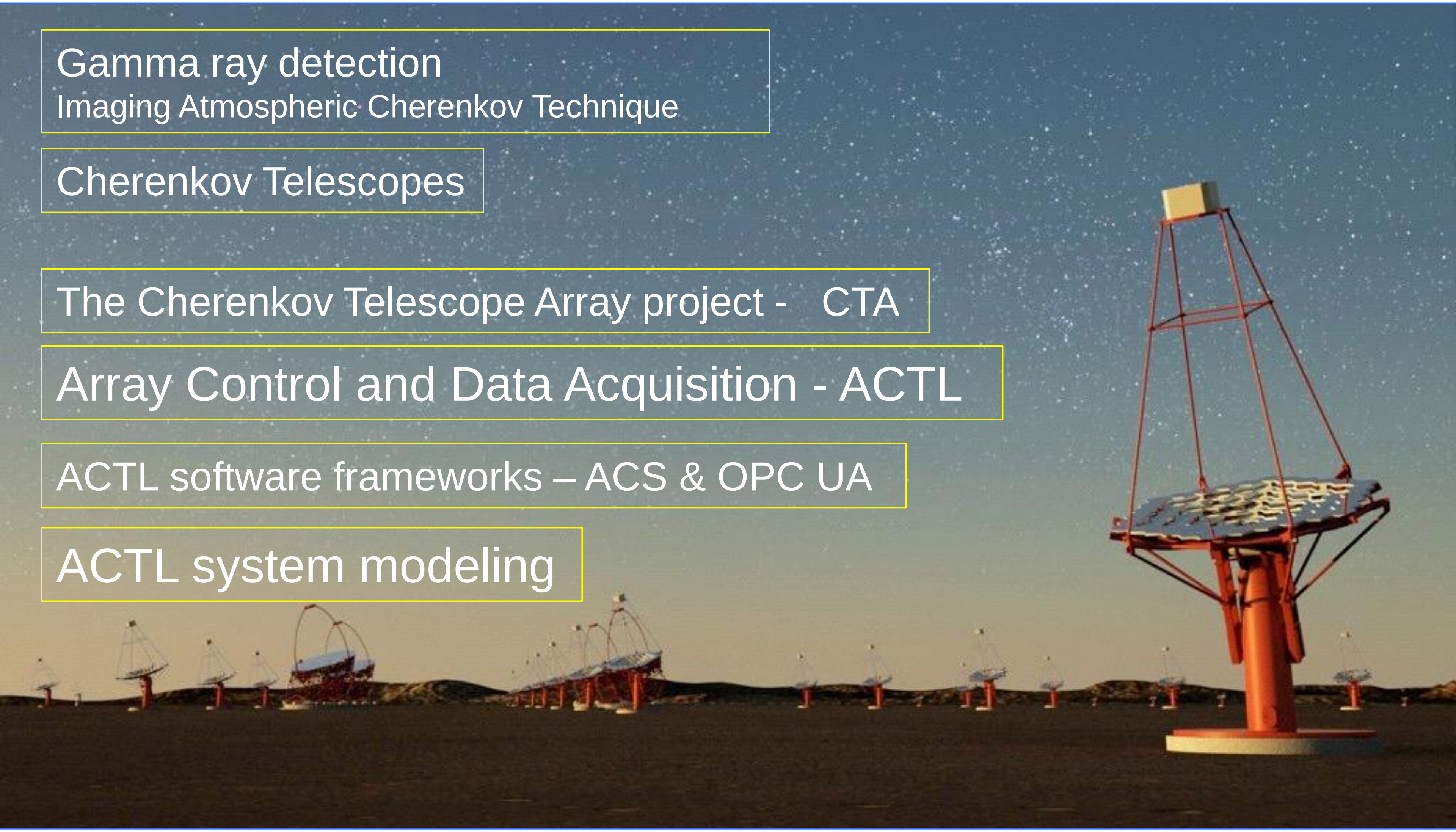
THE SOFTWARE SYSTEM FOR THE CONTROL AND DATA ACQUISITION FOR THE CHERENKOV TELESCOPE ARRAY

Peter Wegner[1]
for the CTA Consortium

[1]DESY, Zeuthen

OUTLINE

cherenkov telescope array



Gamma ray detection
Imaging Atmospheric Cherenkov Technique

Cherenkov Telescopes

The Cherenkov Telescope Array project - CTA

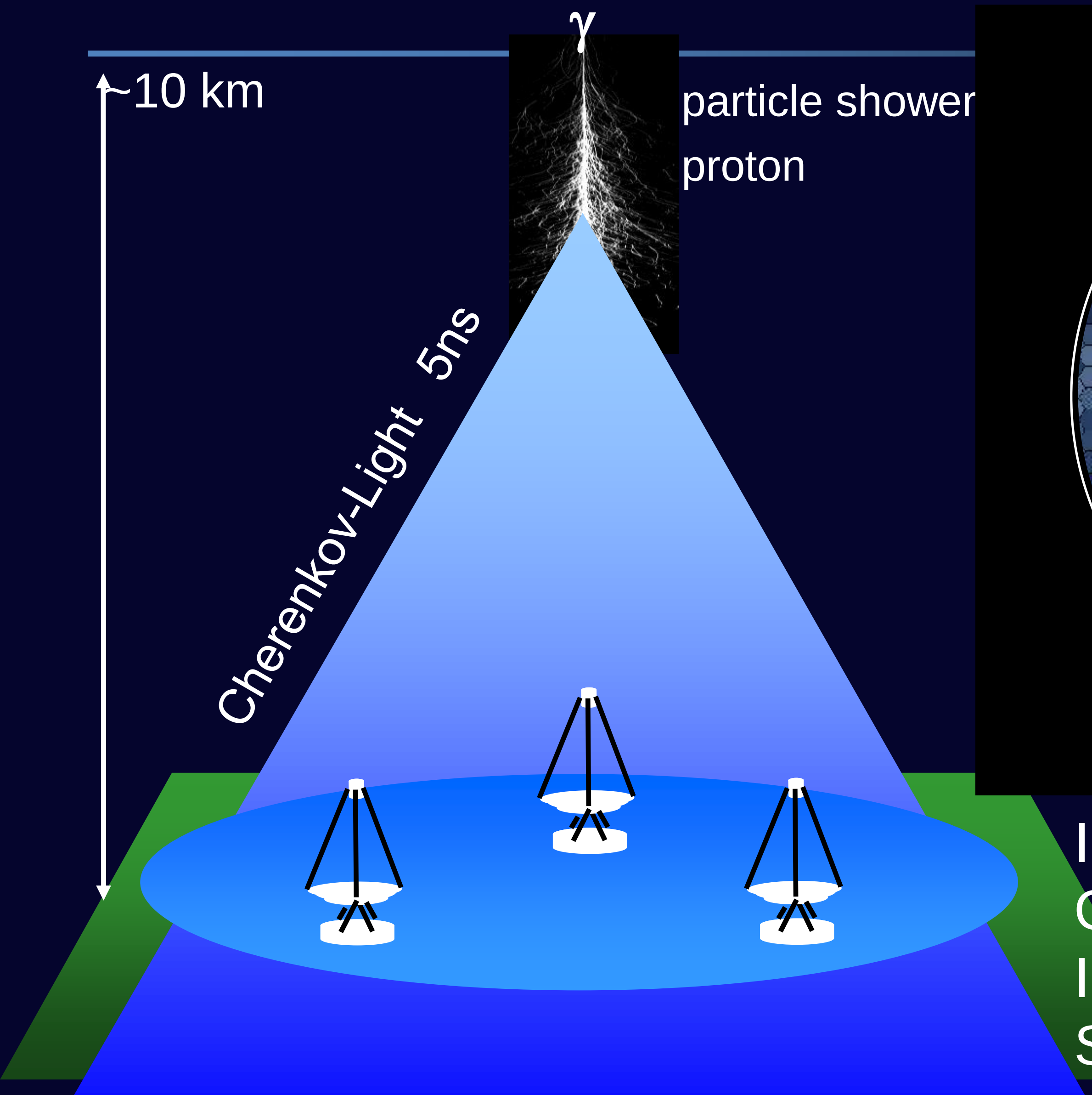
Array Control and Data Acquisition - ACTL

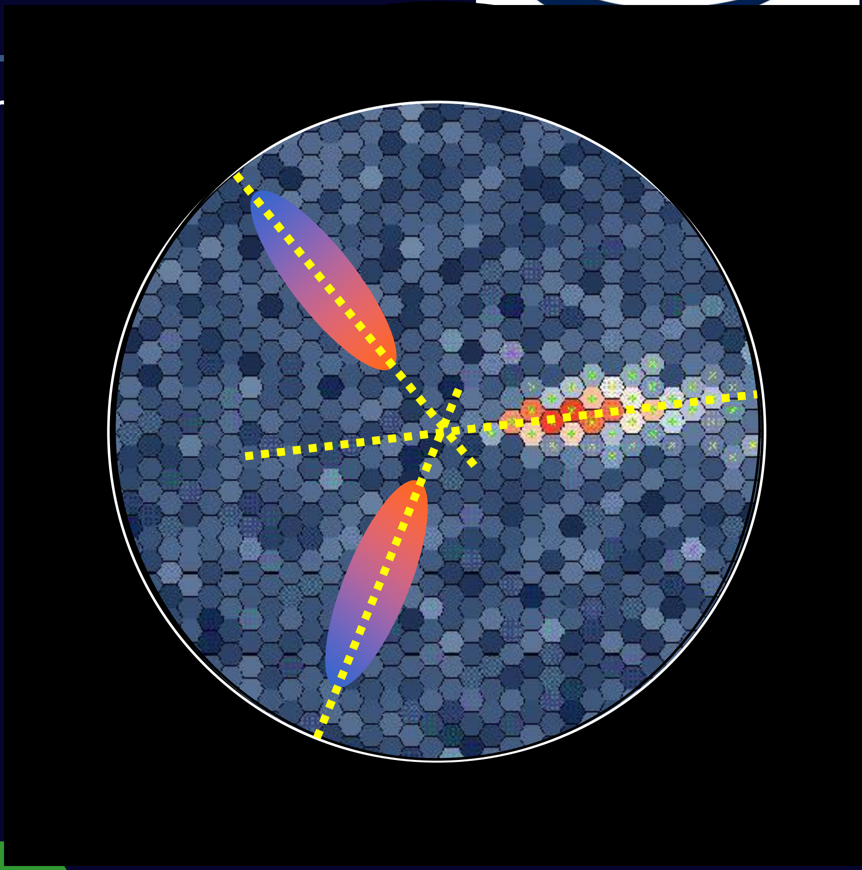
ACTL software frameworks – ACS & OPC UA

ACTL system modeling

Gamma ray detection

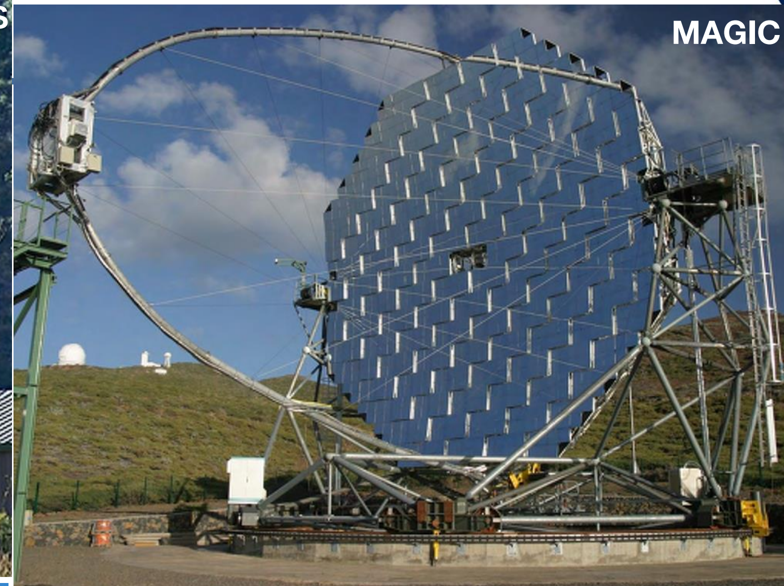
Imaging Atmospheric Cherenkov Technique





Intensity → Energy
Orientation → Direction
Image Shape → Particle
Stereo View → Source

CHERENKOV TELESCOPES



THE CHERENKOV TELESCOPE ARRAY PROJECT - CTA

2 Arrays: North+South→ All-Sky Coverage

More than 30 countries and ~300 M€ of budget.
More than 1000 members in the consortium.
Including the vast majority of the experts from existing experiments.

Medium Size Telescope - MST
core array
100 GeV-10 TeV

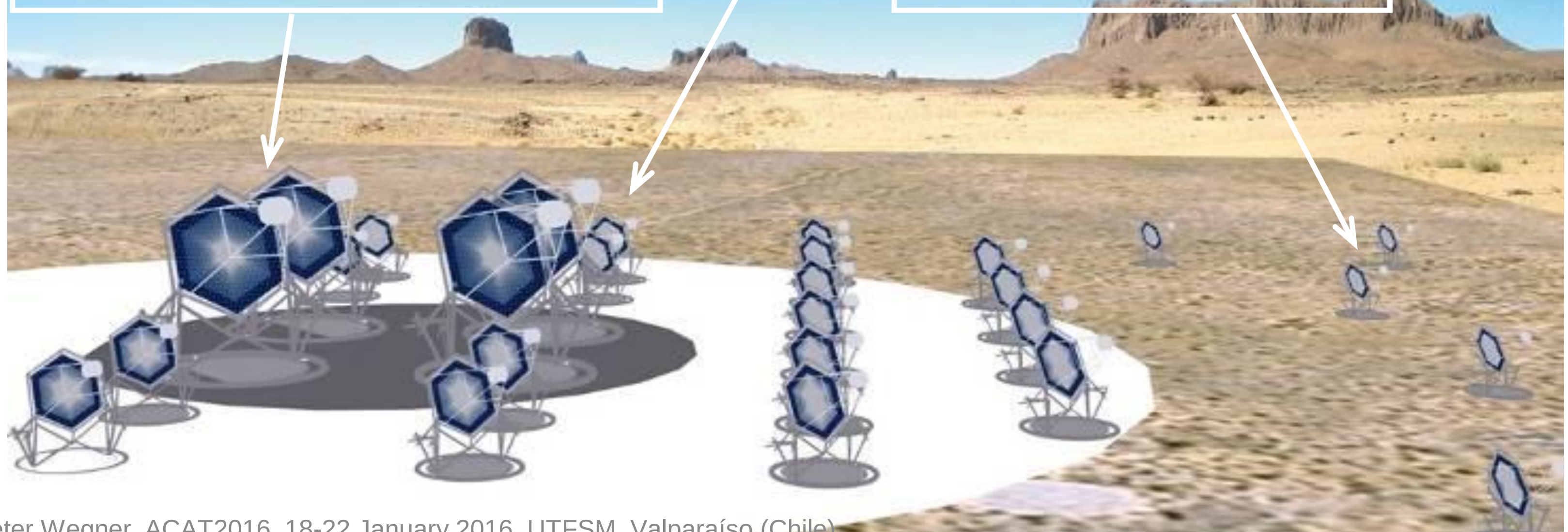
~ 40 Ø=12 m telescopes

Large Size Telescope - LST
low energy section
E_{thresh} ~ 10 GeV

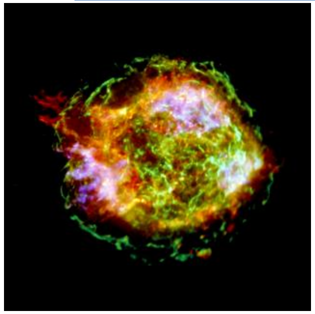
a few Ø=23 m telescopes

Small Size Telescope - SST
high energy section

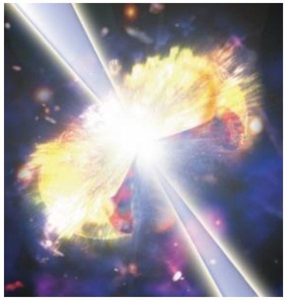
~ 40 Ø=6 m tel.
on 10 km^2 area



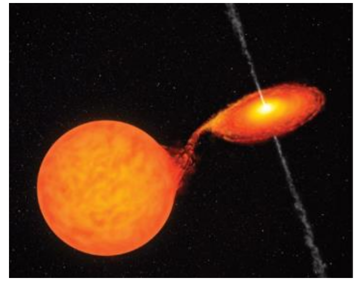
CTA PHYSICS



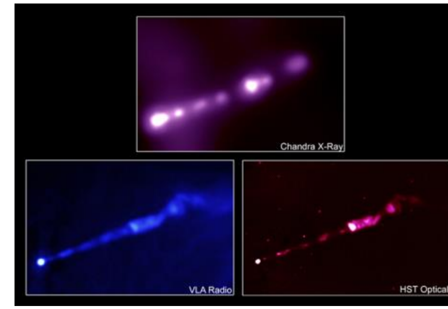
SNR
Supernova Remnants



GRB
Gamma Ray Bursts



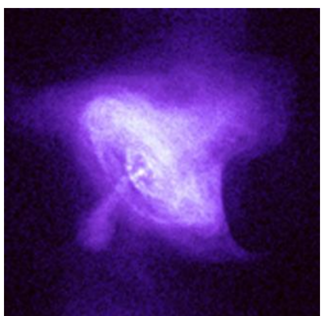
Micro quasars



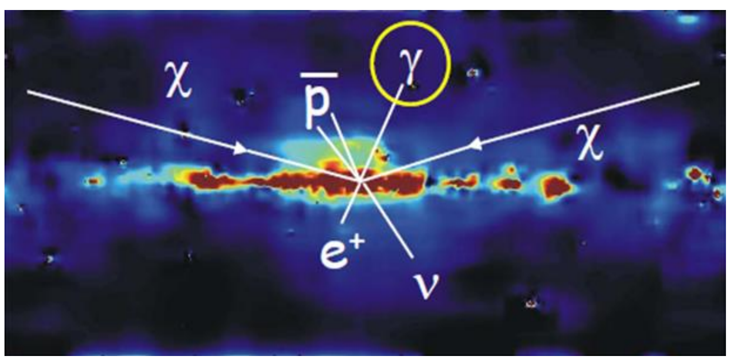
AGN
Active Galactic Nuclei

Understanding of cosmic ray sources

Detailed study of cosmic particle accelerators in and beyond our galaxy

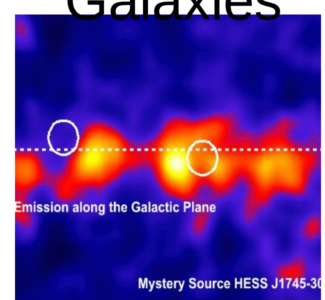


Pulsar, PWN
Pulsar Wind Nebula



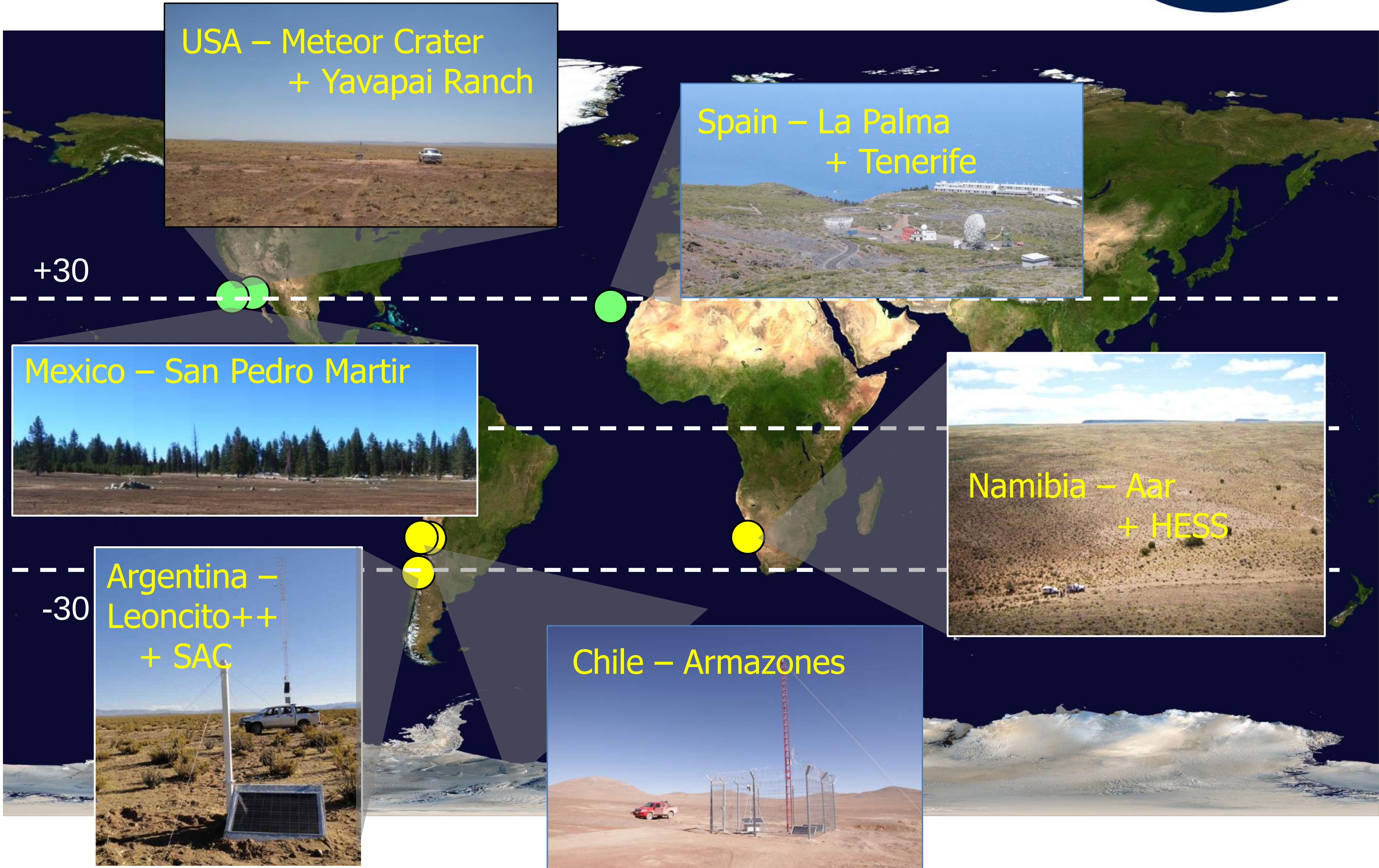
Dark matter

Starburst Galaxies

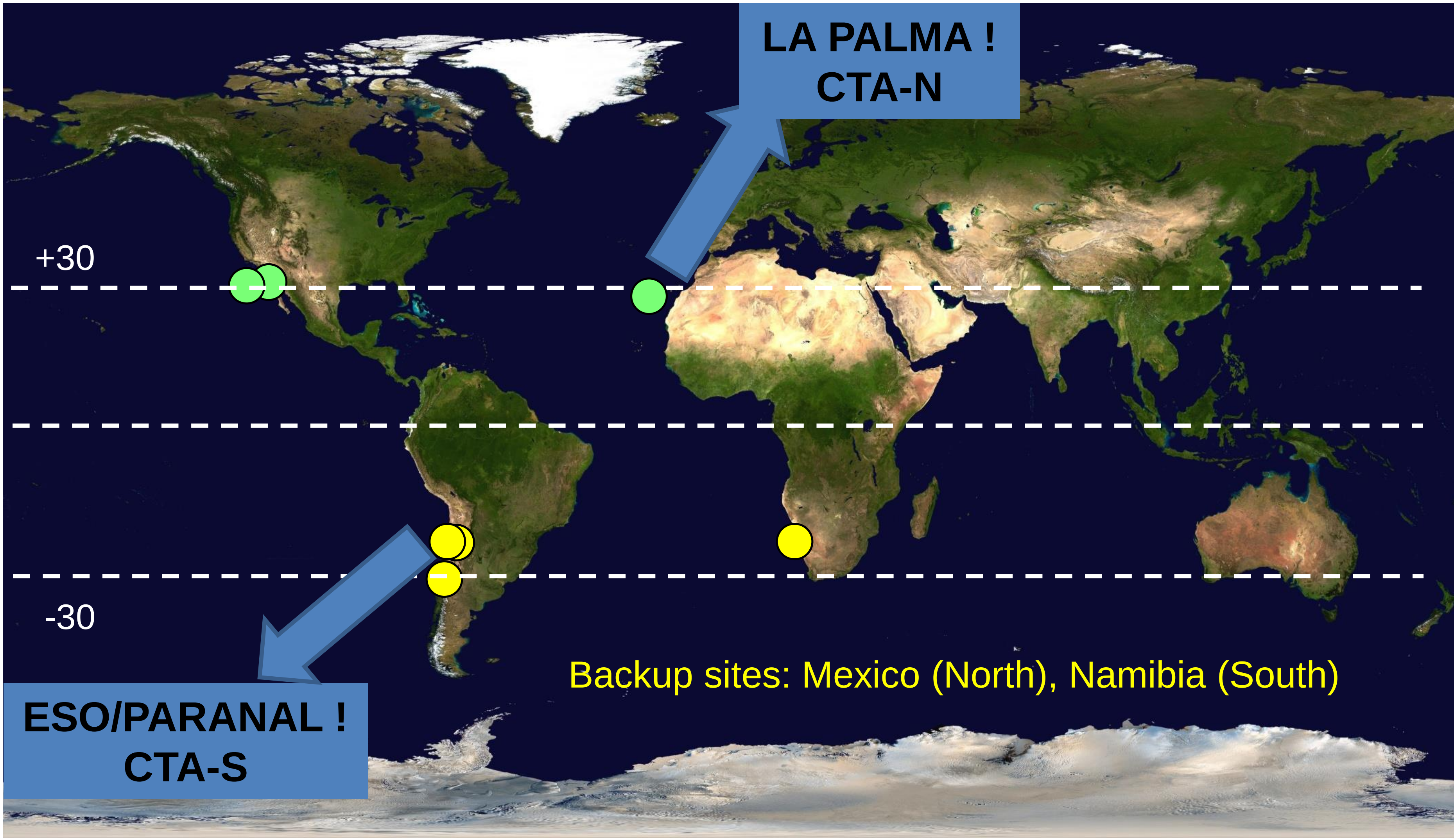


Unknown Sources

CTA SITES FOR SELECTION



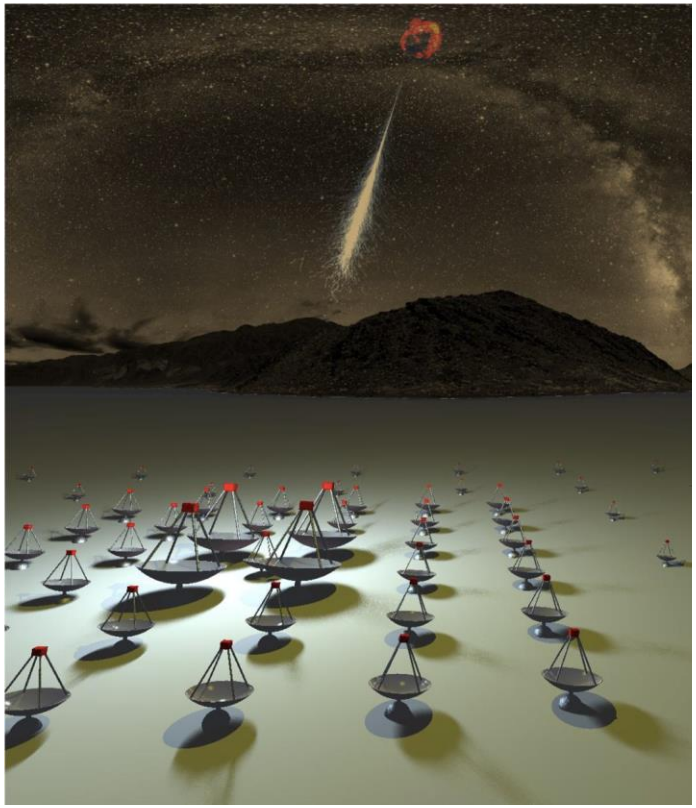
CTA SITE SELECTION – JULY 2015



CTA ARRAY CONTROL AND DATA ACQUISITION - ACTL

ACTL comprises

- Data Acquisition (DAQ)
- Entire array control and monitoring of all Cherenkov telescopes and aux. devices
- Scheduling of observations
- Array trigger and time distribution
- On-site Archive and Level-A analysis



ACTL –
SOFTWARE CHALLENGE/APPROACH

Challenge

- CTA – 10x more sensitive than previous IACTs
  - larger latencies, more difficult synchronization, higher data rates, larger data volume, raw data bandwidth @LHC ATLAS level
  - more telescopes of different types → much higher complexity, heterogeneous hardware architecture
- First IACT observatory → higher reliability requirements
  - Not yet reached by current IACTs
- Very tight schedule, limited resources (esp. manpower), two sites

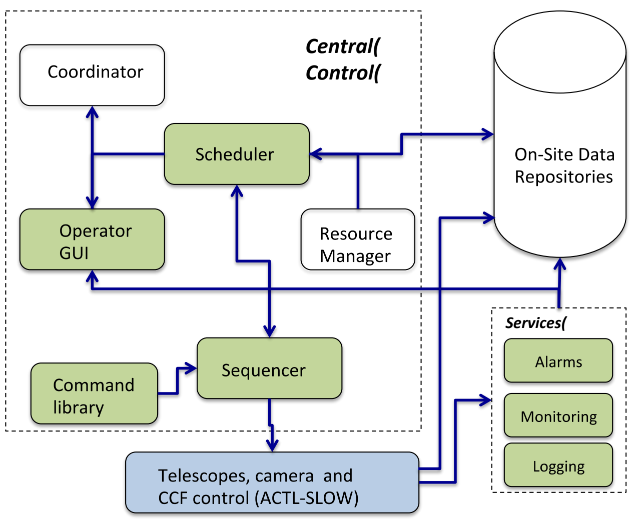
ACTL approach

- Advanced well-conceived software design based on an adequate high level architecture, use of software frameworks and standards
- Use of commodity hardware for processing, data storage, networking, and triggering

ACTL SUB-TASKS (1)

Instrument Operation Software – **OPS**

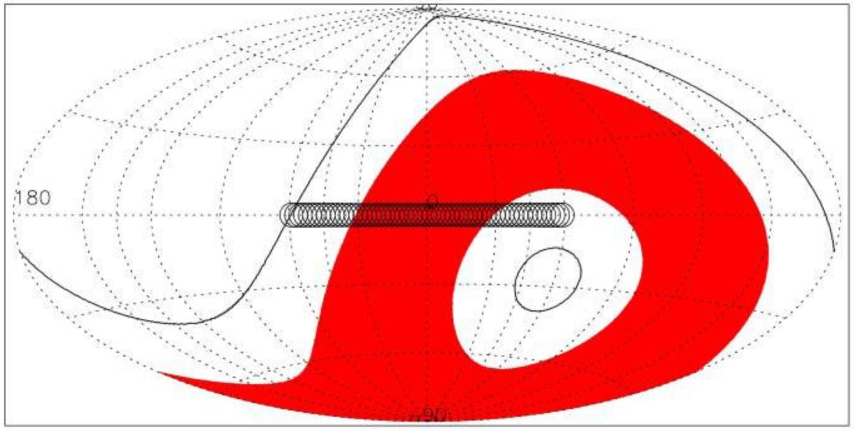
central array control and operation, monitoring, logging, error detection and recovery, operator user interface



Prototypes for ACS monitoring mechanisms, Operator GUI prototypes, NOSQL data base performance test setups, configuration database, software frameworks

Central Scheduler – **SCHED**

long-term and short-term scheduling, scheduling of observations and calibration/maintenance



Prototype system tests with scheduling data from MAGIC and CTA galactic survey simulation as part of Key Science Projects

ACTL SUB-TASKS (2)

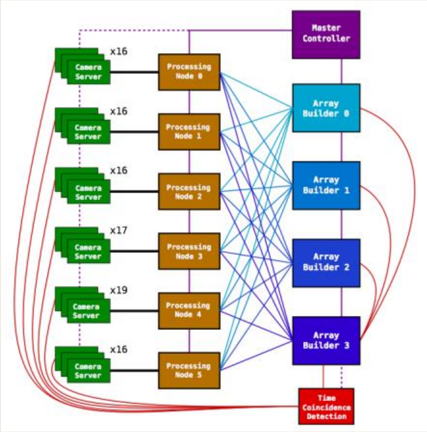
Instrument Slow Control Software – **SLOW**

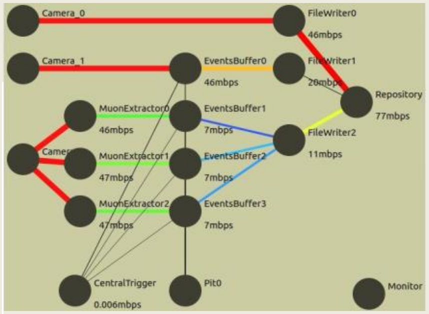
Slow-control for telescopes, camera subsystems, and auxiliary devices, GUIs for engineering purposes

Prototypes for engineering GUIs, Telescope Software - ACTL interfaces tests (e.g. MST, SST-2M ASTRI), ACS components – drive system, CCD cameras existing

Data Acquisition Software – **DAQ**

data readout and bulk data transfer, online data format, array event building & buffering, integration of level-A analysis



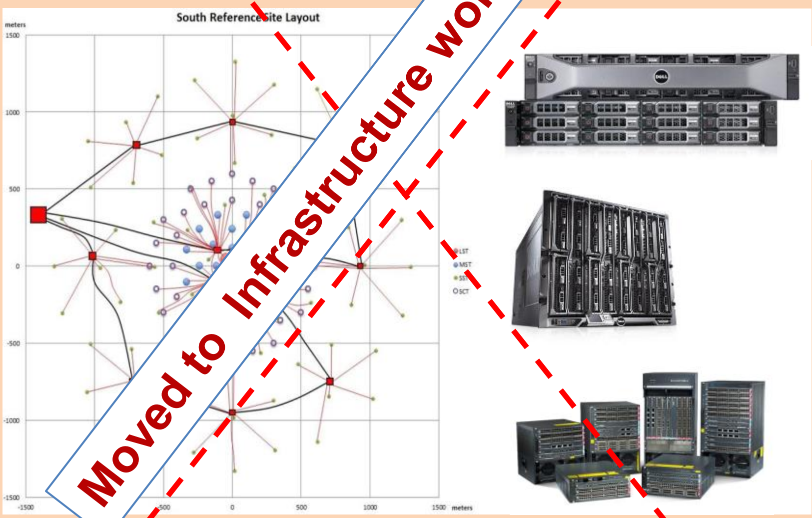


Full prototype, e.g. simulating the processing of data streams coming from 100 camera servers

ACTL SUB-TASKS (3)

On-site IT Infrastructure – **ONSITE**

On-site network, computing farm and storage including system software, interface to camera servers and external network

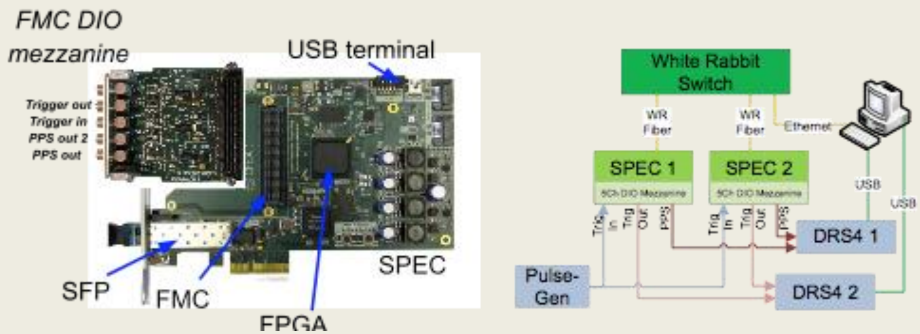


Moved to Infrastructure work package

Detailed detailed design plans for network, hardware specifications exists
Testbed system – hardware prototyping, (server hardware baseline), systems tests

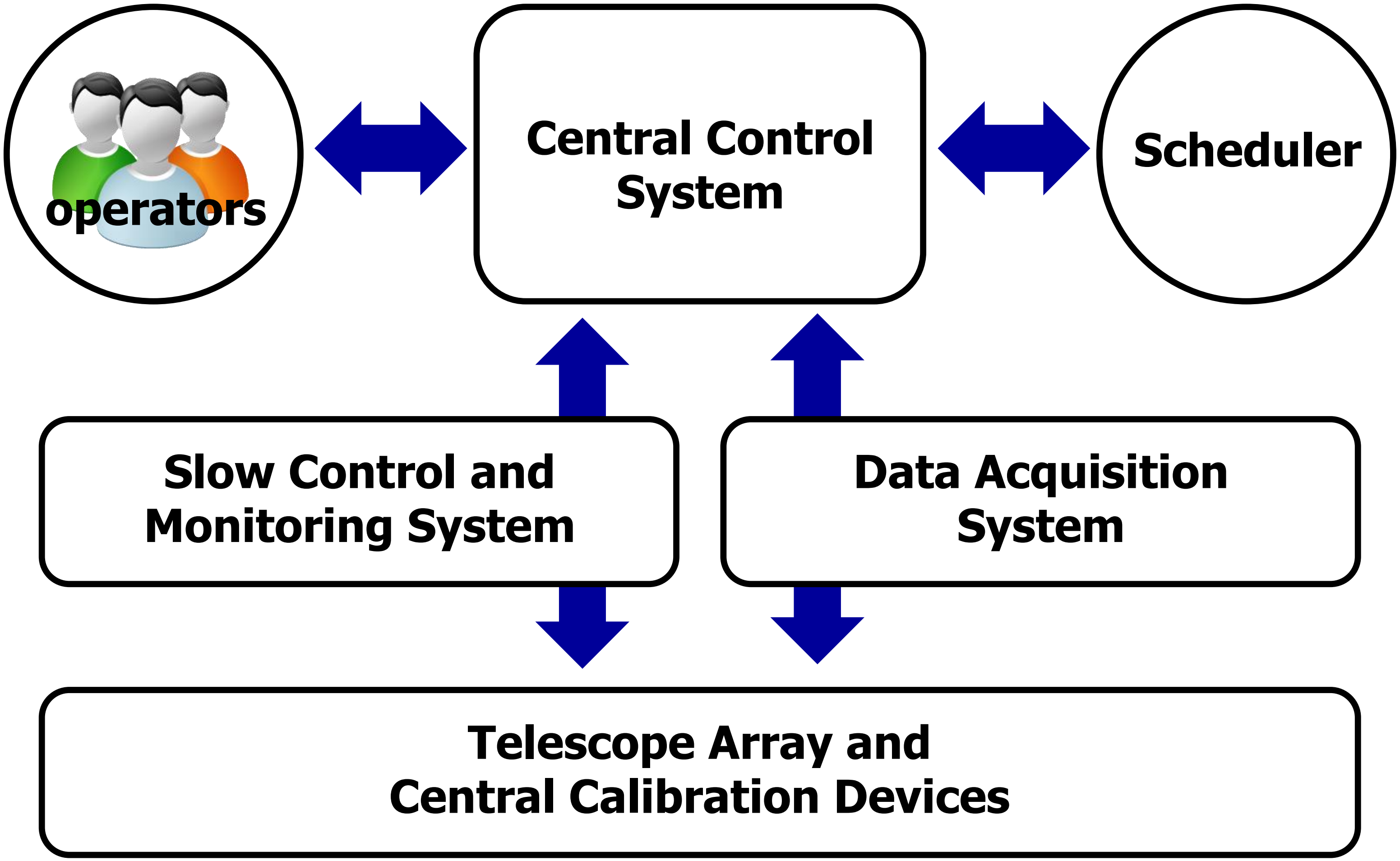
Array Trigger and Timing System – **TRIG**

Array-level triggering (software array trigger), clock distribution and time-stamping

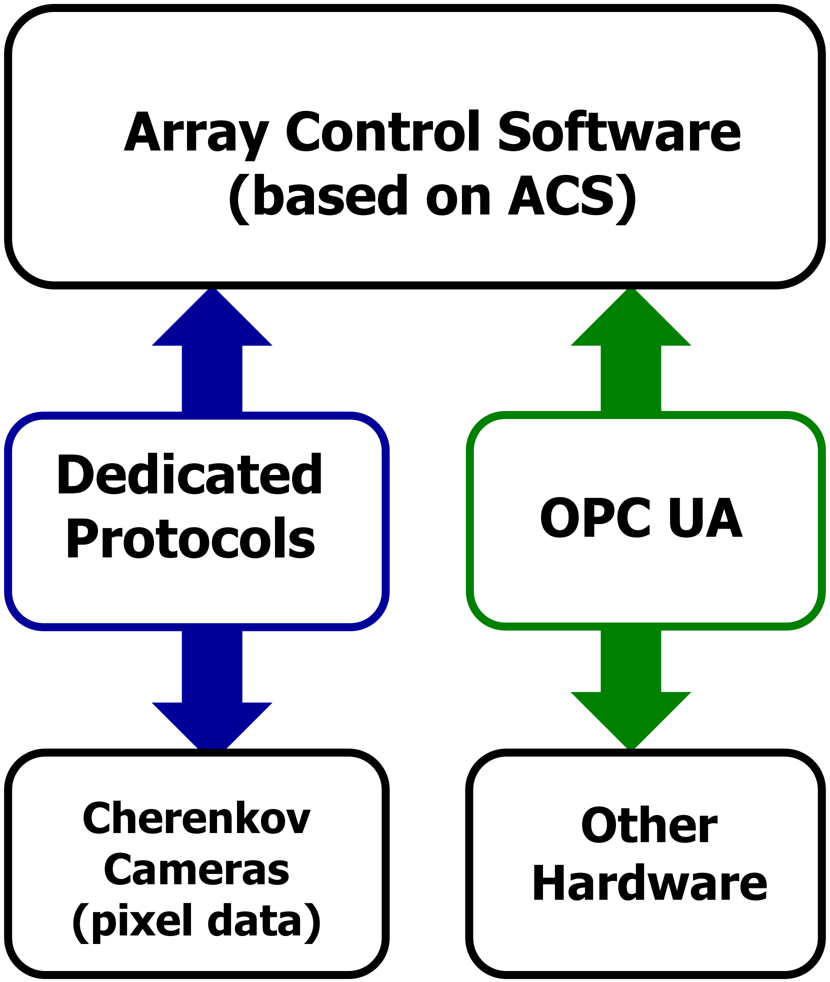


Proof concept hardware for CTA, White Rabbit prototype (HiSCORE) for time distribution, software array trigger simulation system exists

ACTL BASIC BUILDING BLOCKS



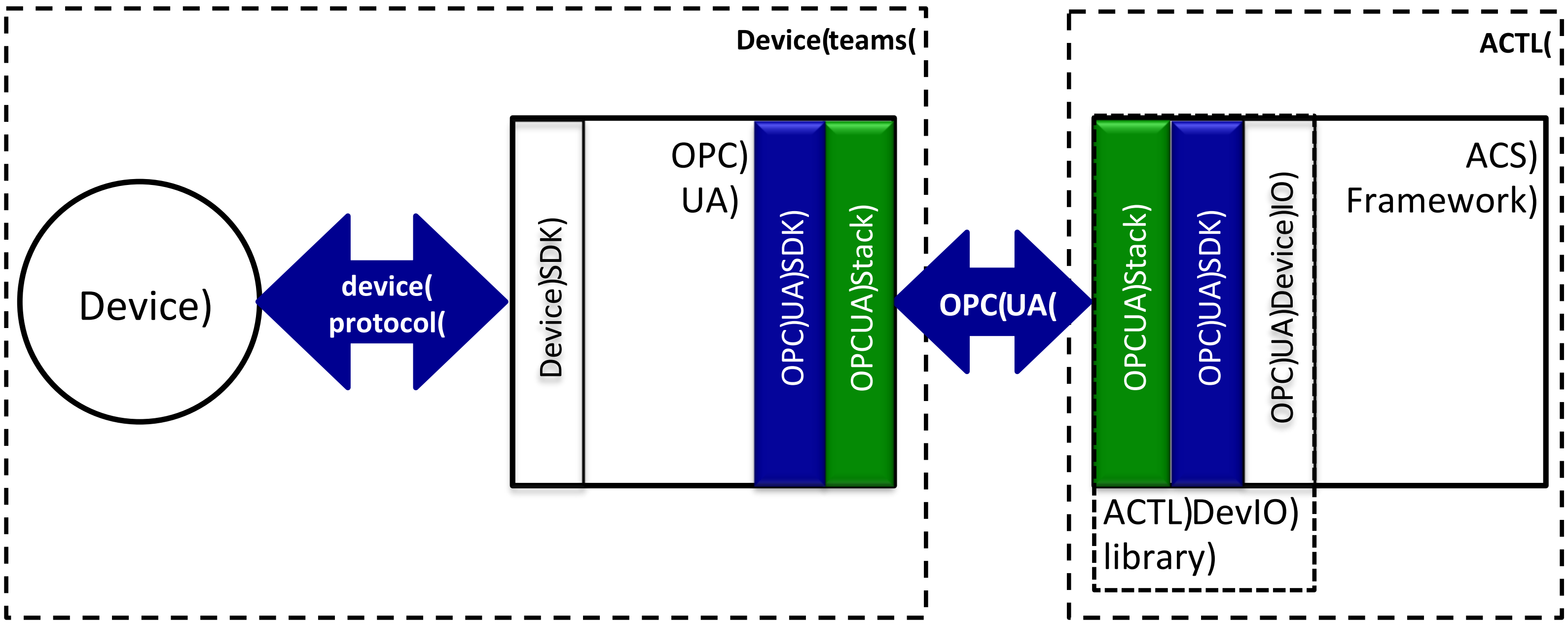
ACTL – SOFTWARE FRAMEWORKS



ACS (ALMA Common Software) mainly developed for ALMA – provides main functionalities for central control (process handling, configuration data base, logging, ...) supported by an active open community

OPC UA (OLE for Process Control - Unified Architecture) for hardware access and integration,
Evolving industrial standard, widely adapted for control systems, provides an abstraction layer to separate central control from device implementation

ACTL – DEVICE INTEGRATION



OPC UA Server

OPC UA Client
/ACS component

Goal: integrating all devices into ACTL-ACS by using OPC UA

TELESCOPE PROTOTYPES

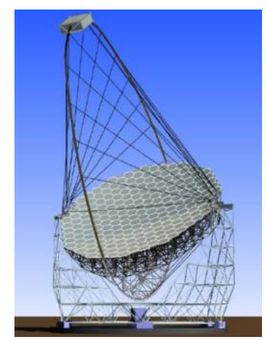
MST – Prototype, Davies-Cotton
Berlin Adlershof, 2013

SST-2M-ASTRI, Schwarzschild Couder, Serra La Nave, (Mt. Etna),Sicily, 2014

SST-2M-GCT, Schwarzschild Couder, Meudon, near Paris 2015

pSCT
Schwarzschild Couder
Mt Hopkins, Arizona,
Veritas site, 20xx

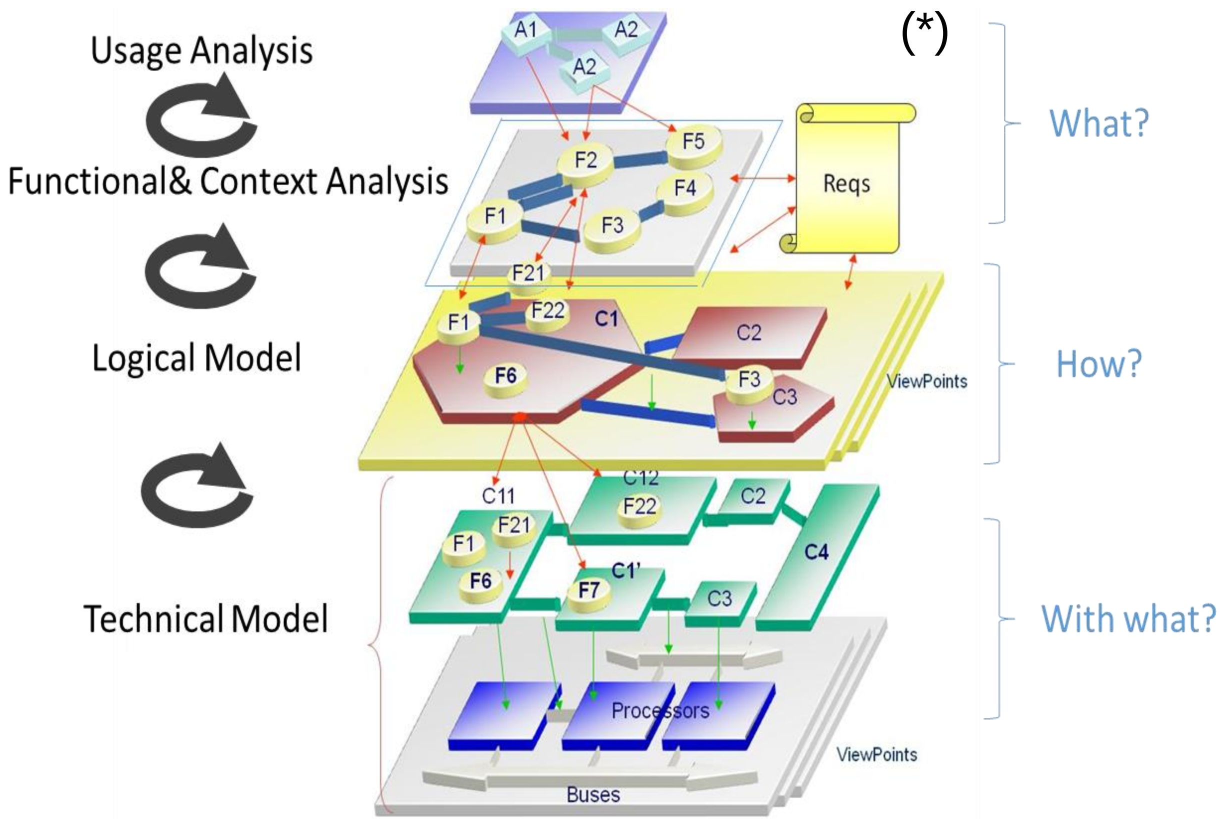
SST-1M,
Davies-Cotton
Krakow, Poland
2015



LST, Parabolic,
La Palma, Spain
2016/2017

Software layer / Common framework: ACS, OPC UA
Prototype software already developed for drive systems, CCD cameras, weather stations, AMC

ACTL SYSTEM MODEL



Use cases,
User requirements,
Functionality

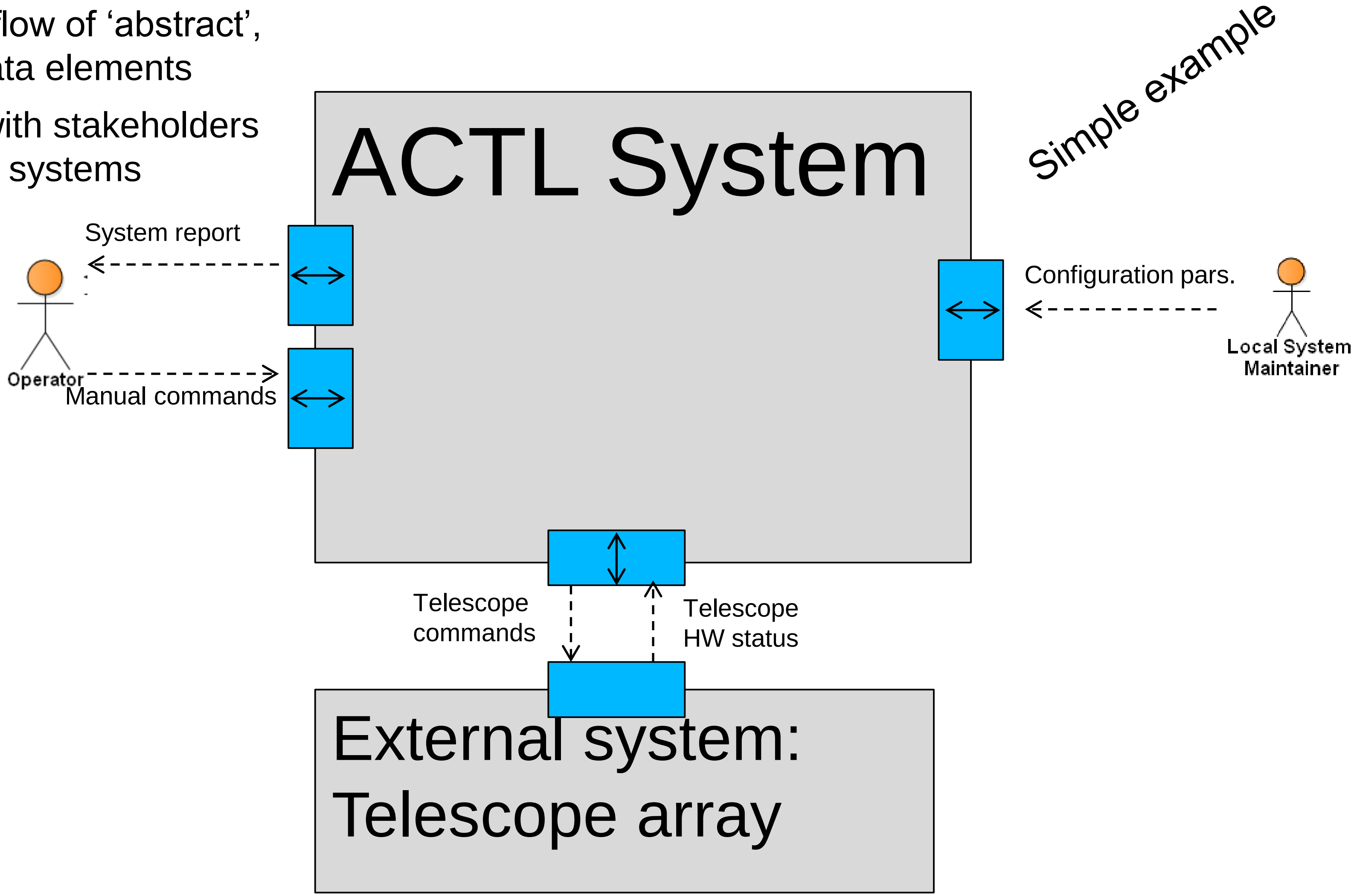
How the functionality is realized,
Communicating and cooperating components

Mapping to software (framework) components,
Deployment to computing and networking hardware

(*) System Modeling by “Fraunhofer Institute for Experimental Software Engineering – IESE”

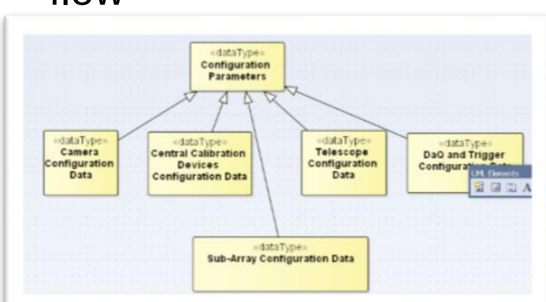
CONTEXT MODEL – ACTL AS A BLACK BOX

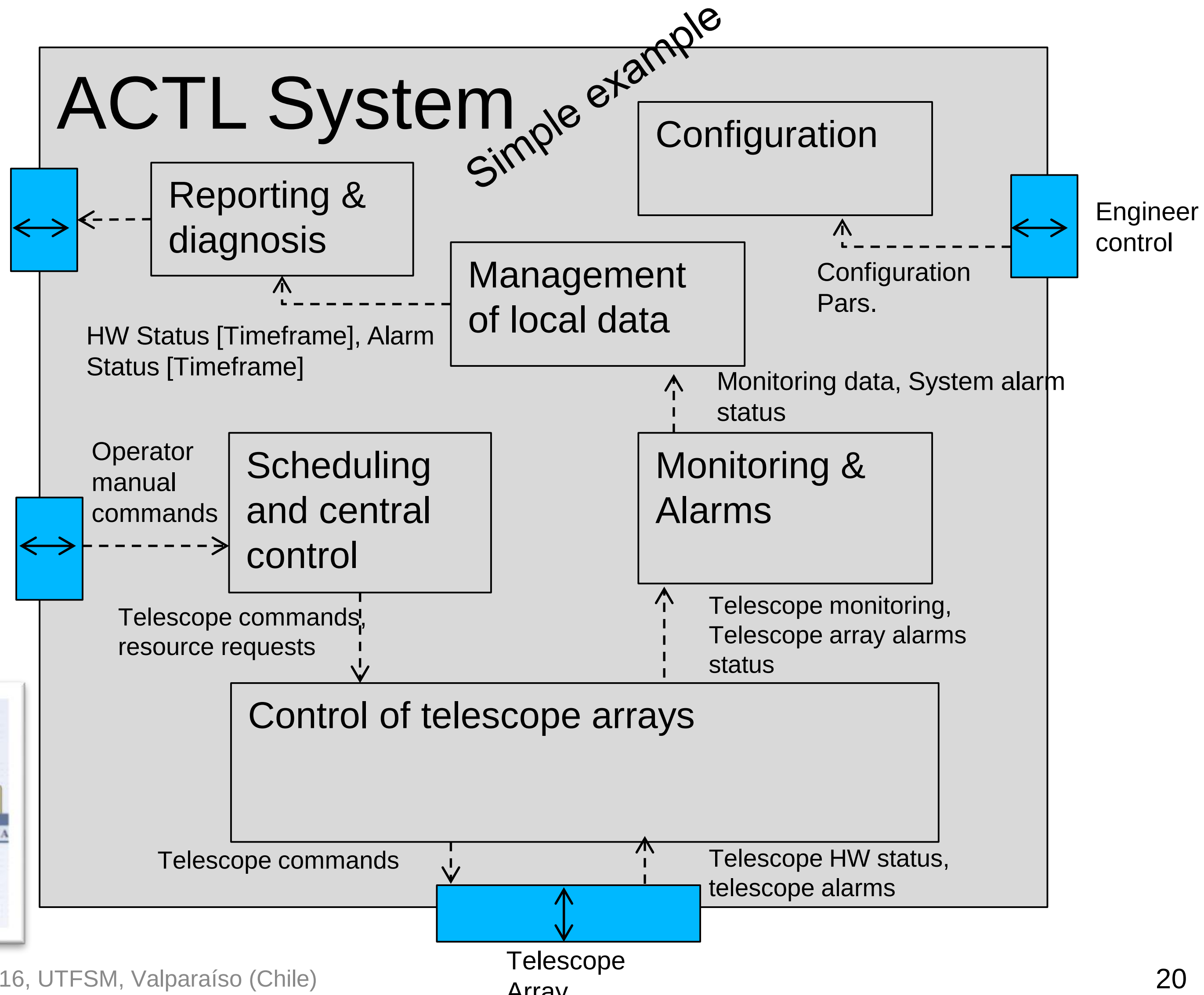
- Information flow of 'abstract', functional data elements
- Interaction with stakeholders and external systems



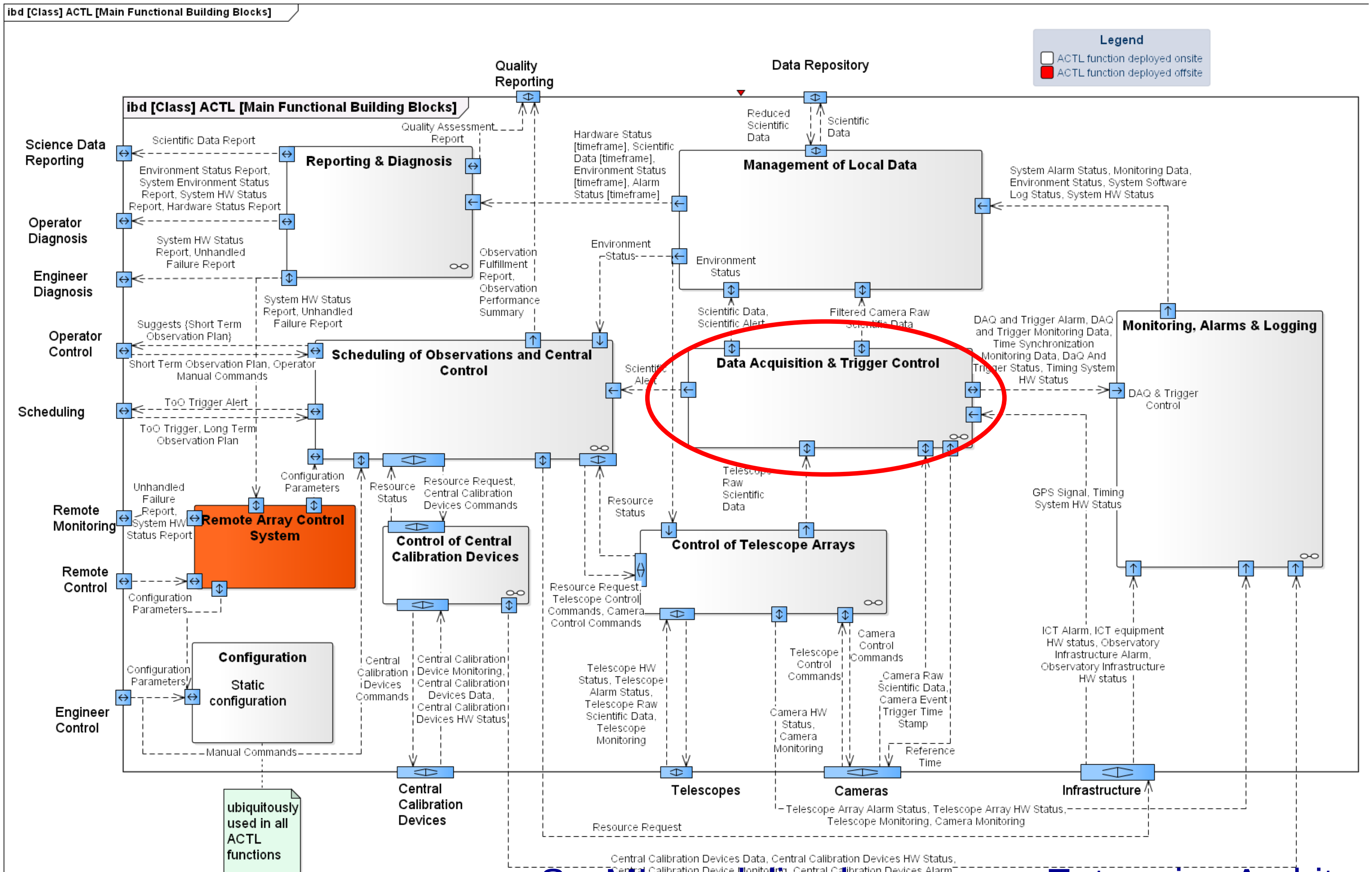
FUNCTIONAL VIEW – ACTL AS A WHITE BOX

- Information flow of ‘abstract’, functional data elements
- System decomposed in functionalities
- Functions have structure and granularity
- Function hierarchy allow to create the WBS
- Functional data associated to each flow





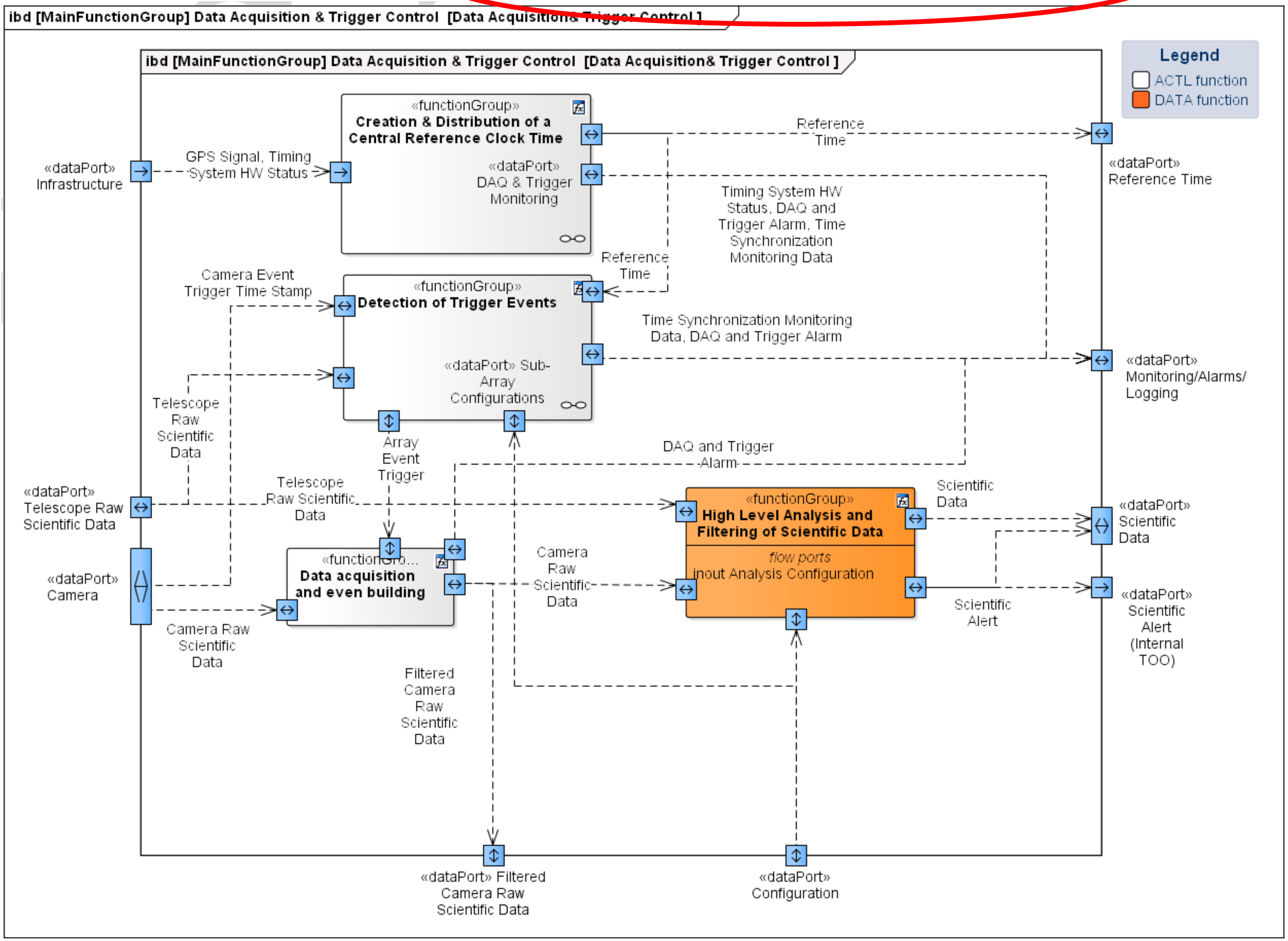
ACTL TOP-LEVEL ACTL FUNCTIONAL VIEW



SysML modeling language – Enterprise Architect

ACTL SYSTEM MODELING

Functional view of the "Data acquisition and trigger control" function group



ACTL SYSTEM MODELING

Architecture-related goals:

- Develop an architecture model for the whole ACTL project
- Identify all architecture drivers, such as requirements, use cases and stakeholders
- Link all architecture drivers to the architecture model in a formal approach
- Identify missing architecture drivers (requirements, use cases, stakeholders)
- Allow for full traceability from the requirements and use cases to the architecture and corresponding functionality and software and hardware components to be provided by ACTL
- Provide a framework for all ACTL product owners to further develop the detailed design of their products
- Provide guidelines to be followed by all ACTL software developers in the development and implementation of their software components
- Provide means for evaluation and integration of software components to be developed as well as existing prototypes or previous project solutions
- Document each design choice and its implications

ACTL SYSTEM MODELING

Project-related goals:

- Develop a project model for ACTL based on the system model
- Develop an implementation plan (what will be implemented when) and enable progress control
- Identify unplanned work and assign responsibilities
- Evaluate ACTL project priorities and their implications
- Evaluate ACTL system risks and risk mitigation
- Provide means for product acceptance (verification and validation)
- Revise cost and effort estimates for realizing the ACTL components based on the
- system model and following a formal approach

(Matthias Füssling, Igor Oya, Lars Hagge, Fraunhofer IESE)

SUMMARY

- CTA will be a major research infrastructure for high-energy astronomy in the coming decades
- ACTL is a challenging and very complex project within CTA, demanding new management and development methods in comparison with other IACT projects

As a consequence

- ACTL software design and development is based on frameworks and standards, basically ACS and OPC UA and the ACTL software management, while architecture and design is following a comprehensive system modeling approach

Thank you !