ASTRI Mini-Array SCADA/Central Control software system: Statement of Work

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1. Introduction

The **ASTRI Mini-Array (MA)** is an INAF ground-based project to construct, deploy and operate a set of nine identical dual-mirror Cherenkov gamma-ray telescopes. The ASTRI Mini-Array will exploit the imaging atmospheric Cherenkov technique to measure the energy, direction and arrival time of gamma-ray photons arriving at the Earth from astrophysical sources. The ASTRI Mini-Array will also perform Stellar Hambury-Brown intensity interferometry and direct measurements of cosmic rays. The site selected for the installation and operation of the ASTRI Mini-Array is the Observatorio del Teide in Tenerife (Spain).

This Statement of Work (SoW) describes the activities and the deliverables and work logic necessary for the provision of the "Central Control software system" required by INAF (referred to as "the Customer") in the context of the ASTRI Mini-Array Project.

This SoW will serve as an applicable document throughout the execution of the work by the Contractor to provide the core packages of the ASTRI Central Control software system design, development, integration, and on-site deployment, acceptance and maintenance during the warranty period.

1.1. Objectives

The objective of this document is to provide a general overview of the software products, services and development activities for the provision of the "on-site software system". In particular, the selected Contractor shall produce the **Central Control System**, which coordinates the sequence of operations to perform scientific observations, configure and check the status of the on-site systems. Some auxiliary connectors and control systems shall be developed by the Contractor

Contractor also provides:

1. Integration and Verification of the software subsystems developed by INAF and by the Contractor in the full SCADA system to be deployed on-site.
2. Delivery, installation and deployment of the full On-Site software system in the on-site operational environment.

All the activities and deliveries of the products shall be provided in accordance with the schedule and milestones defined in this document.

1.2. Applicable and reference documents

Updates of these documents will be provided at the kick-off meeting and during the development of the project.
Additional documents could be provided during the development of the project.
If discrepancies are found between this document and the documents of this section, this document overcomes the others.

1.2.1. Applicable documents

The following documents shall be applicable to this document.
The high-level view of the ASTRI Mini-Array software system and management plans are described in the following documents:

- [AD1] ASTRI MA Top Level Software Architecture, ASTRI-INAF-DES-2100-001, issue 2.5
- [AD2] ASTRI-MA Software PBS, ASTRI-INAF-DES-2100-002, issue 2.5
- [AD3] ASTRI MA Data Model, ASTRI-INAF-DES-2100-003, issue 2.5
- [AD4] ASTRI MA Top Level Use Cases, ASTRI-INAF-SPE-2100-001, issue 2.5
- [AD5] ASTRI MA Glossary, ASTRI-INAF-LIS-2100-001, issue 2.5
- [AD6] User Requirements of the SCADA Operator Human Machine Interface System, ASTRI-INAF-SPE-9100-008, issue 1.1
- [AD7] ASTRI MA Software Engineering Management Plan: ASTRI-INAF-PLA-2100-001, issue 1.0
- [AD8] ASTRI Mini-Array Software Quality Assurance Plan, ASTRI-INAF-PLA-3400-001, issue 1.0

1.2.2. Reference documents

- [RD1] ASTRI-INAF-PLA-2100-002 ASTRI-MA Software Development Plan, issue 1.0
- [RD2] ASTRI-INAF-PRO-2100-001 ASTRI Mini-Array Software Integration and Test Model, issue 1.0
- [RD3] ASTRI-INAF-REP-2100-001 ASTRI-Horn legacy
- [RD4] ALMA Common Software (ACS) Documentation, (https://confluence.alma.cl/display/ICTACS/ACS+Documentation)
- [RD5] ASTRI Mini-Array Software Licensing Policy - ASTRI-INAF-SPE-2100-002, issue 1.0
- [RD6] ASTRI Mini-Array On-Site Hardware Architecture, ASTRI-INAF-DES-8100-001, draft

2. ASTRI Mini-Array and SCADA overview

2.1. Overview

The **ASTRI Mini-Array (MA)** is an INAF ground-based project to construct, deploy and operate a set of nine identical dual-mirror Cherenkov gamma-ray telescopes, and several other auxiliary equipment and infrastructures. The ASTRI Mini-Array scientific objective is to exploit the imaging atmospheric Cherenkov technique to measure the energy, direction and arrival time of gamma-ray photons arriving at the Earth from astrophysical sources. In the almost unexplored energy range 1-300 TeV this technique requires an array of optical telescopes (~ 4 m in diameter) at a site located at an altitude of > 2000 m. The telescopes will have reflecting mirrors focusing the Cherenkov UV-optical light produced by atmospheric particle cascades (air-showers), initiated by the primary gamma-ray photons entering the atmosphere, onto ultrafast (nanosecond timescale) cameras. Most of the collected data will come from the large number of charged primary cosmic-ray initiated air-showers, which will also be recorded, then appropriate data analysis methods will be employed to reduce the level of this background and allow an efficient detection of gamma-rays coming from astrophysical sources.
Besides the gamma-ray scientific program, the ASTRI Mini-Array will also perform:

- Stellar Hambury-Brown intensity interferometry: each of the telescopes of the ASTRI Mini-Array will be equipped with an intensity interferometry module. The Mini-Array layout with its very long baselines (hundreds of meters), will allow, in principle, to obtain angular resolutions down to 50 micro-arcsec. With this level of resolution, it will be possible to reveal details on the surface of bright stars and of their surrounding environment and to open new frontiers in some of the major topics in stellar astrophysics.
- Direct measurements of cosmic rays: 99% of the observable component of the Cherenkov light is hadronic in nature. Even if the main challenge in detecting gamma-rays is to distinguish them from the much higher background of hadronic Cosmic Rays, this background, recorded during normal gamma-ray observations, will be used to perform direct measurements and detailed studies of the Cosmic Rays themselves.

The ASTRI MA telescopes (including the Cherenkov Camera) are an updated version of the ASTRI-Horn Cherenkov Telescope operating at Serra La Nave (Catania, Italy) on Mount Etna. The software developed by INAF for the ASTRI-Horn telescope, including development, testing and production environments [RD3], will be partially reused also in the ASTRI Mini-Array context.

The **Supervisory Control and Data Acquisition system (SCADA) software system** is a distributed software system operating at AOC that shall manage startup, shutdown, configure, supervise and control of all site **assemblies** and **subsystems**. SCADA shall control all operations to perform scientific observations and engineering operations; collect monitoring points; manage alarms raised by any assembly; check the health status of all systems and acquire scientific data. The **Central Control System (CCS)** and the **Operator HMI** are part of the SCADA system. The **Central Control System** is responsible for the execution of the Scheduling Blocks to perform observations.

The ASTRI Mini-Array elements are **geographically distributed** in the following main sites:

1. **Array Observing Site (AOS,** see Figure 1**)** at Observatorio del Teide (operated by the Instituto de Astrofisica de Canarias, IAC), where the nine telescopes and all Observing Site Subsystems will be installed. The **SCADA Software System** is installed at the Array Observing Site. The AOS includes a **Data Centre** where all the computing and networking resources used by the on-site software system will be installed.
2. The **Array Operation Centers (AOCs)** include **Control Rooms** located remotely at the IAC facilities in La Laguna (Tenerife), and at the Teide site to be used during the installation and commissioning phase of the Mini-Array.
3. The **ASTRI Data Centre** in Rome.

Other **Array Operation Centers (AOCs)** will be located at different remote locations (e.g. Italy). Control Rooms will allow the **Operator** to supervise and carry out the scheduled observations and calibrations during the night, while the **Astronomer on-duty (AoD)** will support and supervise the observations.

The on-site **SCADA Software System** shall be remotely controlled from only one of the Control Rooms at a time. Control responsibility may change from one AOC to another when necessary and subject to an orderly pre-defined procedure.

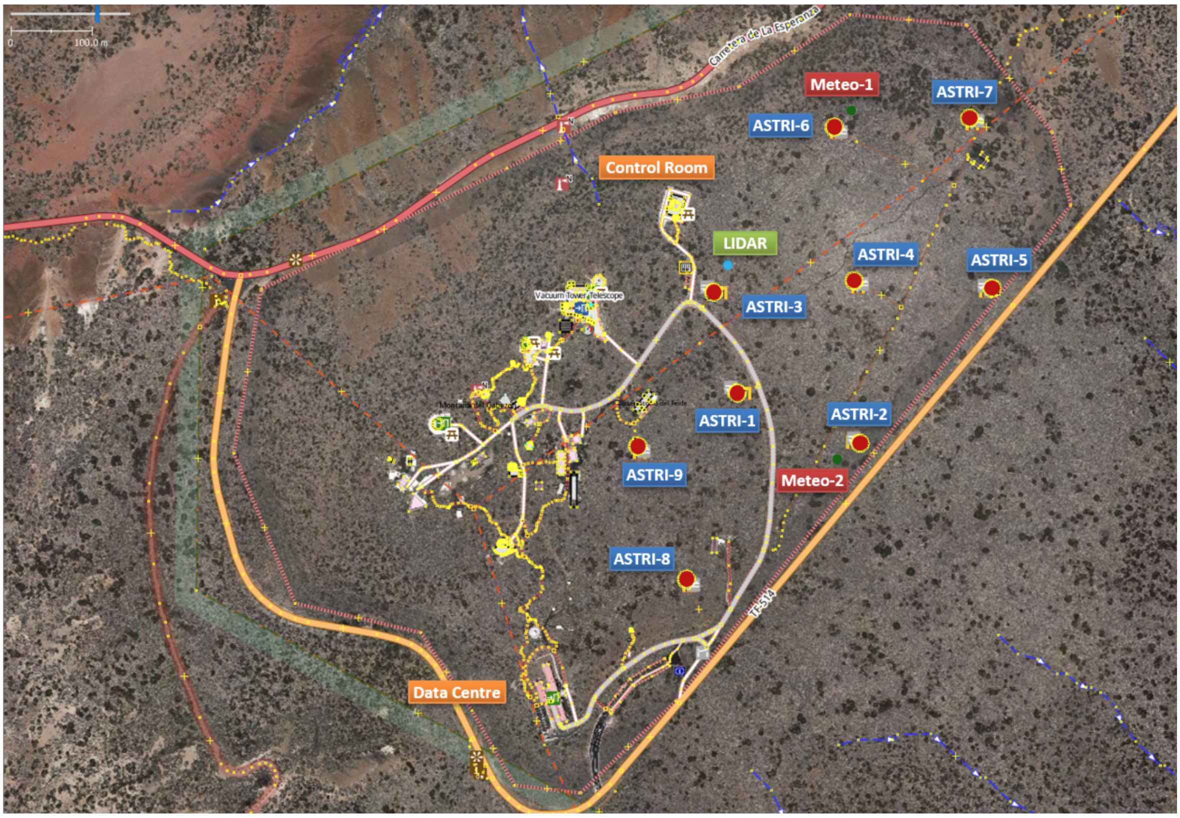

Figure 1: the proposed ASTRI Mini-Array layout at the Array Observing Site on the Teide Mountain

The following **assemblies** and **subsystems** (see [AD1] for more details) shall be controlled and monitored by the **Central Control System**:

- Observing Subsystems:
    - the **Array System,** composed of **nine Telescopes** with their assemblies, including the two main scientific instruments permanently mounted on each telescope: the Cherenkov Camera and the Stellar Intensity Interferometry Instrument. A third instrument, the Optical Camera, can be mounted on a Telescope only for calibration and maintenance activities.
    - Atmosphere Characterisation System:
        - LIDAR (LIght Detection And Ranging) allows us to study the atmospheric composition, structure, clouds and aerosols through the measurement of the atmospheric extinction profile.
        - SQM (Sky Quality Meter): measures the brightness of the night sky in magnitudes per square arcsecond. The system returns integral information about background light intensity inside its field of view on demand, generally, at a frequency of 1 Hz. Two SQM are mounted on two telescopes, plus one with the All-Sky camera.
        - UVSiPM: a light detector that measures the intensity of electromagnetic radiation in the 300–900 nm wavelength range. The analysis of the UVSiPM data will be used mainly to evaluate the level of the diffuse night sky background.
    - Array calibration system:
        - Illuminator: The Illuminator is a portable ground-based device, remotely controlled, designed to uniformly illuminate an ASTRI MA telescope's aperture with a pulsed or continuous reference photon flux whose absolute intensity is monitored by a NIST-calibrated photodiode. The analysis of the ASTRI MA Cherenkov camera(s) data acquired pointing each telescope at the Illuminator will allow measuring their detailed response efficiencies.
- Site Service Subsystems:
    - Telescope Power Management System including centralized UPS system
    - Information Communication Technology, including UPS system
    - Environmental Monitoring System:
        - two Weather Stations: the entire set of all weather station parameters will be monitored and archived at least every 2 seconds. Temperature, wind speed and direction, relative humidity, amount and type of precipitation form the set of critical parameters for the safety of humans and equipment. The **Central Control System** component shall put the entire Array system in safe mode if critical weather conditions are present;
        - Humidity sensors;
        - Rain sensors: for prompt detection of rain, acquired at 2 Hz;
        - All-sky camera: monitoring cloud coverage both during daylight and night time. The images can be used to determine the cloudiness of the sky.
- Protection Subsystems:
    - Safety and Security System.

2.2. ASTRI MA project phases

Figure 2 shows the development phases of the ASTRI Mini-Array project from design to decommissioning:

1. **Design Phase**: development of the concept, architecture, definition of requirements, and design for the mini-array as a whole and for all its subsystems

2. **Construction phase**: during this phase all the major subsystems (infrastructure, telescopes, etc) of the ASTRI Mini-Array as defined by the product tree will be constructed or procured.
3. **AIV phase:** in this phase, the major subsystems of the ASTRI Mini-Array will be assembled and integrated at the observing site and then will go through subsystem and integration tests.
4. **System Commissioning:** the system and science performance of the ASTRI Mini-Array will be verified during this phase.
5. **Operation phase**: Science operations and maintenance activities will take place during this phase.
6. **Decommissioning:** telescopes and infrastructure are dismantled, and the site is returned to its pristine state.

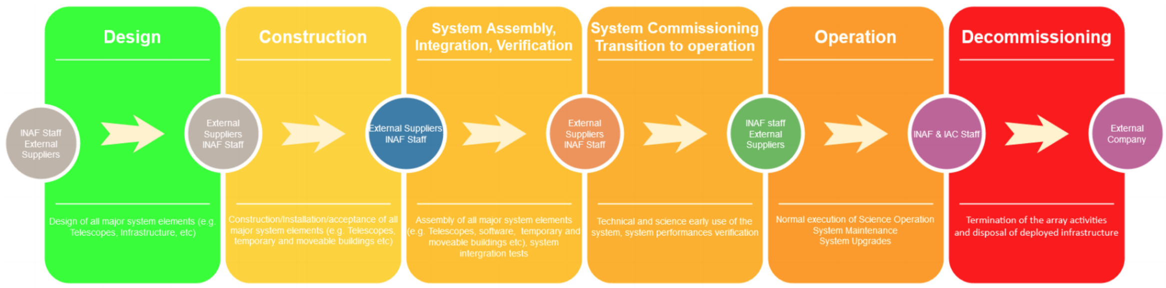

Figure 2: The ASTRI mini array project phases from design to decommissioning

2.3. On-site SCADA Software System

In this section, a general overview of the SCADA system is provided. In Sect. 3 the SCADA subsystems are described in more details.

SCADA has a **Central Control System** which interfaces and communicates with all ASTRI MA subsystems and their dedicated local control software installed at the site. SCADA is responsible for the execution of the observations and shall normally perform the operations in an automated way but is supervised by the **Operator** located in one of the ASTRI Control rooms. Furthermore, SCADA shall collect scientific data provided by the scientific instruments, logging, monitoring, alarms provided by the ASTRI MA subsystems and provide online observation quality information to the **Operator** in order to assess the quality of data during the acquisition.

The SCADA System shall be installed at the Teide MA site and remotely controlled from a single Control room and monitored from one or more Control rooms.

As described in detail in [AD1], the ASTRI MA on-site software is organized into 5 logical layers (see Figure 3):

- layer 0, assembly: an assembly represents a collection of hardware (sensors, actuator);
- layer 1, Local Control Software (LCS): the system directly connected with the hardware and used to switch-on/switch-off, control, configure and get the status, monitoring points and alarms of all parts of the assembly;
- layer 2, OPC-UA interface with SCADA system;
- layers 3 and 4 are part of the SCADA system:

- layer 3: **control software** that performs tasks of control and synchronization of the actions of the assemblies to accomplish the tasks. It must also manage the state machine of the assemblies, detect abnormal conditions or alarms from assemblies, and acquire monitoring points useful to detect events and the health of the assemblies. **Collector** has only the capability to determine the state machine of the assemblies reading appropriate information, detect abnormal conditions or alarms from assemblies, and acquire monitoring points useful to detect events and health of the assemblies;
- layer 4: **Central Control**, is the layer that coordinates all the subsystems of the MA system;

- the SCADA **Operator HMI** shall interact with the **Central Control System**.

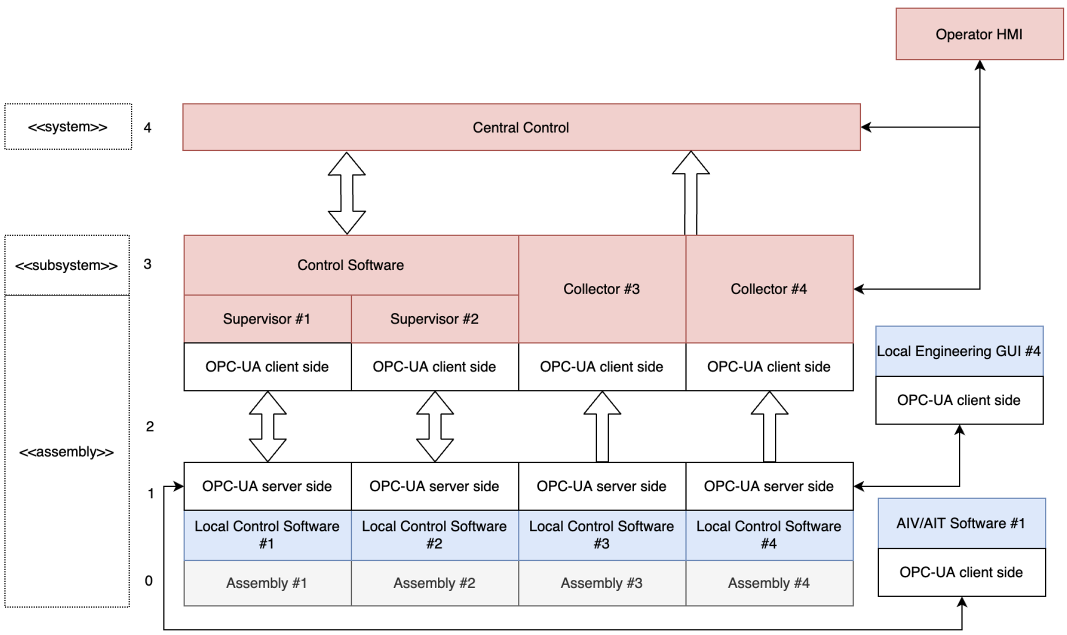

Figure 3: ASTRI MA on-site software logical layers.

2.3.1. SCADA Context Diagram

Figure 4 presents the context diagram of the overall SCADA system with the controlled and monitored ASTRI Mini-Array subsystems and assemblies [AD1]. The short-term observation plan for the observing night (a list of Scheduling Blocks) is retrieved from the **Science Archive** in an automated mode. A manual mode is foreseen as well. The result of an observing night is stored in the off-site Archive, where the data are saved in the **Bulk Archive** and the Science Data Model [AD3] in the **Science Archive.** The data transfer from the on-site **Archive System** to the off-site Archive System is performed in an automated way.
The **System Configuration DB** is used by SCADA subsystems to store and retrieve the configuration of the assemblies of the ASTRI MA System.

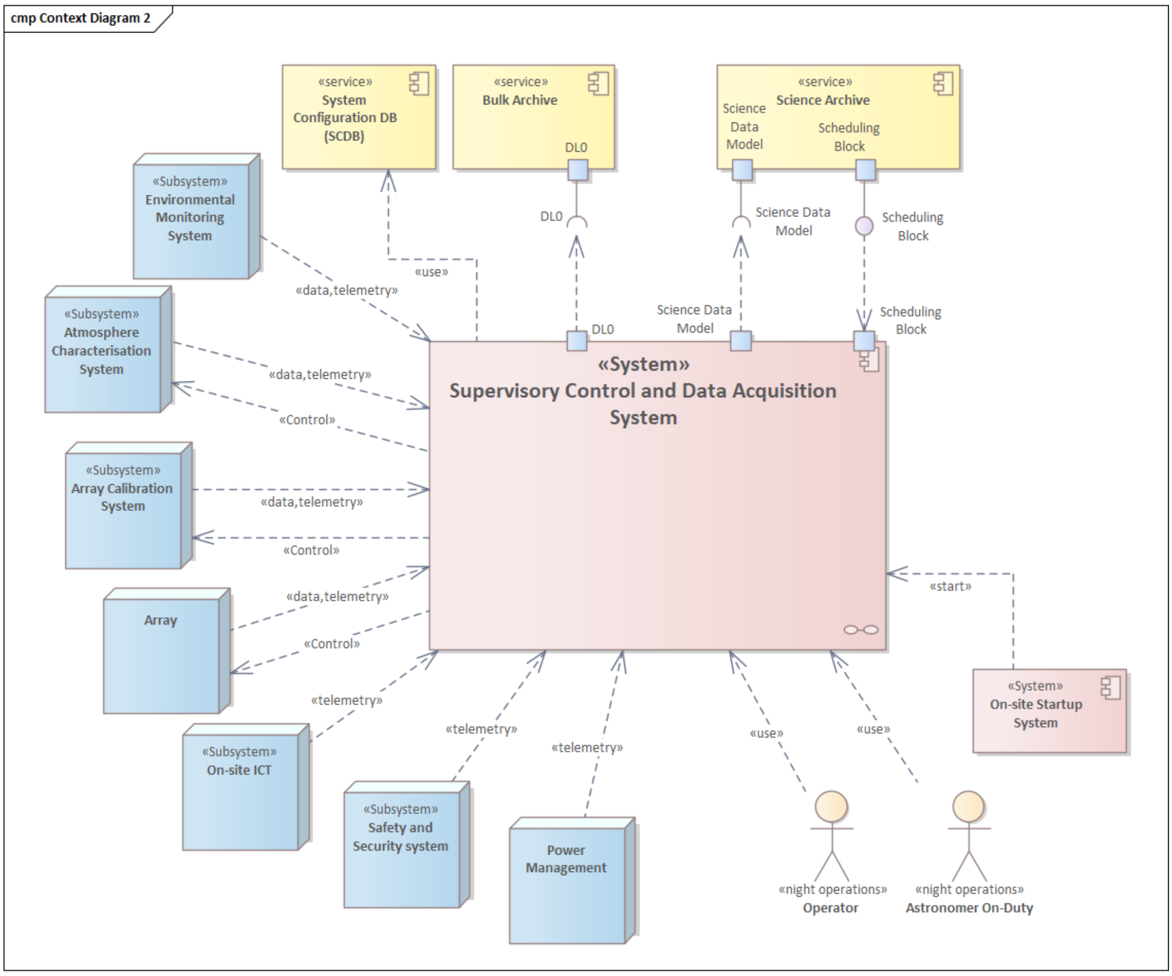

Figure 4: SCADA context diagram.

The main functional blocks of the ASTRI Mini-Array SCADA system are the following (see also Figure 5 and 6):

- **Central Control System**, coordinates the sequence of operations to perform observation, calibration and maintenance. Part of the Central Control Systems are
  - **Central Control,** that coordinates the activities;
  - **Control systems**, to control, monitor, manage alarms and status of the telescopes (**Telescope Control System**), of the assemblies used to characterise the atmosphere (**Atmosphere Characterisation Control System**), of the calibration system (**Array Calibration Control System**)
  - **Collectors**, to monitor, determine alarms and determine the status of environmental devices (**Environmental Monitoring System Collector**), of the ICT system (**On-site ICT System Collector**), of the power system (**Power Management System Collector**), of the Safe and Security System (**Safety and Security System Collector**);
- **Array Data Acquisition System** acquires Cherenkov Cameras and Stellar Intensity Interferometry Instruments data;

- **Online Observation Quality System**: It provides quick-look results from the Cherenkov or Intensity Interferometry observations during the data acquisition to give feedback to the **Operator**;
- **Logging System, Monitoring System** and **Alarm System** monitor the overall performance of the systems through the acquisition of environmental data, monitoring points and log entries and alarms from instruments and generates status reports or notifications to the **Operator**;
- **Operator HMI**: the user interface for the **Operator**.

3. Details on Central Control System

Contractors shall be responsible for the design, development, integration, testing, verification, validation, delivery and deployment in the operational environment of the ASTRI MA at Teide of the Central Control System.

All the software developed by the Contractor shall be uploaded to the INAF Gitlab repository [RD2] and released under LGPL [RD5] License and shall run on machines using the Linux operating system (see [RD1,RD2]).

3.1. SCADA/Central Control System (CCS)

The **Central Control System (CCS)** of **SCADA** plays a central role in on-site operations. It acts also as a **Startup System** of the SCADA subsystems.

The **SCADA/Central Control System** shall be built atop the same framework that has been successfully used by ALMA, namely, the **ALMA Common Software (ACS)** [RD4]. ACS is a container component framework, designed for distributed systems, with standardized paradigms for logging, alarms, location transparency, and support for three programming languages: Java, C++ and Python.

The **Central Control System** shall allow the **Operator** and the **Astronomer on-duty** to interact remotely with the ASTRI MA System. The ASTRI MA shall be operated from the Array Operation Centers (AOCs) available from different locations, including the Control Rooms located at Teide and La Laguna. The Central Control System shall be controlled via the **Operator HMI**. There is only one Array Operation Center that can control the Array at the same time. Other AOCs are only in reading mode.

The **Central Control System** coordinates the sequence of operations to perform observation, calibration and maintenance; startup, supervise and shutdown of the controlled assemblies and subsystems; configuration of the on-site subsystems and assemblies reading the configuration from the System Configuration Database (SCDB); checks the status of the assemblies; gets the Scheduling Blocks of the short-term observation plan and interprets the Observing Mode specified to command the telescopes and other subsystems.

The CCS includes the **Central Control** that coordinates all operations, and control software and connectors described in Sect. 3.1.1. The **Data Capture** module, part of the Central Control, saves the information associated with the execution of an Observing Block (the Science Data Model) necessary to process the acquired scientific data (see also [AD1, AD4]).

The **Data Capture** shall save the Science Data Model into a dedicated database, that should be functionally part of the Science Archive. The design and the selected technology of this part will be agreed upon between INAF and the Contractor. The data that is part of the Science Data Model is a sub-sample of the time series data generated by all Mini-Array assemblies, plus links to acquired data files, links to the SCDB and links to the observing block with the status of the observation.
INAF will provide a detailed definition of the Science Data Model.

The main functional requirements of the **Central Control System** are given in [AD1].

Figure 5 and Figure 6 describe the interconnection between the main functional blocks of SCADA and assemblies and subsystems:

- **red boxes** of the figures are software subsystems that are part of the SoW and shall be developed by the Contractor;
- **green boxes** are software subsystems developed by INAF and shall be integrated, and deployed by the Contractor to build the full SCADA system. The nine Telescope Control Systems, Array Data Acquisition Systems and Online Observation Quality Systems, are connected and coordinated by the Central Control System;
- **blue boxes** are the ASTRI Mini-Array subsystems that shall be controlled through interfaces with SCADA;
- **yellow boxes** are external databases that shall interface with the **Central Control System**.

All ASTRI MA elements controlled and monitored by SCADA have the <<assembly>>, <<subsystem>> or <<device>> stereotypes.

Information that is exchanged between SCADA and these elements is represented by dashed lines and marked with the following stereotypes in Figure 5 and Figure 6:

- The <<telemetry>> stereotype represents monitoring points, alarms, errors, logs, and status information.
- The <<control>> stereotype represents the control flow, i.e. startup/shutdown, command and configuration.
- The <<flow>> stereotype represents a generic exchange of information;
- The <<data>> stereotype represents the data flow between the MA subsystems and the SCADA system. The data categories that can be acquired by the SCADA system are:
  - Cherenkov Camera Data;
  - Intensity Interferometry Data;
  - Atmosphere Characterisation Data;
  - Environmental Monitoring Data;
  - Calibration Data.

More details can be found in the Data Model description in [AD3].
A detailed description of the Central Control System is given in [AD1], and use cases in [AD4].

Note: the core logic to control and move a telescope is embedded in the Telescope Control System developed by INAF. The Central Control System must coordinate the nine TCSs.
Note: the data acquisition chain shown in Figure 6 is developed by INAF and coordinated by the Central Control System provided by the Contractor.

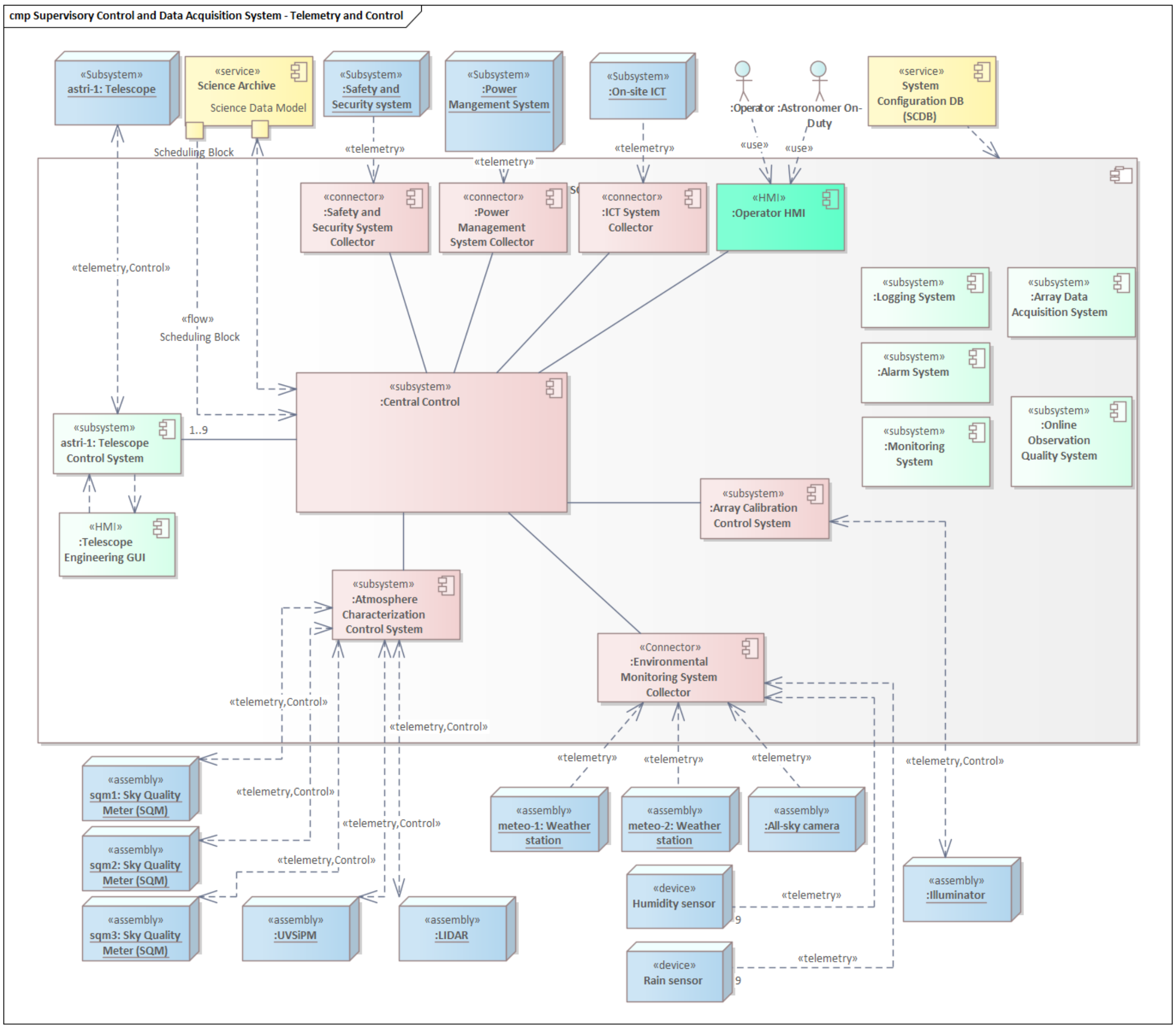

Figure 5: Telemetry and control flow. The Logging System acquires logs from all sources that have been programmed to emit them. The Monitoring System acquires monitoring points from all assemblies. The Alarm System receives alarms from assemblies. Only one of the nine telescopes is shown explicitly. See text for more details. Red boxes are subsystems subject to this SoW; green boxes are subsystems developed by INAF; blue boxes are the ASTRI Mini-Array assemblies; yellow boxes are databases. The <<telemetry>> stereotype represents monitoring points, alarms, errors, logs, and status information, and <<data>> stereotype represents the data flow. The <<control>> stereotype represents the control flow.

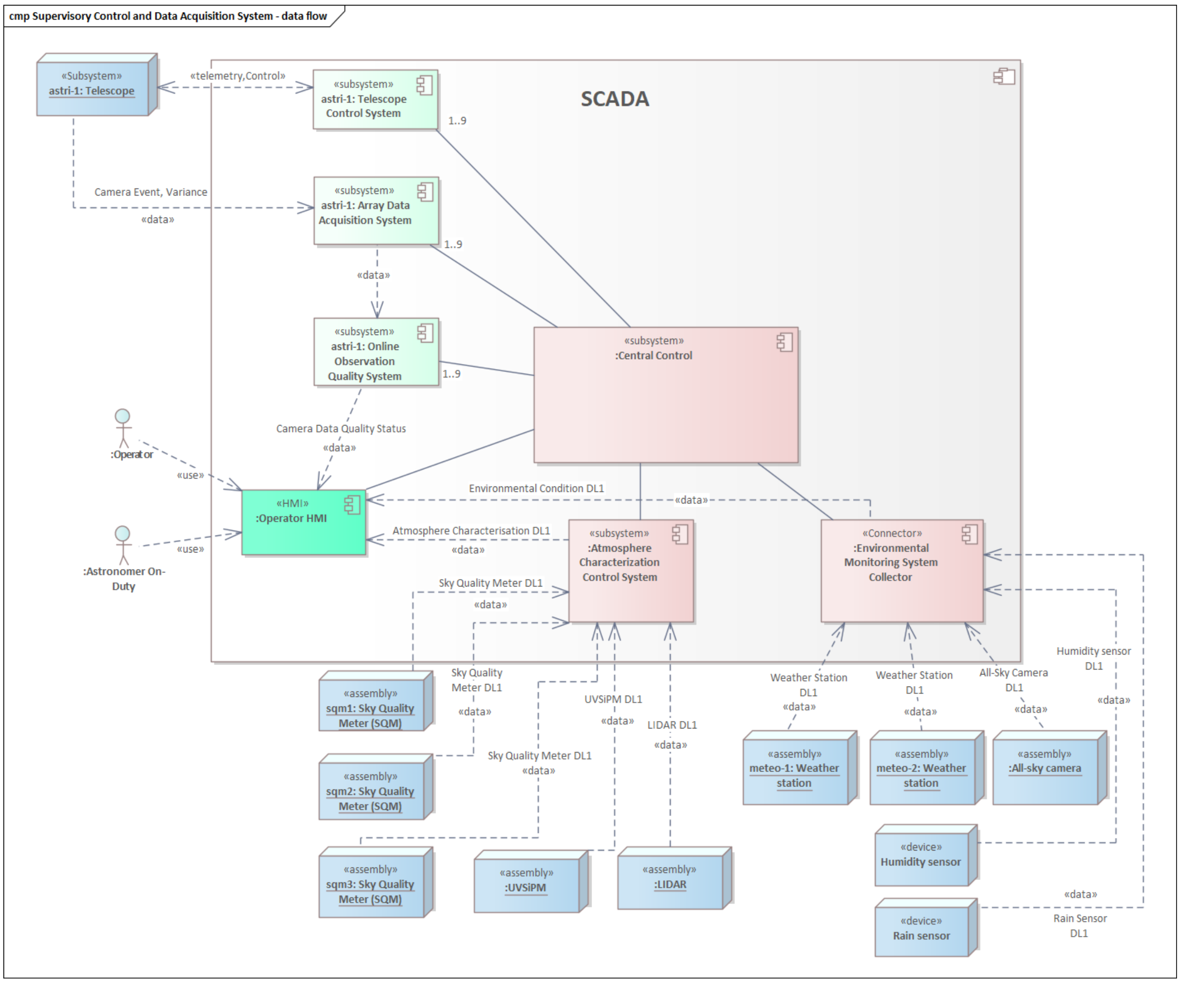

Figure 6: Data flow between assemblies and SCADA subsystems. Only one telescope is shown. See text for more details. Red boxes are subsystems subject to this SoW; green boxes are subsystems developed by INAF; blue boxes are the ASTRI Mini-Array assemblies; yellow boxes are databases. The <<telemetry>> stereotype represents monitoring points, alarms, errors, logs, and status information, and <<data>> stereotype represents the data flow. The <<control>> stereotype represents the control flow.

3.1.1. SCADA Control Systems and Collectors

These systems shall be activated and are connected to the **Central Control,** and shall read assemblies configuration from the System Configuration Database:

- **Atmosphere Characterisation Control System** to control, monitor, determine abnormal conditions or alarms and the status of the assemblies used to characterise the atmosphere. It also provides notification of abnormal conditions from atmosphere characterisation;
- **Array Calibration Control System** to control, monitor, determine abnormal conditions or alarms and the status of the Illuminator.
- **Environmental Monitoring System Collector** to monitor, determine abnormal conditions or alarms and the status of environmental devices. It also provides notification of alarms from environmental conditions;

- **On-site ICT System Collector** to monitor, determine abnormal conditions or alarms and the status of the on-site ICT system, master clock and white rabbit time synchronization system.
- **Power Management System Collector** to monitor, determine abnormal conditions or alarms and the status of the power system.
- **Safety and Security System Collector** to monitor, determine abnormal conditions or alarms and the status of the Safety and Security System.

Note: There is a Monitoring System and a Logging System developed by INAF that acquires and stores all reading points from assemblies. The "Collectors" shall only acquire critical reading points.

3.2. Standard workflow of an observation

This section reports a summary of the workflow of an observation. Details are provided in [AD1].

1) [Manual] Before starting the automated procedure, the **Operator** checks through the **Operator HMI** the status of the array assemblies, atmosphere characterisation, environmental monitoring, and the planned observations for the night.
2) [Manual] The **Operator** sets the **Central Control System** (CCS) in an automated way.
3) [Automated] The **Central Control System** selects the short-term observation plan for the current night and executes each observing block, and
   3.1) [Automated] The **CCS** validates the observing block (OB) w.r.t. environmental condition, atmosphere characterisation conditions, the status of the assemblies.
      3.1.1) [Automated] If everything is ok, **CCS** starts the execution of the OB.
      3.1.2) [Automated] If some conditions are not verified, **CCS** gets the next OB.
   3.2) [Automated] (exception). If there are critical environmental conditions or critical assembly status, **CCS** puts the Array in a safe state and stops the full observation.
      3.2.1) [Manual] (optional) The **Operator** restarts the observation
   3.3) [Manual] (exception). If there are changes in environmental condition, atmosphere characterisation conditions, the status of the assemblies that can generate a degradation of the observation, data quality degradation, the execution of the OB continues until its end. The **Operator** could decide to stop the current OB and
      3.3.1) [Manual] (optional) The **Operator** selects the first OB for which the degraded conditions fulfill OB execution requirements.
      3.3.2) [Automated] (optional) the CCS selects the first OB for which the degraded conditions fulfill OB execution requirements.
      Note: When a new OB starts, the **Central Control System** execute step 3.1)
4) [Automated] At the end of the night, **CCS** stops the observation and puts the Mini-Array system in a safe state.
5) End of the workflow.

Alternate

- [Manual] It is always possible for the **Operator** to stop the current observation, and restart the observation, or upload a new Scheduling Block to be executed during the night (e.g. ToO management), restarting the observation in a manual way.
- [Manual] It is always possible for the **Operator** to put the Array in a safe state. This implies stopping the current observation.

Notes:

- It is not foreseen to remove a telescope in an automated way. If a telescope does not work
   a. the **Operator** or the CCS stops the observation;
   b. the **Operator** marks the telescope as unavailable and restarts the observation.

- Each SB specifies the minimum number of telescopes to perform the observation. If there are not enough telescopes, the **CCS** tries with the next SB

4. Services, support and responsibilities

The following **environments** are used for the project:

a. **Testing environment**: the ASTRI Mini-Array off-site integration environment;
   i. ICT testbed (logical representation of on-site ICT)
   ii. INAF GitLab
   iii. HW Simulators
b. **Operational environment** (on-site): the ASTRI Array Observing Site.
   i. on-site mini-ICT
   ii. full ICT
   iii. real hardware
c. **Data center** (off-site)

The Contractor shall have the responsibility for the following **activities** until the end of the contract:

1. **Integration** of the software subsystems developed by INAF and by the Contractor in the full SCADA system to be deployed on-site. INAF will provide the following software subsystems that the Contractor shall integrate into the overall SCADA system:
   a. Telescope Control System
   b. Array Data Acquisition System
   c. Online Observation Quality System
   d. Monitoring System
   e. Logging System
   f. Alarm System
   g. Operator HMI
   h. Databases: Science Archive, Monitoring Archive, Quality Archive, Log Archive, and Alarm Archive.
2. **System verification** of the integrated SCADA system
   a. Definition of the System Software Verification Plan
   b. Execution of the System Software Verification Plan
3. Support in **system validation** of the integrated SCADA system in the testing environment
   a. The ASTRI Team will define and execute the SCADA Validation Plan
   b. Support in the definition and execution of the SCADA Validation Plan
4. **Delivery**: management of software delivery (not continuous delivery, but delivery based on milestones)
5. On-site **deployment** on the operational environment
6. **Support on integration with real on-site hardware systems**
7. Support in **system validation on the operational environment**
   a. The ASTRI Team will define and execute the Validation Plan on the operational environment
   b. Support in the definition and execution of the SValP

4.1. Warranty

The Contractor shall provide preventive and corrective **maintenance** during the warranty period. The duration of the warranty period shall not be less than one year starting after the Final Operational Readiness Review of the Contractor provided products.

5. Activities and planning

5.1. INAF Provided items

INAF is committed to develop the full ASTRI MA system. The software products described in this document are only a part of the full system in which those products shall be integrated and are interfaced with.
The Contractor shall be aware that the following items of relevance for the Contractor activities will be provided by INAF:

- Full on-site ICT system including computing, networking and time distribution apparatus;
- ASTRI Mini-Array off-site integration environment ICT infrastructure (where the environment for continuous integration of SCADA software must run)
- SCADA software subsystems to be integrated and interfaced by the Contractor with those provided by the Contractor in this context:
    - Monitoring System
    - Alarm System, that shall interface the ACS alarm system
    - Logging System, that shall interface the ACS logging system
    - Online Observation Quality System
    - Telescope Control System
    - Array Data Acquisition System
    - Archive System

INAF is also committed to the development and installation at the Teide site of all ASTRI Mini-Array system elements to be controlled by SCADA (e.g. Telescopes, weather and atmosphere monitors, infrastructure).
Whenever available and relevant, INAF will provide the Contractor information about the above-listed items at its full discretion and when INAF considers it useful for the Contractor activities. In particular, **Interface Control Documents** for hardware assemblies and software systems will be provided to the Contractor as soon as they become available to be delivered. However, the availability of this INAF provided information shall in no case be considered showstoppers for the tasks required to be performed by the Contractor to realize the products that are described in this document; in this respect, they have to be deemed as support material only.

5.2. Work Logic

The applicable documents [AD1, AD2, AD3, AD4, AD5] on which the description of the products that are the object of this document, and are made available for consultation, already passed a Concept Design Review (CoDR) by a panel of external reviewers organized by INAF. An internal Preliminary Design Review for some subsystems listed in Sect. 5.1 has been conducted.

The Contractor work shall be organised on the basis of the software life-cycle phases, adopted by INAF for the ASTRI MA project and presented in Figure 7:

- **System Definition phase**: the entire software system will be defined, from requirements to software architecture. The main phases are:
    - System/Software requirement;
    - Definition of interfaces, through the use of Draft Components approach;
    - Design;
- An iterative and incremental phase for the development, delivery and deployment of the software. The main phases of each iteration are:
    - Detailed Design;
    - Development;
    - Subsystem Test;
    - Integration and System Verification;
    - System Validation, if applicable;
    - System Operation, if applicable.

According to the [AD7, AD8], the following **major reviews** shall be held:

1. Preliminary Design Review (PDR): this review demonstrates that the preliminary design of the system/subsystem HW/SW meets all system requirements with acceptable risk and within the cost and schedule constraints and establishes the basis for proceeding with detailed design. Documentation describing the baseline design is the output of this review.
2. Critical Design Review (CDR): the scope of this milestone is to demonstrate that the design reached an appropriate level of detail to support the production of the code, assembly, integration and test, meeting all performance, scheduling, and operational requirements.
3. Acceptance Test Review (ATR): the scope of the review is to verify the completeness of the developed software, documentation, and test and analysis reports. Also, it ensures that the software reaches a level of maturity to be deployed at the Array Observing Site (Teide Site). After this review, the software is delivered to the Customer and deployed at the Array Observing Site (Teide Site).
4. Operational Readiness Review (ORR): the scope of the ORR is to establish that the software system is ready to be used for operations at the Array Observing Site, maintenance, emergency and recovery operations of the ASTRI MA, through examination of test results, analyses, and operational demonstrations. It also shows that documentation is complete for each software configuration item. This review must be performed at the ASTRI Array Observing Site (the operational environment).

A **Draft Components approach** allows to quickly-developed implementations of interfaces in IDL in the ACS framework, on which design can be agreed, with the following advantages:

- enriches the design process hands-on experience through;
- allows the development team gain experience on the Central Control System and its underlying technologies faster;
- allows a faster detection of conceptual errors given implementation constraints.

To reach these objectives, only for the **first iteration** the System Definition phase and the Detailed Design phases are considered as a single, iterative design phase (based on Draft Components) to take into account an incremental definition of the interfaces and other aspects of project management. In this first iterative design phase a generation of “work-in-progress deliverables” is foreseen, where a simplified versions of the deliverables intended for traceability and validation of the design are

provided. This will include the use of wiki platforms, and auto-documentation tools, to simplify the interaction between Customer and Contractor.
Final design deliverables will be released once coding of the first iteration is successfully completed. A CDR is conducted at the end of the first iteration, that includes the Central Control system design validation with the Customer. **An intermediate PDR, agreed between Customer and Contractor, is foreseen before the CDR of the first iteration.**

Integration, verification and validation responsibilities are:

1. Discussion with Contractor about interfaces, and approval with ICDs.
2. INAF will implement agreed interfaces for its subsystems.
3. Contractor realize agreed interfaces for its subsystems.
4. If this will require additional functionalities on INAF subsystems, no intervention on INAF subsystems is foreseen by the Contractor
5. INAF will be responsible for its subsystem tests, and the contractor will be responsible for its subsystem tests
6. Integration is in the phase “Integration and System Verification”. The Contractor is responsible for phases “Integration and System Verification” and “System Validation” with the strong support of the INAF team.
7. The Contractor will provide support at the beginning of System Operations (to be defined)

Note: Standard interfaces are under definition by the INAF team, which should simplify the integration, e.g. (i) publisher/subscriber mechanism with Kafka topic and Avro schemas, (ii) common ACS pattern based on a Master Component for the lifecycle of the system and a Manager for the business logic, (iii) common interfaces for Monitoring System, Logging System and Alarm System.

After the **Final Operational Readiness Review,** the **warranty period** starts.

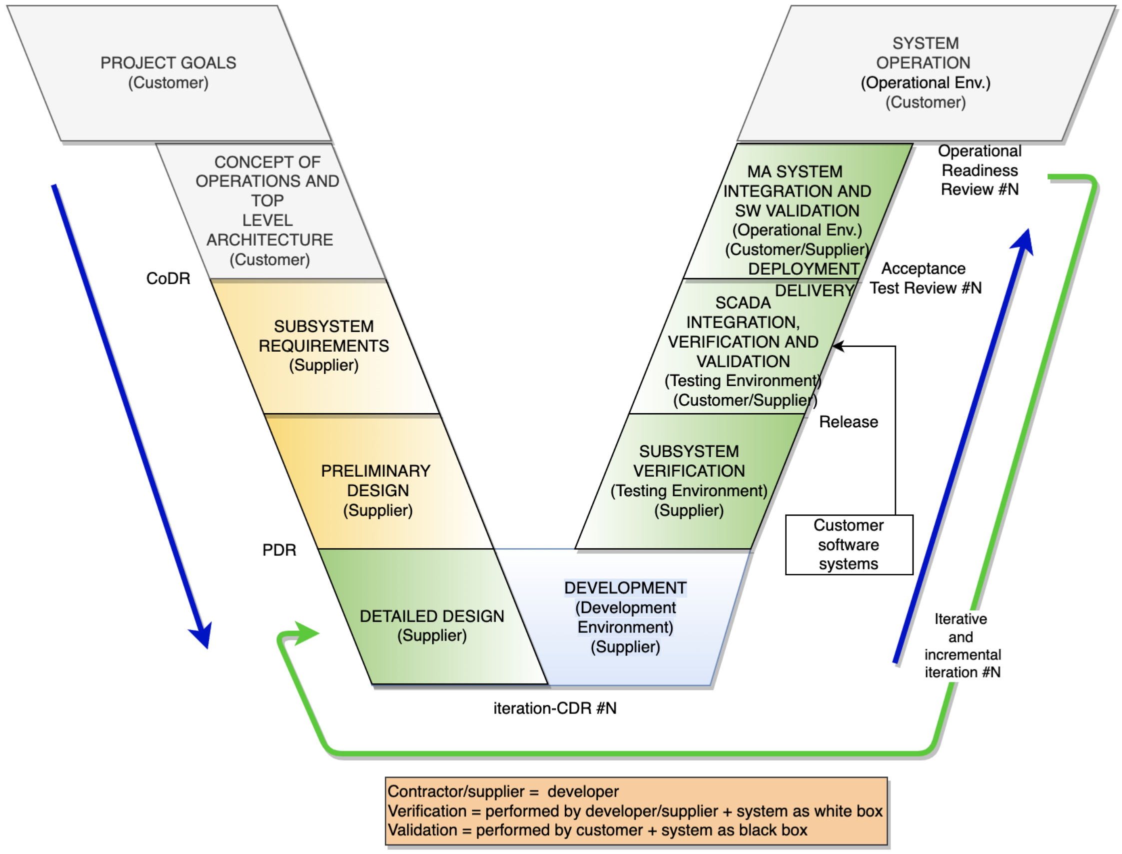

Figure 7: ASTRI MA Software software lifecycle and reviews. The Customer is INAF, the supplier is the Contractor. System and Subsystem are software systems.

The Contractor shall define and implement a Software Development Plan to be used during the development, verification and validation phases and shall include aspects of agile development methodologies [RD1], including:

1. Frequent iterations and releases;
2. Feature-driven development;
3. Unit and component tests created with the source code by the development teams during each iteration;
4. Automated testing and continuous integration;
5. Distributed configuration management.

Iterations will be agreed between INAF and Contractor based on the milestones foreseen by the ASTRI MA project connected with hardware procurement and related on-site installation.

5.3. Deliverables and responsibilities

The deliverables produced by the Contractor at the conclusion of each work life-cycle phase are listed in the following table:

Phase	**Inputs and Deliverables**	**Responsible of deliverables**	**Review**
Definition phase. First iteration			
Subsystem Requirements and Preliminary Design	Input: all applicable and reference documents, all Customer subsystems available documents, available ICDs. Deliverables: - CCS Software Requirement Specification (SRS) - CCS Architectural schemas and auto-documentation tools. - CCS Preliminary Data Model, including data dictionary - CCS FMEA and risk analysis - SCADA Preliminary Integration, Release, Delivery and Deployment Plan Additional Interface Control Documents (ICDs) are agreed between Contractor and Customer.	Contractor	**Preliminary Design Review** (PDR)
For each iteration: iterative and incremental phase. Note: the first iteration includes: System Requirements, Preliminary Design and Detailed Design			
Detailed Design	Input: all applicable and reference documents, all Customer subsystems availabel documents, available ICDs. Deliverables: - CCS Software Design Document (including architecture) or updates - CCS Data Model, including data dictionary or updates - CCS Verification Test Plan - SCADA Integration, Release, Delivery and Deployment Plan or updates. - Update of PDR documents as needed - Maintenance Plan Additional Interface Control Documents (ICDs) are agreed between Contractor and Customer.	Contractor	**Critical Design Review** (CDR) of the iteration

CCS Development, Verification	- CCS Source Code (on INAF GitLab) - CCS Code Quality Report - CCS Verification Test reports - CCS Software User Manual and Training material - CCS Installation procedure - CCS Installation report - SCADA Verification Test Plan	Contractor	CCS Release
CCS Validation	Input: CCS Validation Test Plan prepared by the Customer - CCS Validation Test Report	Customer (with the support of the Contractor)	
SCADA Integration, Verification	- SCADA Verification Test Report - SCADA Installation procedure - SCADA Installation report	Contractor	SCADA Release and Delivery
SCADA Validation	Input: SCADA Validation Test Plan prepared by the Customer - SCADA Validation Test Report	Customer (with the support of the Contractor)	**Acceptance Test Review** of the iteration
SCADA Deployment	- SCADA Deployment procedure - SCADA Deployment report - Training material	Contractor	Deployment on the operational environment
MA System Integration and SW Validation	Input: - SCADA System Integration Test Plan prepared by the Customer - SCADA Validation Test Plan prepared by the Customer - SCADA Integration Test Report - SCADA Validation Test Report - Operational Test Report	Customer (with the support of the Contractor)	**Operational Readiness Review** of the iteration
Final System Validation			
Final System Validation	- Final Operational Test reports - updates and final version of the documents and source code		Final Operational Readiness Review

5.4. Schedule

The Contractor work life-cycle phase durations should be consistent with the following schedule, that should be reviewed in the final contract based on priorities and schedules change (due economical, political, and technical issues) of the ASTRI MA project.

Project phase	**Period**
Kick-off	T0
PDR	T0 + 6 M
First CDR	T0 + 9M
First CCS release	T0 + 12 M
First OOR	T0 + 15 M
Additional releases (incremental way) based on hardware availability on-site.	T0 + 15 M - T0 + 30 M
Operational Readiness Review of the last iteration, with the complete ASTRI MA System. Support during commissioning including system improvement based on system use. Final Operational Readiness Review	T0 + 30 M - T0 + 36 M
Final Operational Readiness Review	T0 + 36 M

The legal warranty period starts after the Final Operational Readiness Review. After the warranty period, INAF may decide on an additional maintenance contract. All terms and conditions will be defined in the final contract.