CTAO
Cherenkov Telescope Array Observatory

GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN
Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

CTAO | ACADA COLLABORATION

The online data taking system of the Cherenkov Telescope Array Observatory

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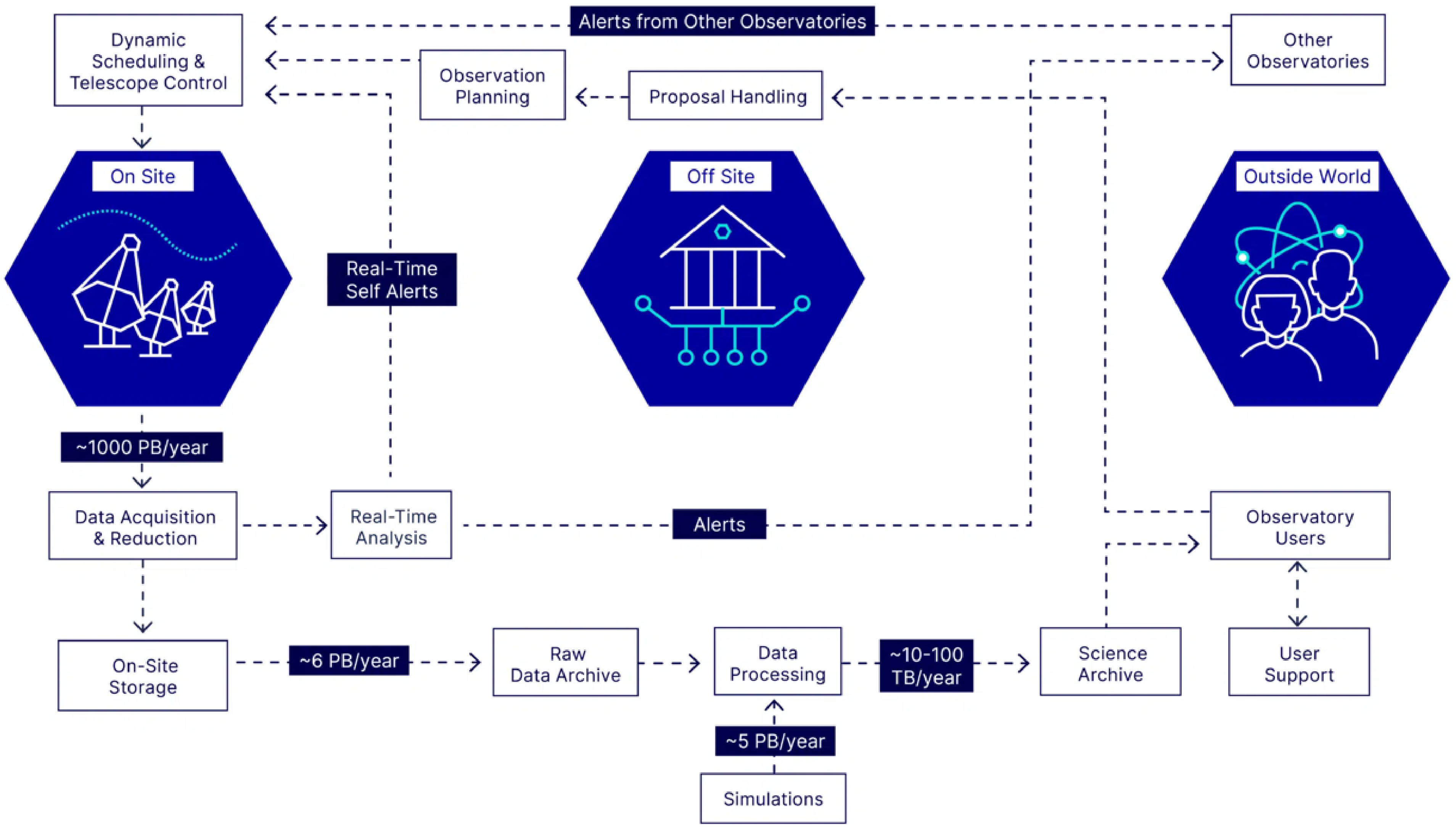
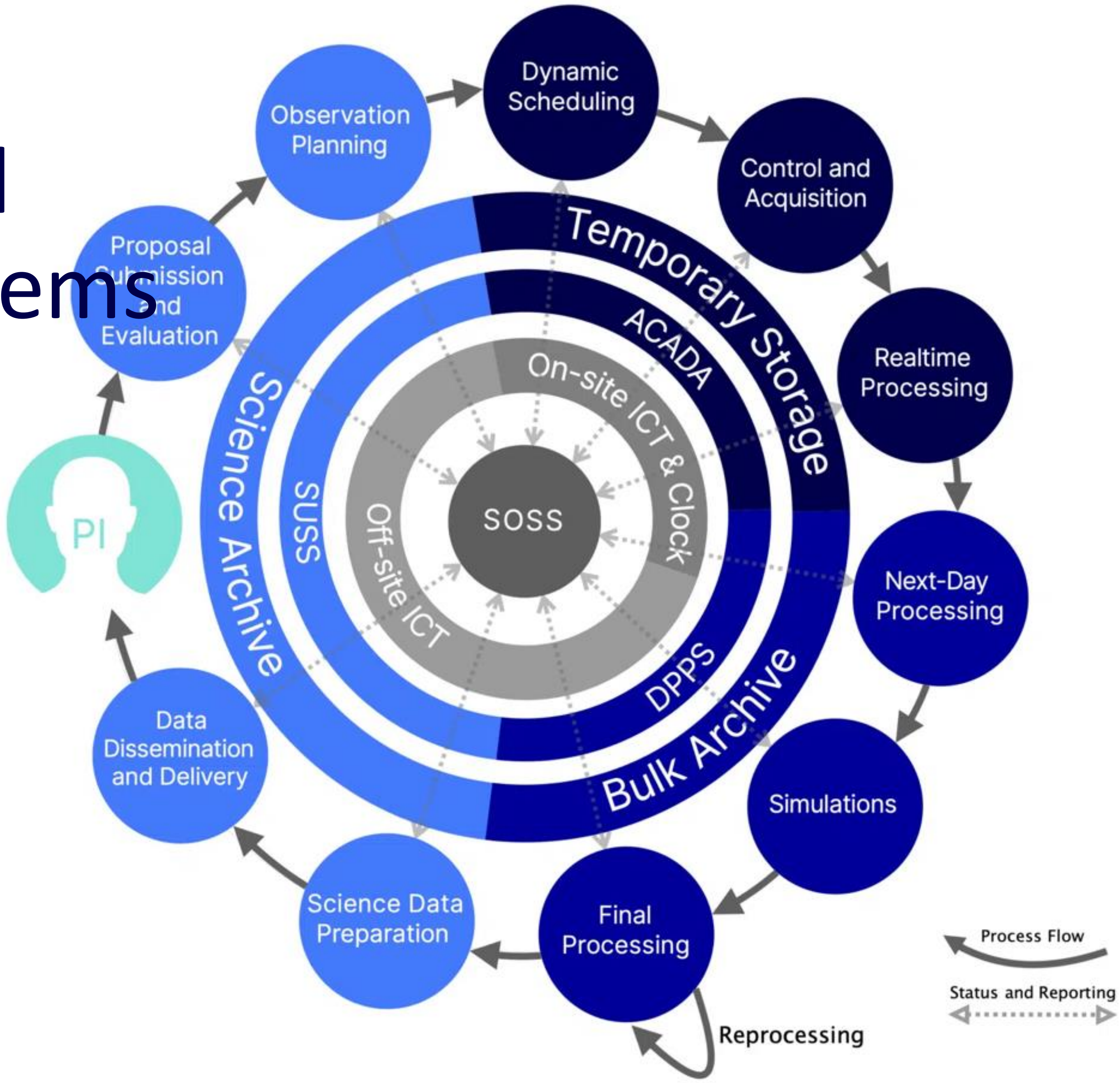
For the CTAO ACADA Collaboration (see in last slide)

CTAO – Data Flow

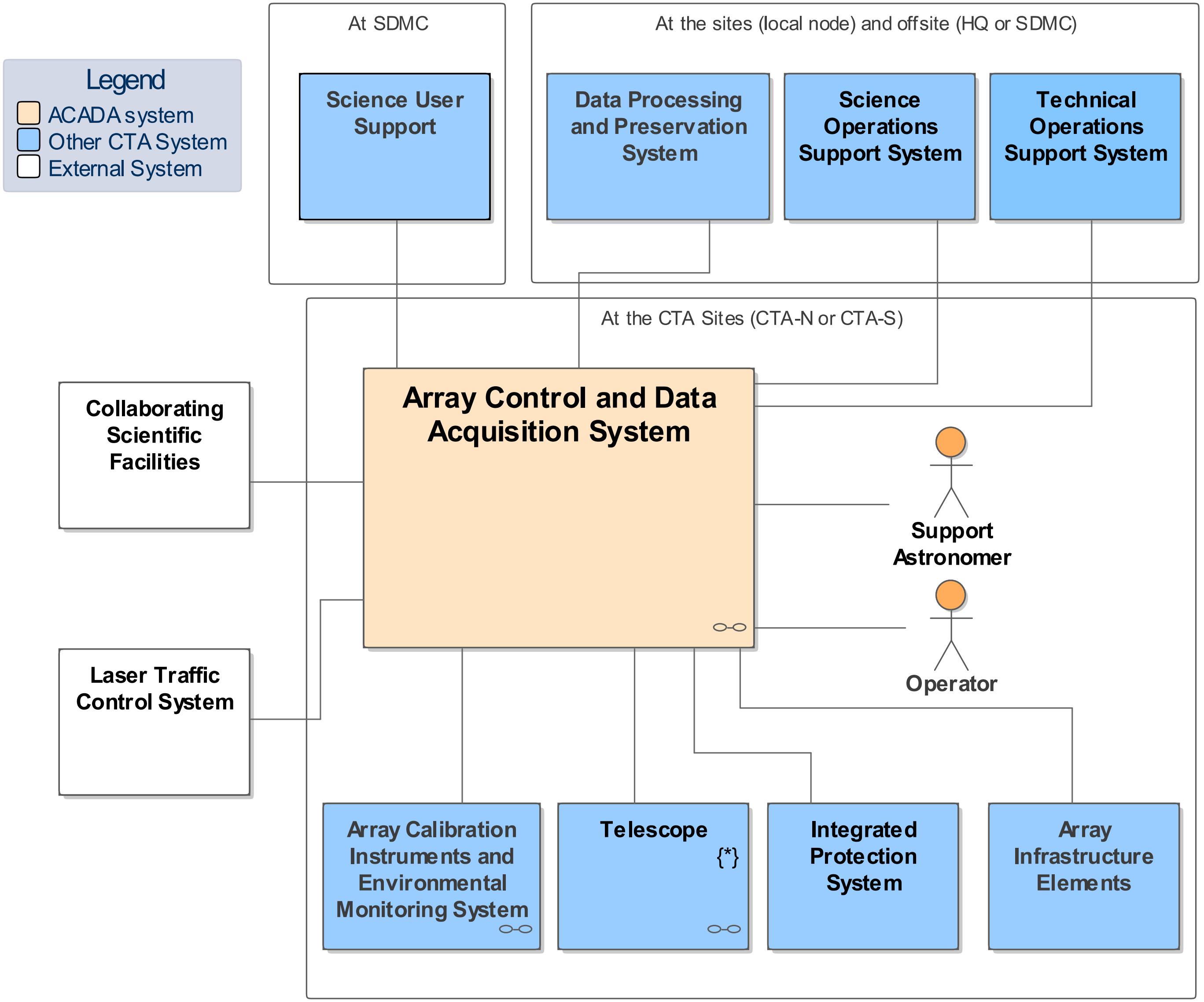


- Control 60+ telescopes
- BIG DATA project, generate hundreds of petabytes (PB) of data in a year (at least 6 PB after compression)
- Two sites and four off-site data centres

Observatory Operations and computing systems

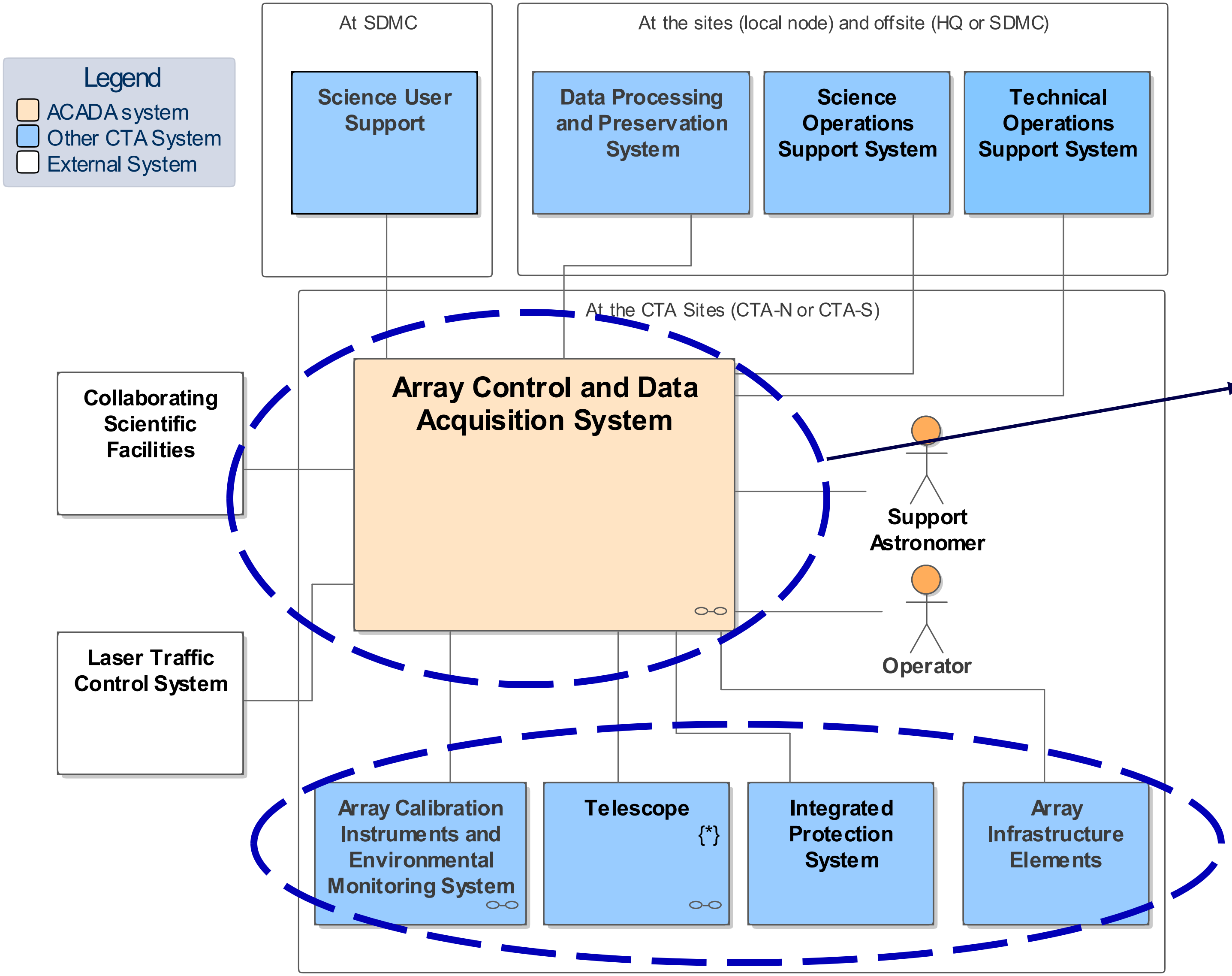


ACADA: Role and Context



- ACADA = **A**rray **C**ontrol and **D**ata **A**cquisition system
- System for central control and data acquisition of all telescopes & instruments at both CTAO sites

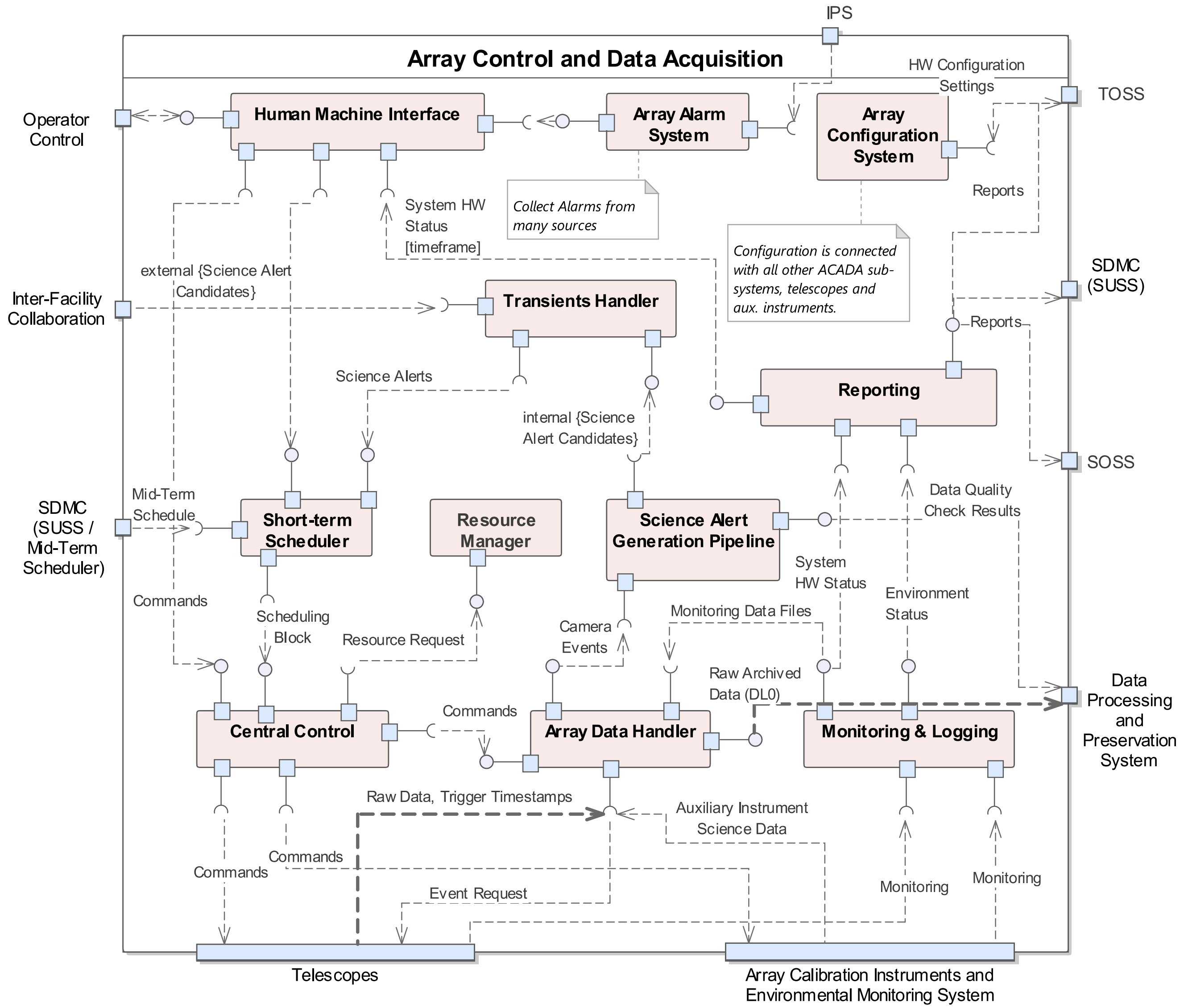
ACADA: Role and Context



Array-level control and supervision.
Focus of this presentation.

Low-level control and DAQ systems.
Interface based on ACS, OPC UA, zeroMQ (see later).

ACADA System



Tech Stack

- **Middleware:** Alma Common Software (ACS), OPC UA (for access to monitoring data only)
- **Programming languages:** Python, Java, C++, Javascript (for the Human-Machine Interface (HMI) front-end only)
- **Databases:** MySQL, MongoDB, Redis, Cassandra
- **Messaging and serialization:** Apache Kafka, ZeroMQ, Google Protocol Buffers. CORBA (via ACS), REST/JSON
- **Workload management system:** Slurm
- **Containers:** Docker
- **Other:** ESO's Integrated Alarm System(IAS)

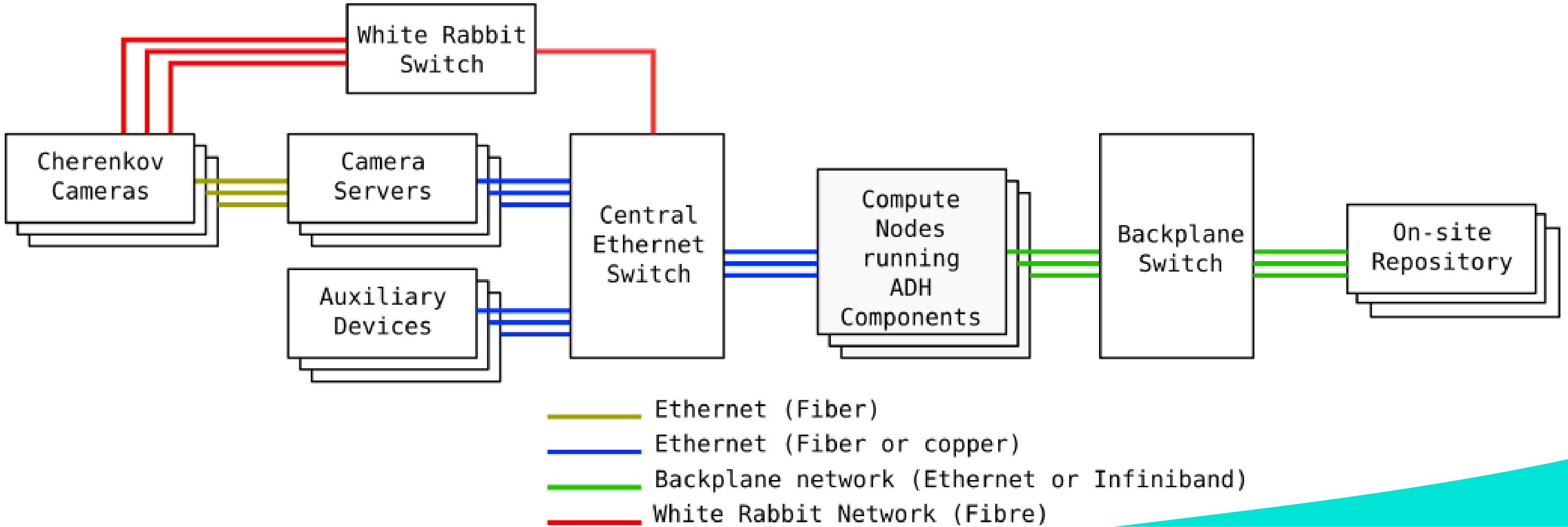
Scheduling, control and supervision aspects

- ACADA Governs all non-safety-critical automatic on-site operations
- Scheduling Blocks (SBs) are submitted by the Short-term Scheduler (STS), resources are allocated by the Resource Manager (RM), and commands are issued by the Central Control (CC)
- 99 telescopes in addition to numerous additional instruments
- Reaction times on the few seconds timescales
- Manage the simultaneously operating units (“subarrays”), with some shared resources (e.g. shared LIDAR jumping from one subarray to another)
- Implements different operation strategies (e.g., “wobble” mode, on-off, scans)

ACADA – Data Handling

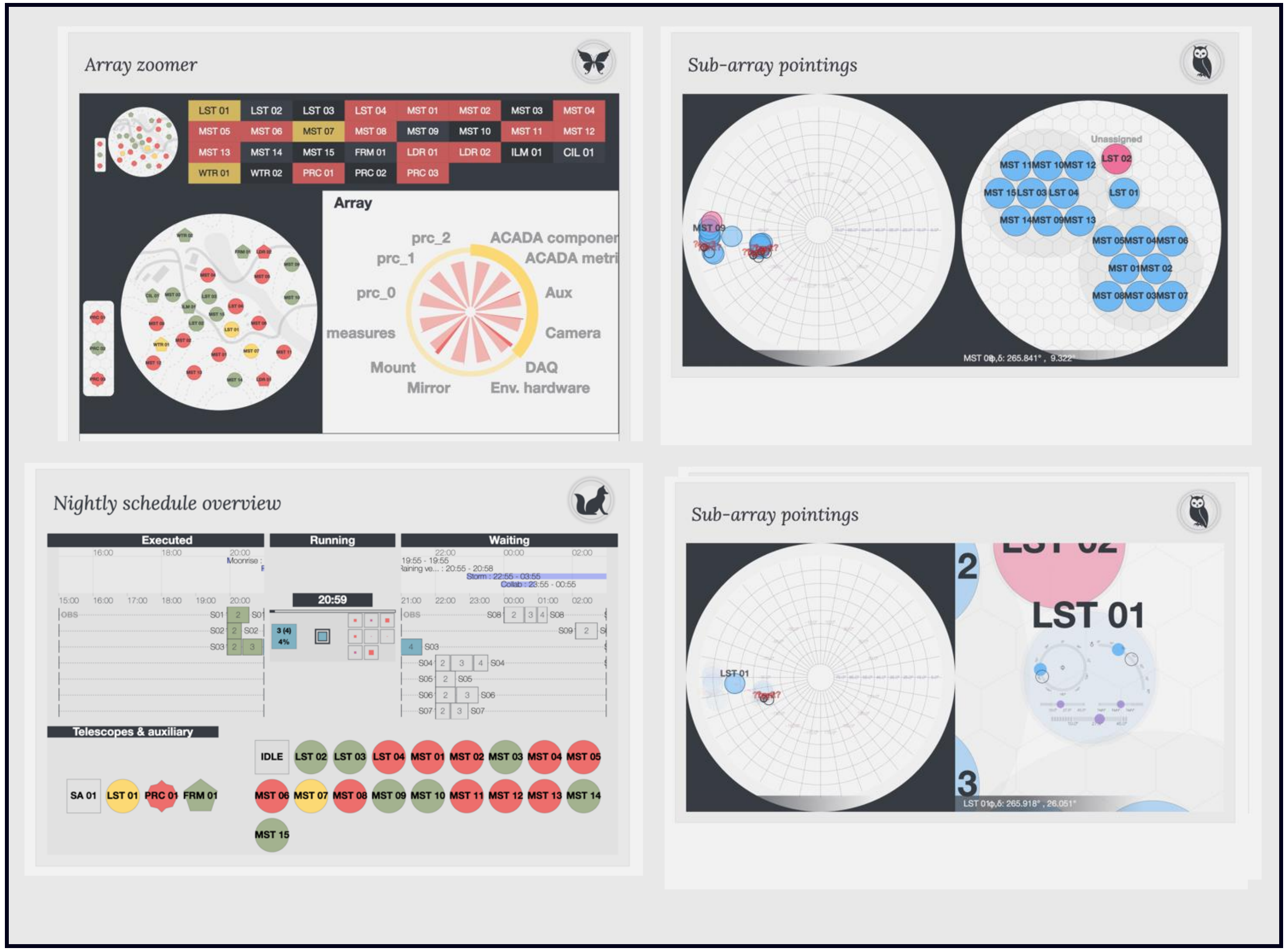
- The Array Data Handler (ADH) is responsible for receiving and storing scientific data from the telescopes
- Receive trigger timestamps from the cameras and send back confirmation from the central trigger (after timestamp comparison)
- Reduce online the volume of received data
- Hand over the stored data to the Data Processing and Preservation System (DPPS)

Data throughput	**24 Gb/s/LST (up to four)**
	12 Gb/s/MST (up to 25)
	2 Gb/s/SST (up to 70)
Individual telescope trigger rates	**15 kHz/LST (up to four)**
	14 kHz/MST (up to 25)
	1.2 kHz/SST (up to 70)
Array-level trigger rates	**40 kHz**
Dead time after a coincidence	**of 250 ns**
DVR factor	**Up to 50**



ACADA - HMI

- Expose the status of the Array Elements and the ACADA system to the operator and provide interfaces to interact
- Monitor and modify predefined operation sequences, such as starting up the array at the beginning of the night
- Monitor the output of a SAG pipeline: results of the analysis and the representation of the data quality indicators
- Alarm management
- Environmental status, weather monitoring, sky quality, weather forecasting
- Provide access to terminals, shift logs, expert call sheets, incoming science alerts, etc



ACADA – Other

- Monitoring, Logging, Alarm systems
  - Cassandra/Kafka-bases solutions
  - Using ESO’s Integrated Alarm System (IAS)
- Transients Handler (TH) System
  - External and internal transient science alerts, filtering, processing, and ranking.
  - Submitting SBs to the STS
- SAG Pipeline
  - Quick-look online analysis of the data, producing scientific results and data quality indicators, to be exposed in the control room
    - Using gammapy
  - Generate candidates for internal *science alerts*, submitted to the TH
- Array Configuration System
  - Store and serve the configuration datasets to ACADA components and array elements
  - Dedicated REST and ACS-based API

Releases (RELs)

ACADA PDR (passed)

ACADA CDR (passed)

We are here

acceptance at the end of every major release

final acceptance

REL0
- Integrate prototypes

REL1
- One telescope:
  - Control
  - Data
  - Monitor and supervise

REL1.5
- Incorporate Lessons Learned
- Configuration database
- FRAM (Photometer) control

REL2
- 4 telescopes
- Automatic schedule
- Alarm system
- Illuminator

REL3
- 5 Telescopes
- Two subarray
- Add a LIDAR.

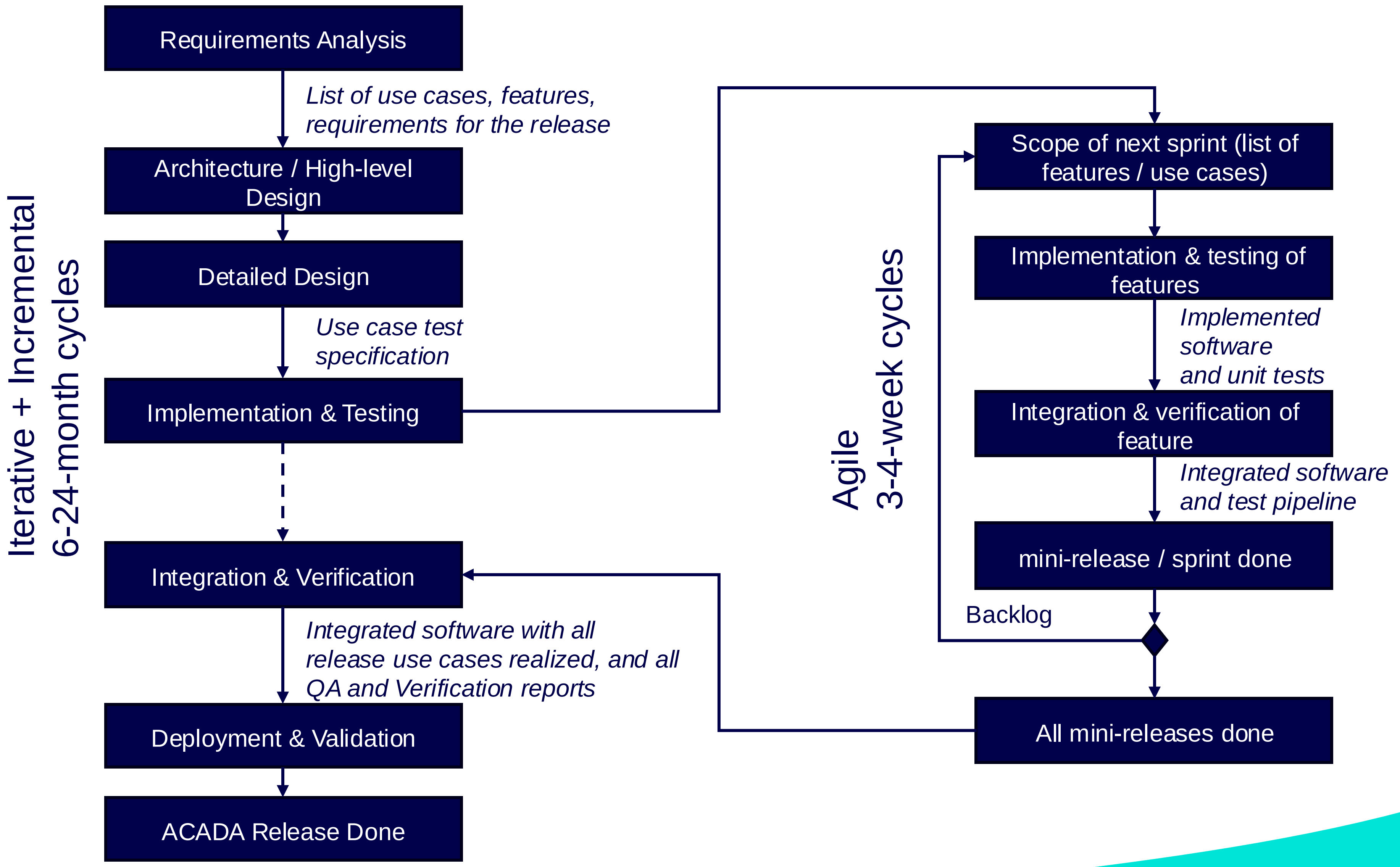
REL4
- Full Support CTAO-N (9 tel)
- More auxiliary instruments

REL5
- 14 tel
- 4 subarrays

REL6
- Full support CTAO-S (51 tel)

REL7
- 8 Subarrays, 99 tel
- Fully automatic

ACADA – development process



ACADA REL1 capabilities

- Control a single telescope
- System start-up
- Data handling from the Cherenkov telescope camera
- Central trigger with unique ID assignment
- HMI: SB submission and execution and system start-up and shut-down
- Storage of monitoring and logging data from the telescope and ACADA processes
- Manual scheduling: queuing, validating, and submitting SBs via the HMI and the TH
- Handle gamma-ray burst science alerts by the TH
- (Simple) online analysis by the SAG, with the production of an event list, lightcurves, skymaps, and basic data quality checks
- Command line interface (CLI)
- Using official ICDs, state machines, and data models
- ~50% of ACADA's code already in place

A **Python** package for **gamma-ray** astronomy

ACADA REL1: QA metrics

Metric	Target
Lines of Code	290k
Code test (Line coverage)	>50% for every subsystem, 62% average (real values higher – ACS)
Automated tests	100% passed
Maintainability rating (SonarQube)	B (technical debt ratio max. 10%)
Reliability rating (SonarQube)	C (no blocker and no critical bugs)
Security hotspots (SonarQube)	100% reviewed
Duplicated lines (SonarQube)	<3%
Verification by inspection, demonstration, or analysis	100% passed
Verified ACADA level-B requirements	79
Verified ACADA subsystems level-C requirements	250
Verified use cases	34 (some alternate and exception paths skipped)

ACADA-LST1 test fall 2023

- ACADA REL 1.5 soon available
- New test campaign with LST1 planned in a few weeks from now

https://www.ctao.org/news/major-telescope-operations-milestone-with-acada-integration/

ACADA REL1.5

- Stabilization phase concluded, release is basically done
- Includes lessons learned and backlog from REL1
- Replace file-based configuration with service-based configuration
- Support operations with the FRAM (F/(Ph)otometric Robotic Atmospheric Monitor) instrument
- Upgrade ACS and OS: Almalinux 9 and ACS 2023DEC

Findings and lessons learned

- The ACADA system works
- A more agile process is preferred by the team
  - We have installed a 3-week sprint dynamics and we are executing it in REL1.5
- Lots of small findings and experiences that helped polish the development workflow, and our Gitlab repository, Jenkins, and SonarQube setup
- Learning and addressing issues of the tech stack: ACS, Slurm workload management system…
- Understanding well use cases and turning them into test cases and pipelines
- Importance of CI pipelines
  - It was an effort to set up the CI, but it paid back well
  - We learned we need different pipelines: short, long, nightly pipelines, subsystem-, and system-level pipelines
- Understanding how to fix unstable/flaky test pipelines

Next ACADA releases

REL 2

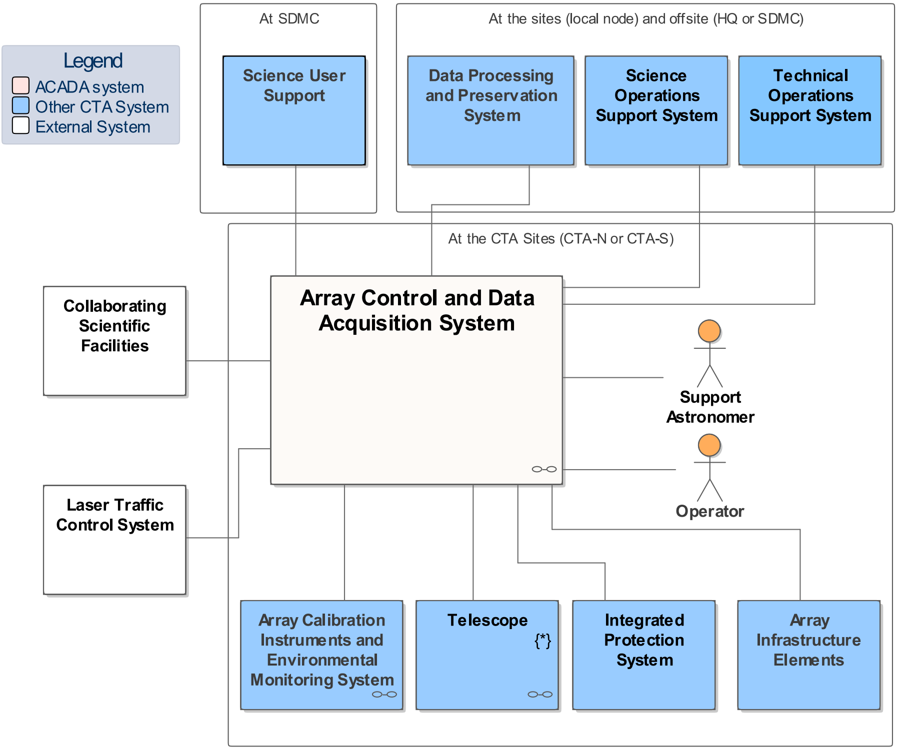
- Support multi-telescope operations (up to 4)
- Support *Illuminator* instrument
- Automatic scheduling
- Deployment of the *Array Alarm System*
- More HMI panels

REL 3…7

- Support multi-telescope and multi-array operations incrementally up to 99 telescopes & 8 subarrays
- Support other instruments such as the LIDAR, integrate with the laser traffic control system
- Automatic alarm reaction
- DVR: Online lossy compression
- Higher reliability
- Optimized HMI
- …

Conclusions

- ACADA: System for central control and data acquisition of CTAO
- REL1 includes the core capabilities of ACADA
- ~50% ACADA code in place
- ACADA-LST1 I&T campaigns were successful
  - And a new campaign is scheduled in a few weeks from now
- ACADA REL1.5 will be out soon
  - Incl. Upgrade to new ACS2023DEC and Almalinux9
- ACADA REL2 Scheduled for 2025
  - Muti-telescope support
  - Automatic operations
- Further ACADA RELs with incremental capabilities
- Support development of the CTAO sites, telescopes integration, and early operations



CTAO | ACADA COLLABORATION

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