Development of the CTA/LST telescope control system

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Cherenkov Telescope Array project

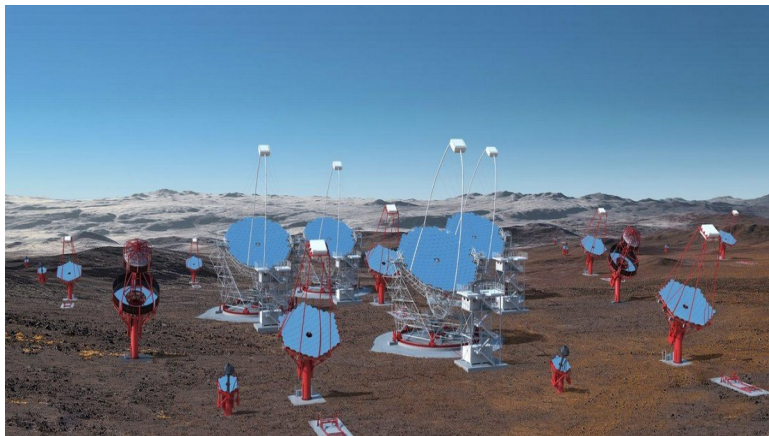*The largest Cherenkov observatory every built*

~1500 scientists and engineers
~200 institutes
31 countries

→ Large international effort

Southern site (Chile)

Northern site (Canary Islands)

Layout: 4 large-sized telescopes
25 medium-sized telescopes
70 small-sized telescopes

Layout: 4 large-sized telescopes
15 medium-sized telescopes

Extremely rich scientific outcome is expected

CTA LST telescope control system

Telescope control unit (TCU):

- unified control of all subsystems
- operation/control/orchestration logic
- automation of alert handling
- joint LST1 + MAGIC observations
- remote operations

Crucial for CTA/LST1 commissioning
(remote / robotic operation – also from ICRR)

Critical for CTA array control
(high-level management of telescopes)

TCU implementation performed within this project
(ICRR, Japan and UniGe, Switzerland; budget in FY2022-2023: 50+60 万円)

Milestones

We need:

- **reliability**
  - full-scale off-site TCU testing
  - automated fault fixing

- **safety**
  - external conditions check (reaction before subsystems reach safety limits)
  - authentication

- **compliance**
  - integration with CTA / ACADA REL1
  - adaptation to the CTAO FSM scheme

- **convenience**
  - automation of camera calibrations execution / processing / application

TCU is developed with the goal of fulfilling the LST needs and ensuring smooth telescope control by CTAO

Where do we stand: reliability

Testing

- on-site:
    - performed regularly (experts + operators)
    - operations-driven (may miss edge cases)
- off-site:
    - full «Camera» side emulation, ready tests for all camera-related FSM transitions;
    - «Structure» testing under development;
    - conditional (... no camera operations during the day - even the virtual one)

Problem solving:

- semi-automatic fault fixing for «Camera»: FSM transitions from Fault state with automatic reconfiguration of subsystems. → Reduce recovery time and minimize operators' mistakes.

Very few TCU-intrinsic problems these days

Where do we stand: safety

TCU is designed for night-time operations only and implements only the first layer of instrument protection.

Safety checks in TCU:

- implemented:
  - telescope unparking only after sunset;
  - camera opening only after sunset (astronomical);

- discussed / in developement:
  - Moon omission
  - weather (e.g. rain, humidity, wind)
  - technical (power outage, subsystems connection loss etc)
  - authority (remote vs local control, heartbeat for subsystems)

Implementation in close coordination with LST system engineering and respective subsystems teams

Where do we stand: compliance

TCU by design complies with CTAO interface definitions

Extra functionality (for LST commissioning):

- extra FSM transitions (e.g. from Fault);
- extra data points ("busy" state, elapsed time, config ID etc)

This is acceptable but is not needed for CTAO.

Missing functionality (non-crucial for LST)

- pointing measurements, proper motion etc
- unused API calls are kept as placeholders

September & October 2023: first integration test of LST TCU into the CTA control framework

- two weeks activity with TCU and CTA experts on-site
- telescope preparation and regular observations covered
- **confirmed that TCU correctly implements CTAO API**

Where do we stand: convenience

We have

- full night-to-night operation cycle
- regular telescope calibrations
- semi-automatic recovery from faults
- automatic configuration (depending on sky brightness)
- automatic run summaries
- MAGIC follow-up (for commissioning)
- alerts follow-up (for commissioning)

**Might need to improve**
(non-crucial for commissioining)

- run summary contents
- include additional calibrations
- trigger calibrations processing

LST TCU already implements most of the telescope control logic
and
has been a primary interface for LST-1 control over the past 2 years

Adaptation to LST2-4 control

TCU

- flexible enough to support individual configurations for each telescope
- expect LST-1 TCU to be usable for LST2-4 with minor modifications and adaptations
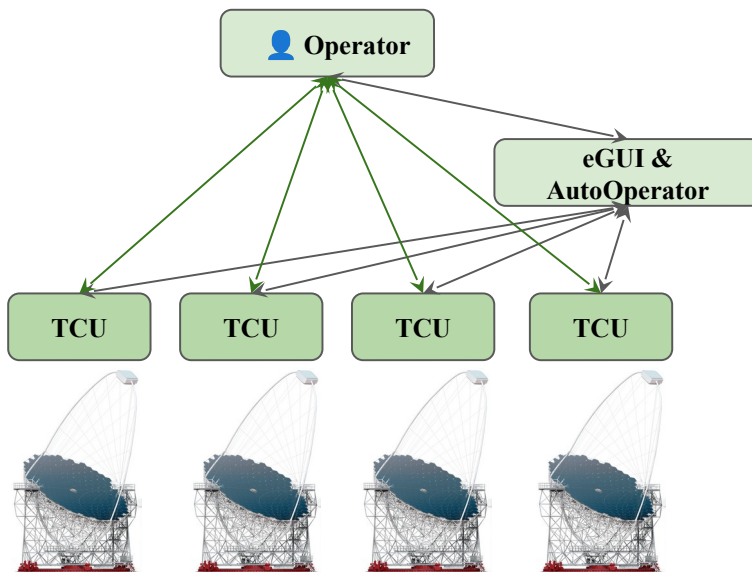
eGUI & AutoOperator:

- web-based unified interface that can support multiple LSTs
- orchestration and automatic (schedule-based) operation execution for all telescopes
- standalone per-telescope operations and maintenance
- telescopes array operations

→ CTA-like control of LST array prior to telescope acceptance by the Observatory

Summary

LST telescope control software: substantial progress in FY 2022-2023

- stable, semi-robotic daily operations
- ~ 90% complete functionality-wise
- joint observations with MAGIC
- first successful for integration with CTAO control framework
- ready to support LSTs 2-4

**ICRR Inter-University Research Program support
is greatly appreciated**