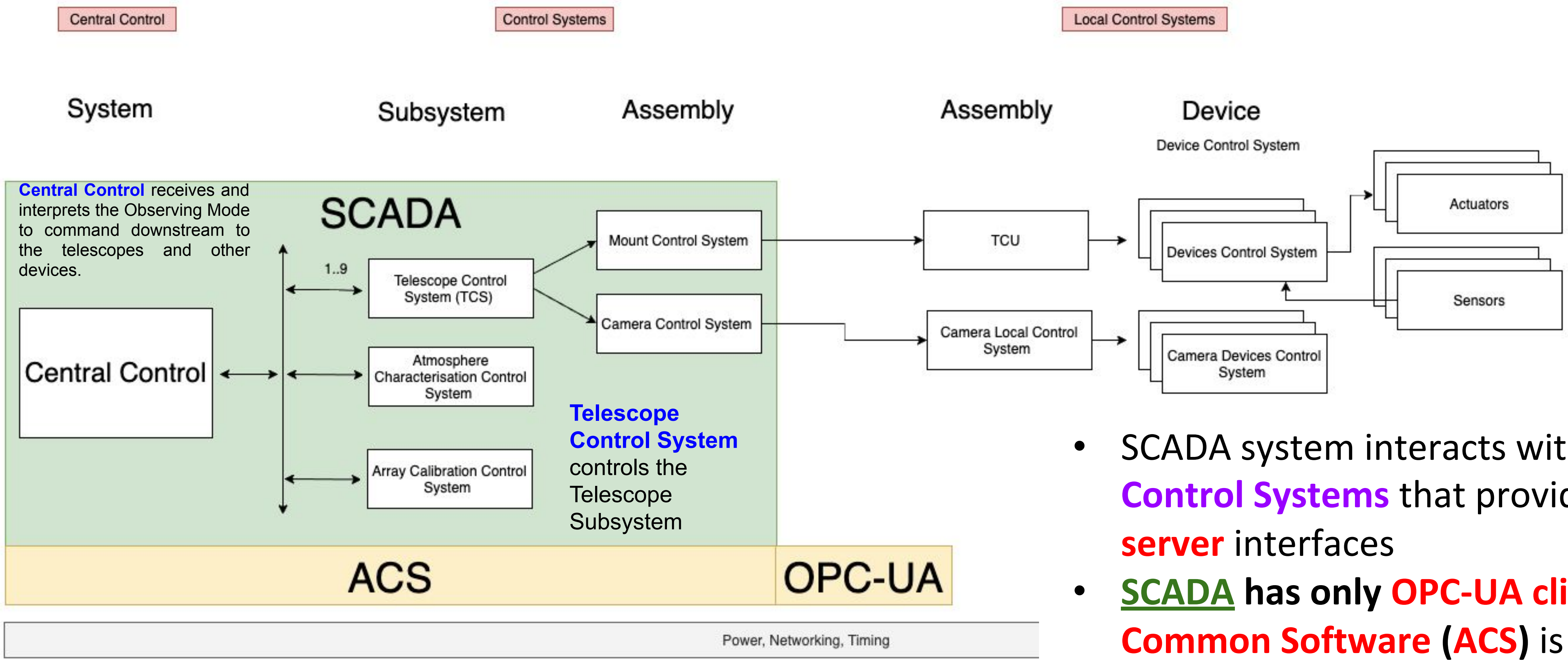
SCADA

- 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**;
    - Alarm system: ALMA Integrated Alarm System: https://integratedalarmsystem-group.github.io/



The SCADA software system: technical architecture

SCADA control software, ACS and OPC-UA

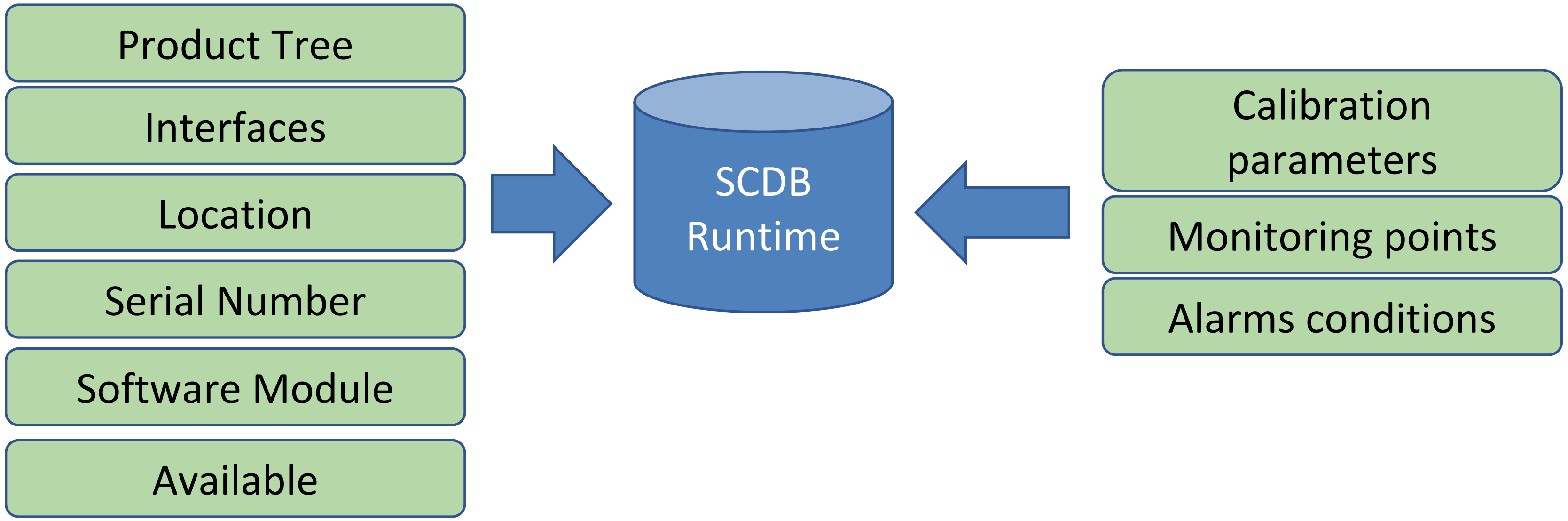


- ACS monitor all running software components.

- 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

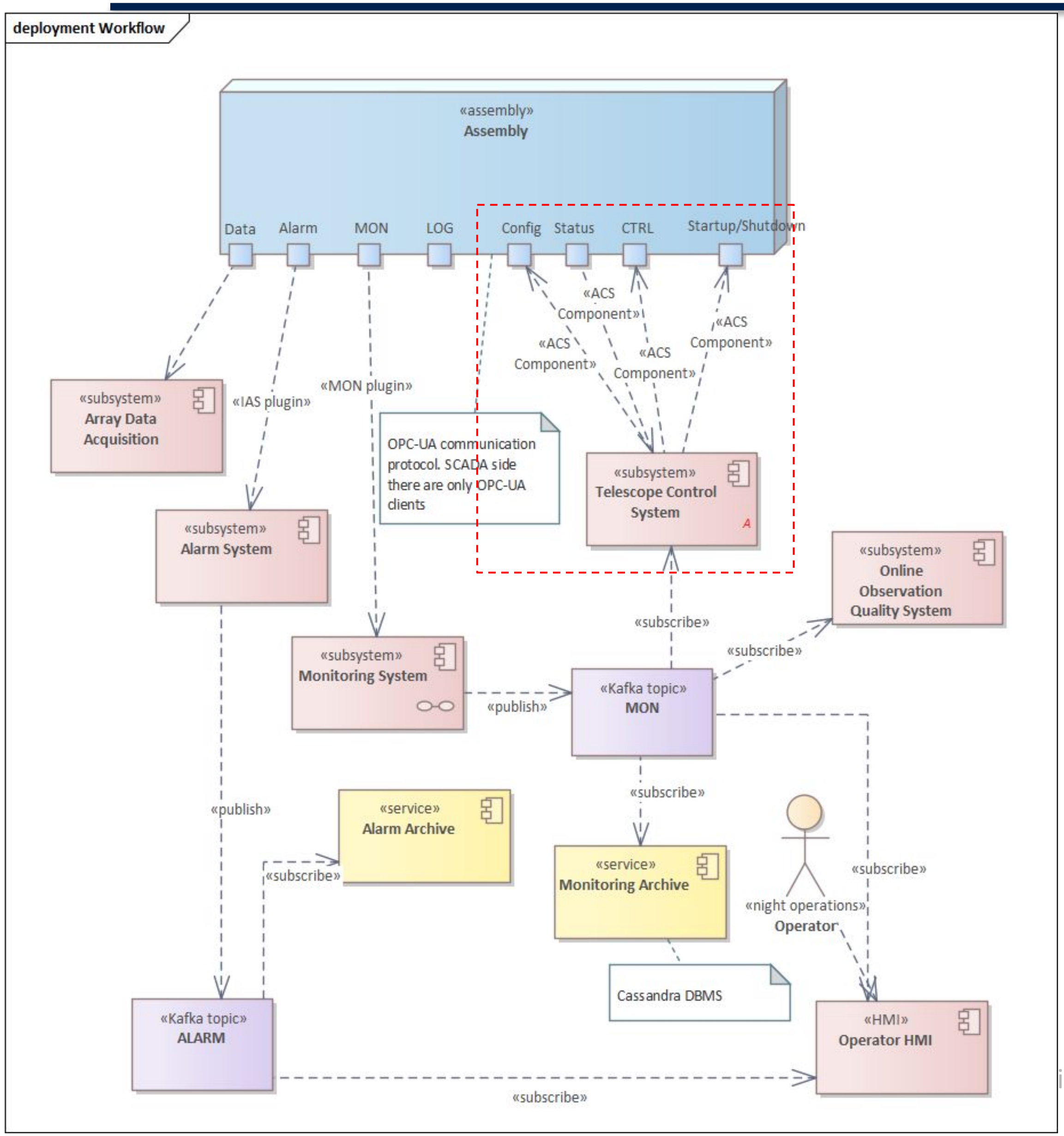
System Configuration DB (SCDB)

- 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.



ACS and Kafka

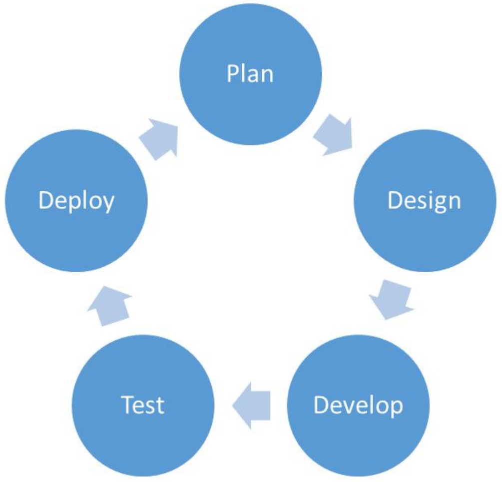
Mini-Array



- **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



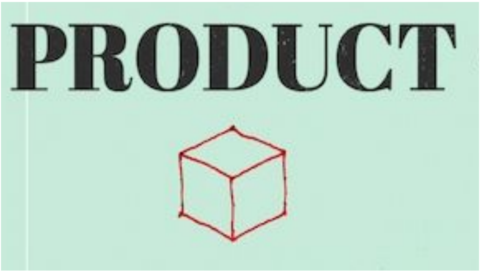
Development tools:

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

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

SOFTWARE QUALITY ASSURANCE

Quality Assurance Management Organization



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

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

Conclusions

Conclusions

Mini-Array

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