The H.E.S.S. Data Acquisition System

Controlling The Biggest Cherenkov Telescope Ever Built

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HELMHOLTZ ASSOCIATION

Universität Potsdam

H.E.S.S.

DESY

H.E.S.S. Phase I

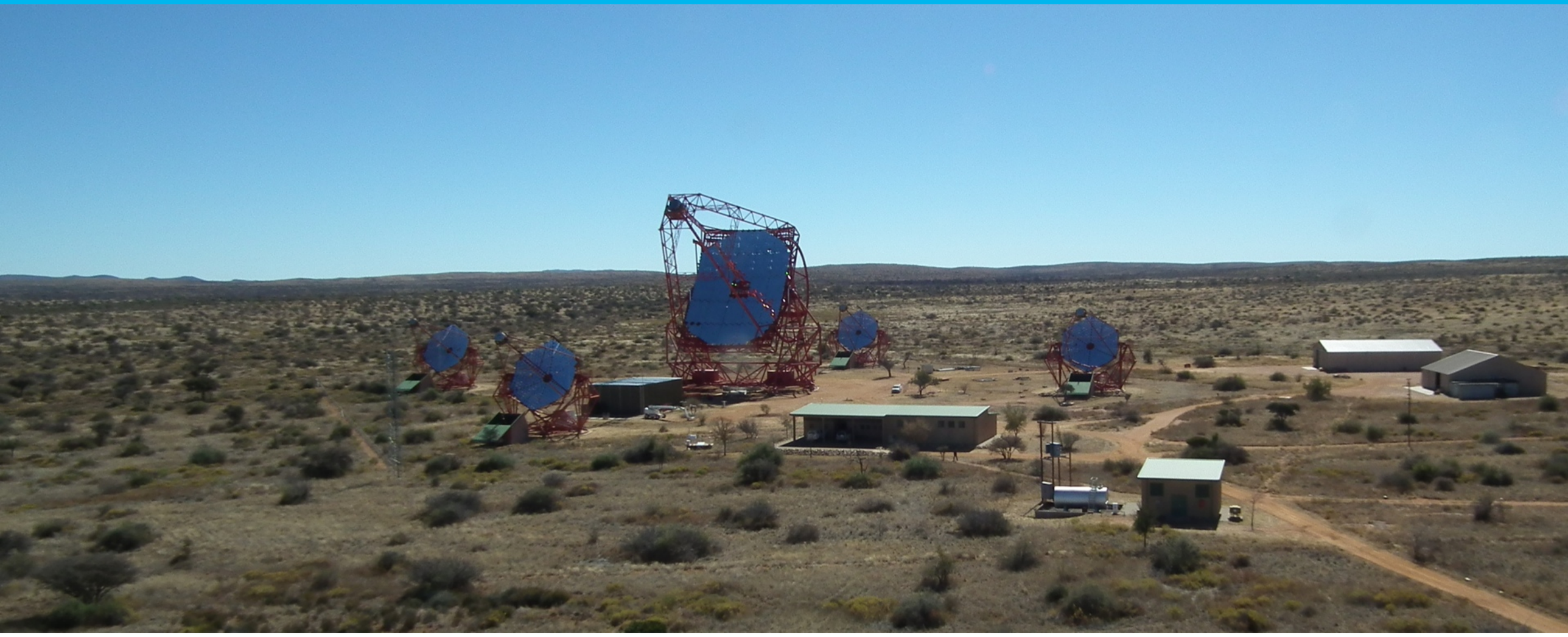
> Four Cherenkov telescopes

- 60 t weight, 13 m dish diameter
- 15 m focal length, 107 m^2 mirror area
- 960 PMTs, 5° field of view

> Energy range

- from ~100 GeV
- to several tens of TeV

H.E.S.S. Phase II



> Additional fifth Cherenkov telescope

- 560 t weight, 24 m * 33 m dish diameter
- 36.1 m focal length, 590 m^2 mirror area
- 2048 PMTs, 3.2° field of view

> Energy range

- from ~20 GeV
- to several tens of TeV

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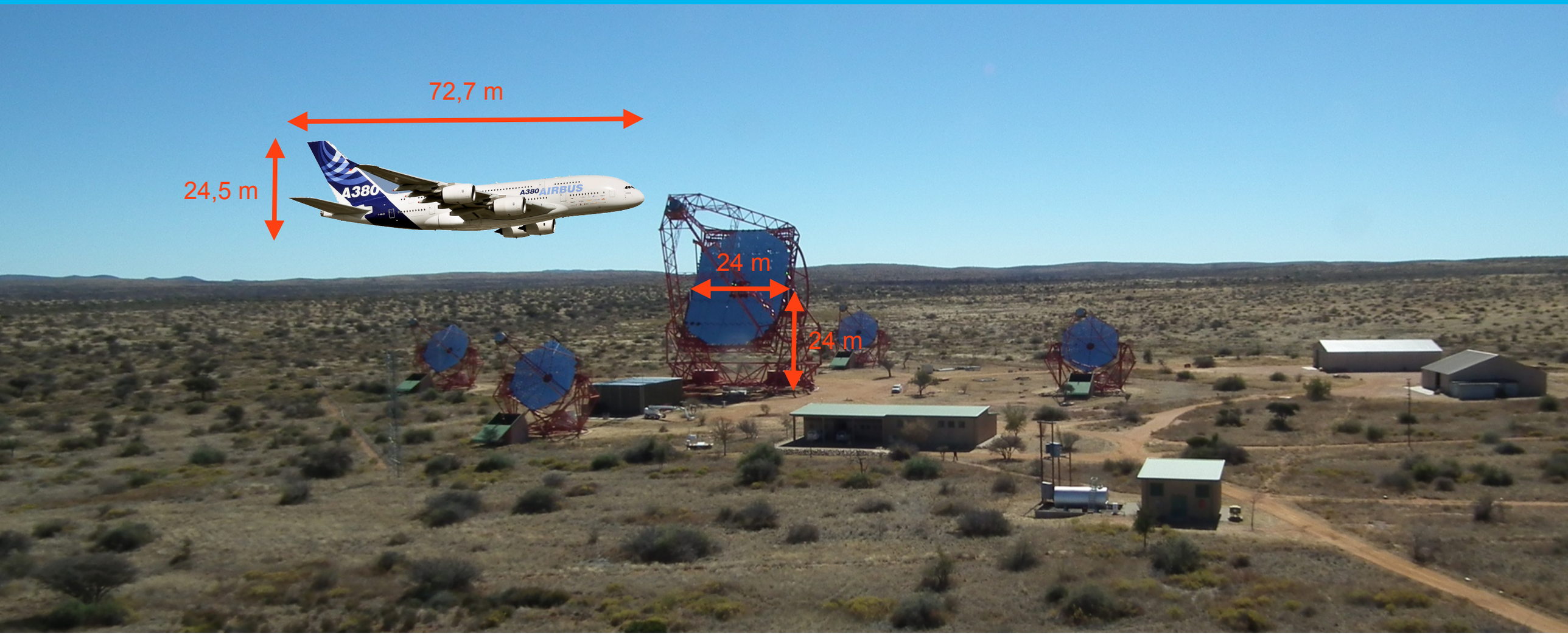

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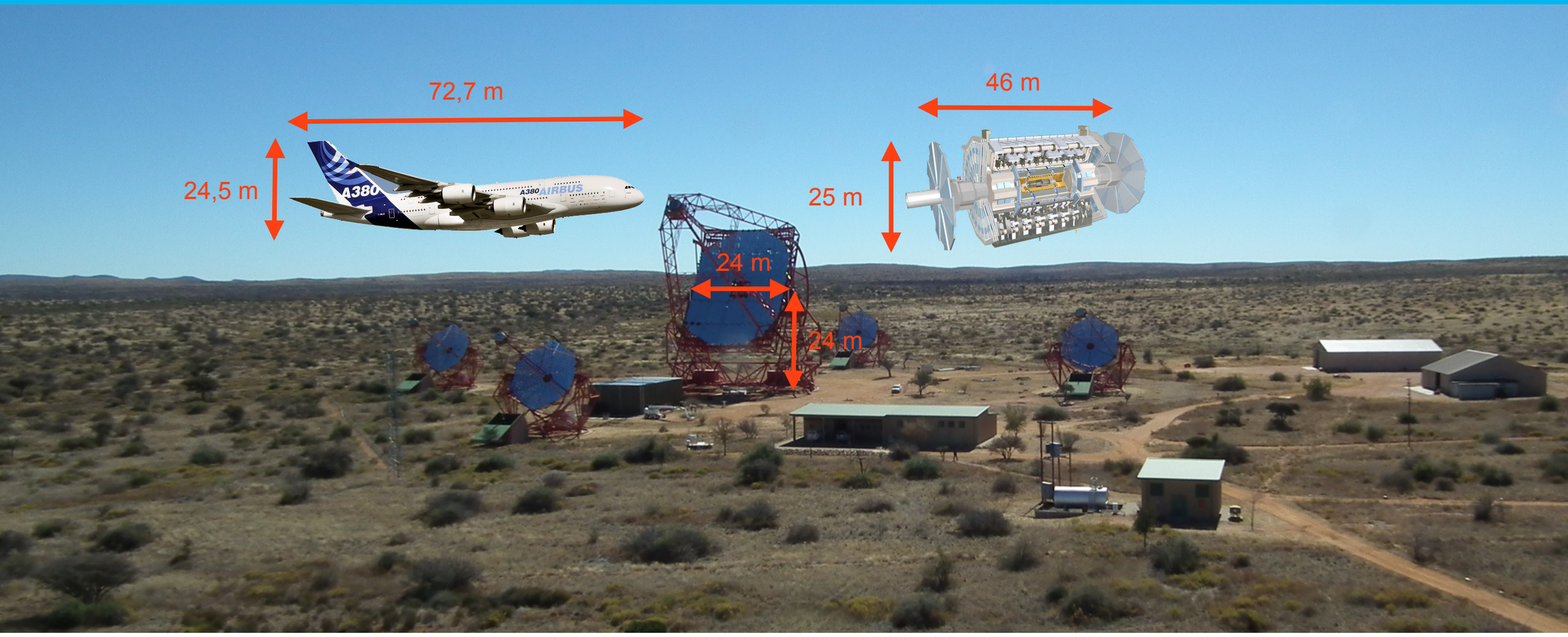

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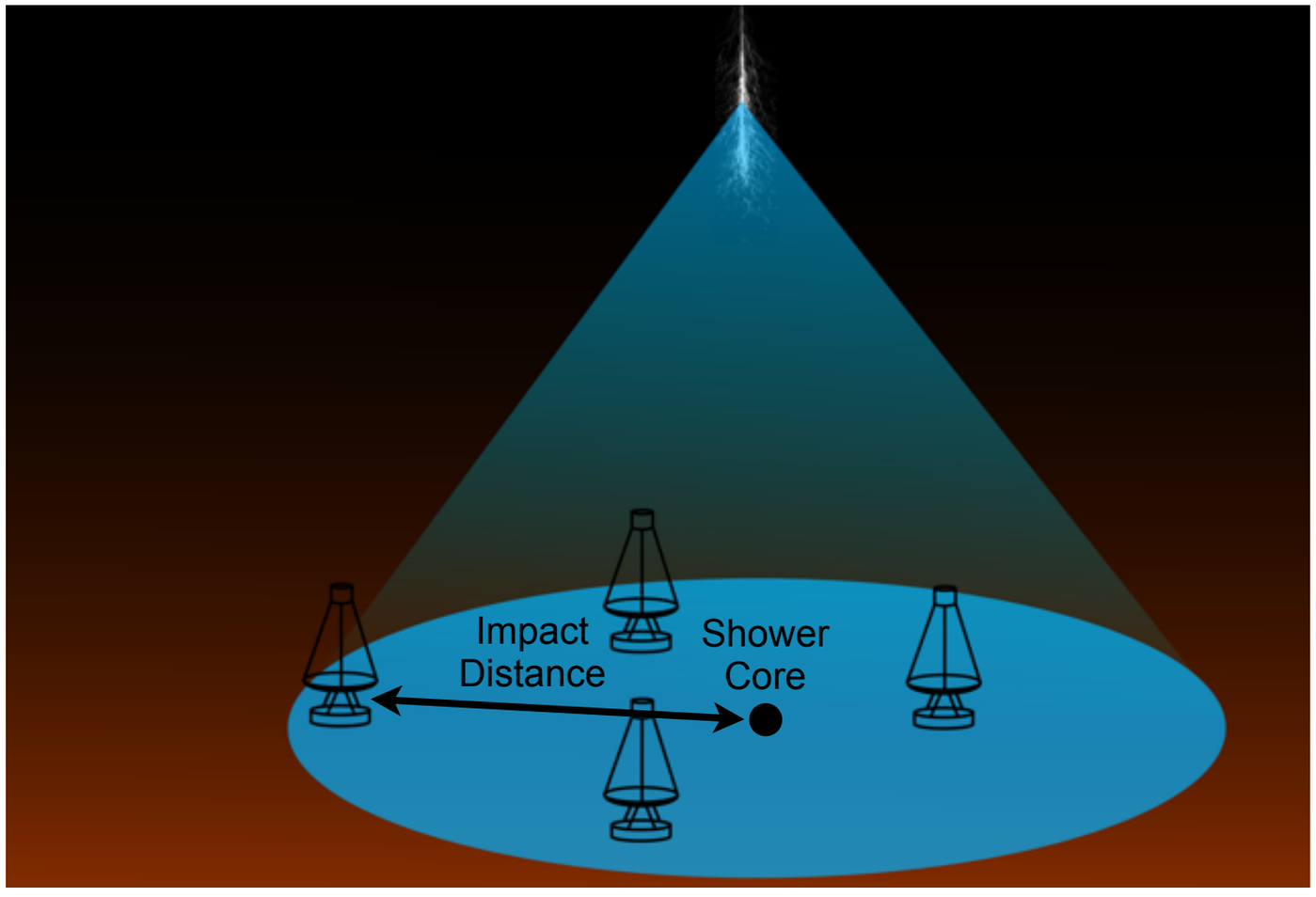
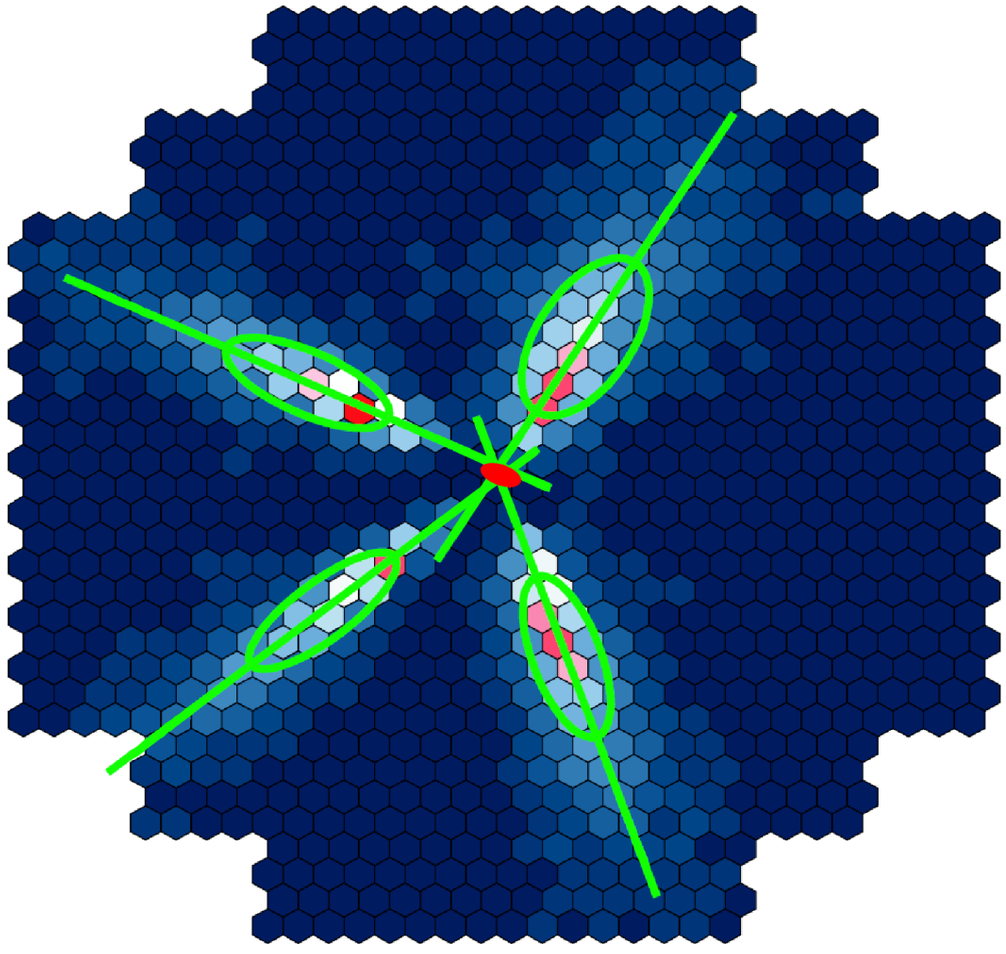
Shower Reconstruction

- The shower images in the camera are approximated as ellipses
- Intensity → Energy
- Orientation → Direction
- Shape → Primary Particle



Courtesy A. Schulz

Four telescope event in
common camera plane



Operating the H.E.S.S. Array

- Data taking only during astronomical darkness (dark time)
  - roughly 1000 hours a year
- Array operated by monthly changing non-expert “Shift Crew”
  - 1 “Shift Expert”
  - 2 “Shifters”
  - Supported by technical staff on site and sub-system experts in Europe
- Dark time split up in 28 minute “runs”
  - each run can be taken on a different source on the sky
  - each run can use a different detector configuration
- Data taking highly automized
  - Except for:
    - Manual activation of tracking system of telescopes
    - Loading and unloading of CT5 camera
    - Error handling
    - Weather monitoring

Array Control for H.E.S.S. Phase II

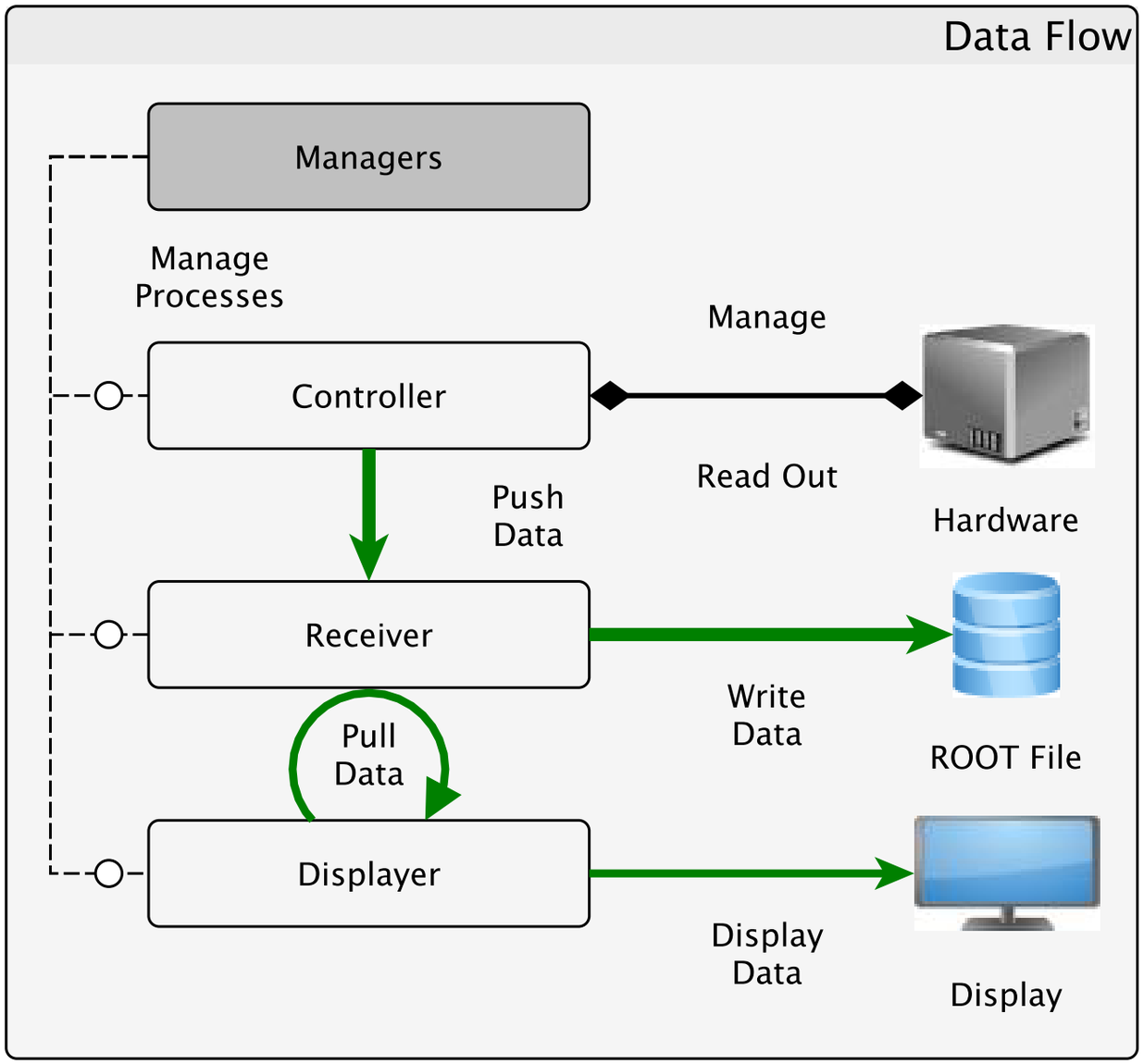
- Central DAQ Cluster
  - 4 * 48 port switches, 10 worker nodes, 6 server
  - ~100 cores, ~200 GB Ram, ~150 TB disk space
  - ~ 46 MB/s data rate
- H.E.S.S. DAQ
  - multi-core, multi-process, multi-machine system
  - ~240 processes
  - data taking, slow control, error handling, user interaction

H.E.S.S. DAQ Overview

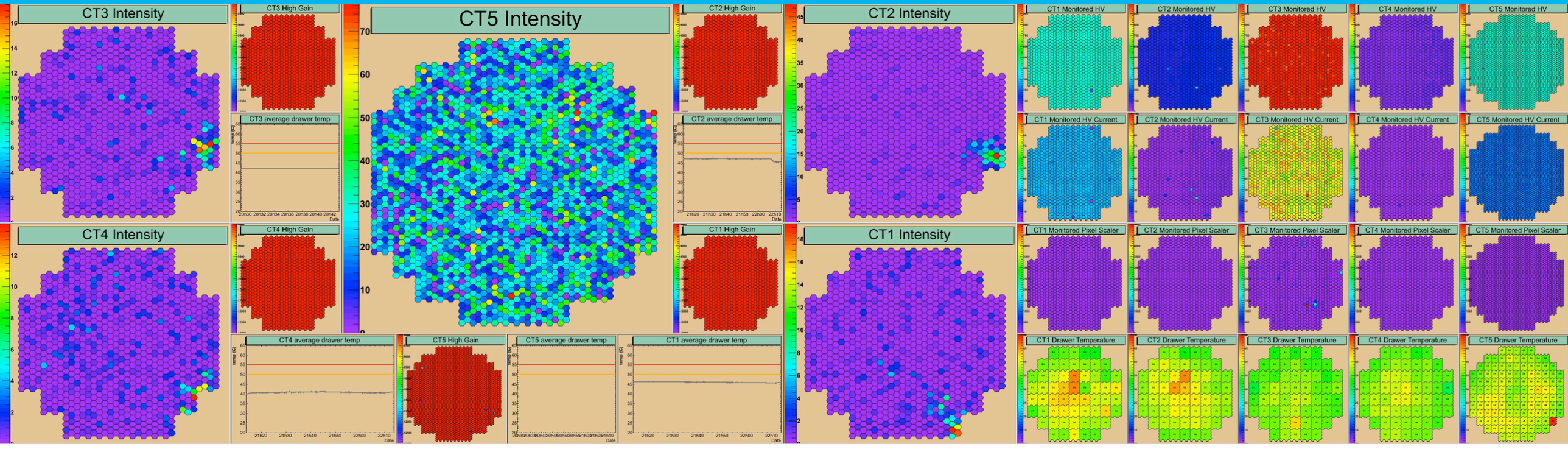
- Every piece of hardware represented by at least one Controller
  - Responsible for activation, management and deactivation of hardware
- Dedicated management controllers called Manager
  - Responsible for synchronization and error handling
- Several other Controller types with different purposes in use
  - Receiver, displays, sound & alerts, real time analysis, calibration …
- Inter-Process Communication using the OmniORB implementation of the CORBA standard
- Supported programming languages:
  - C++
  - Python
- Lost dark time from 2009 to 2012 due to Central DAQ problems was less than 1%

Data Flow

- Own Receiver for each hardware Controller
- Every Receiver may have a Displayer
- Data storage classes are experiment specific
- Data is stored using ROOT object serialization mechanism
- Data calibration and reconstruction algorithms can be used online and offline

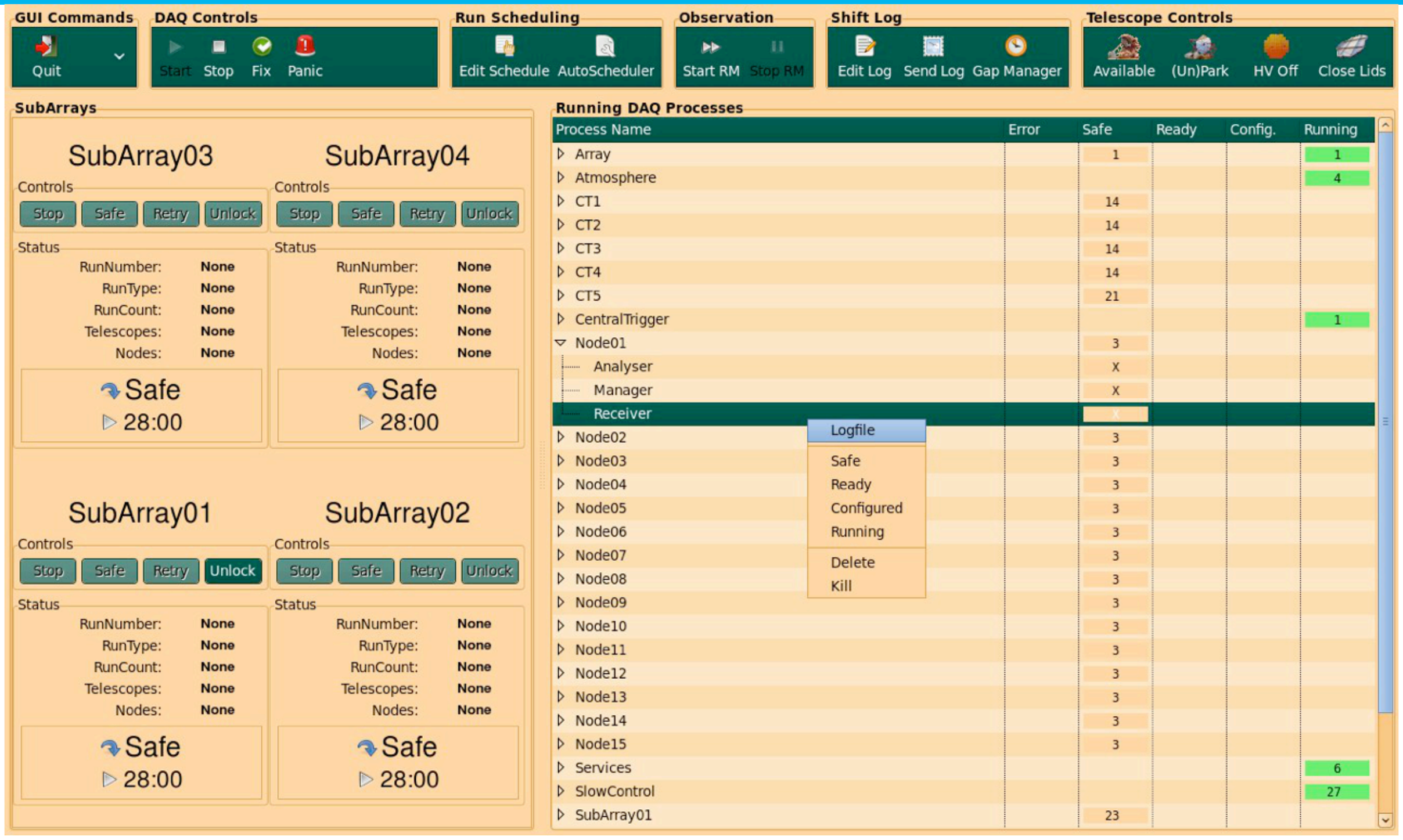


Displaying SlowControl Information

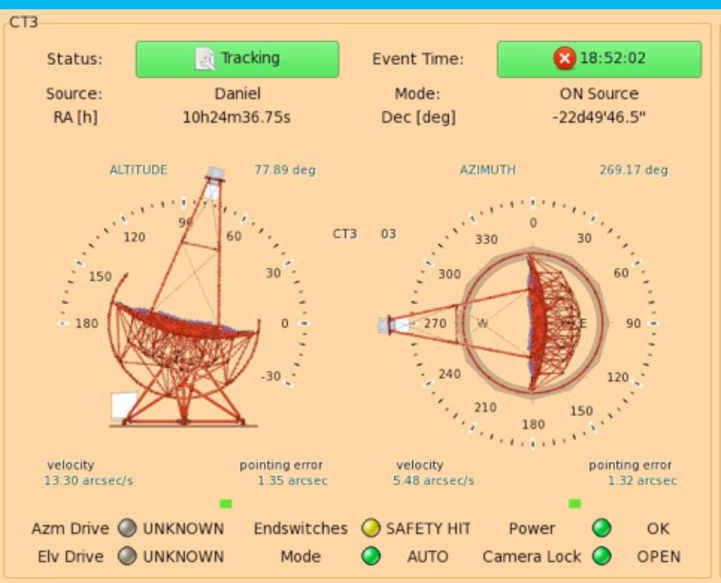


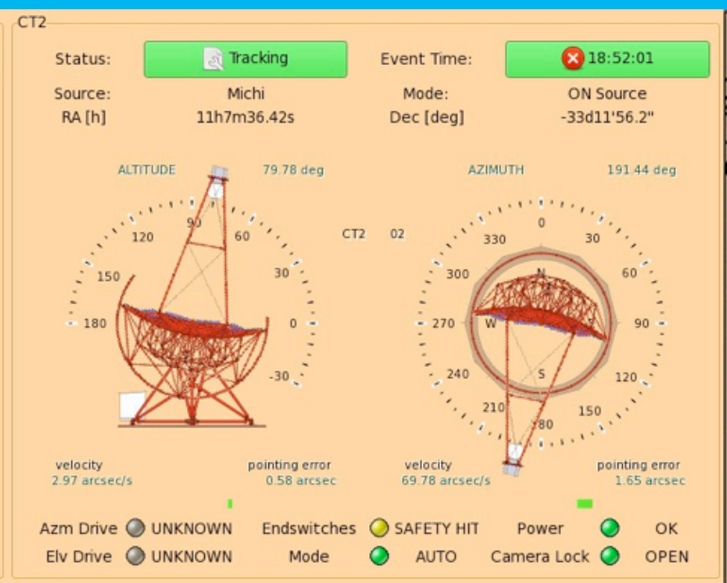
- One generic display controller configured solely via a MySQL database
  - Uses ROOT object introspection capabilities and histograms
  - Able to display any data member of any storage class
- Dedicated display machines
  - X11 forwards from any machine in the data network
- Some displays written in Python using PyGTK 2.4

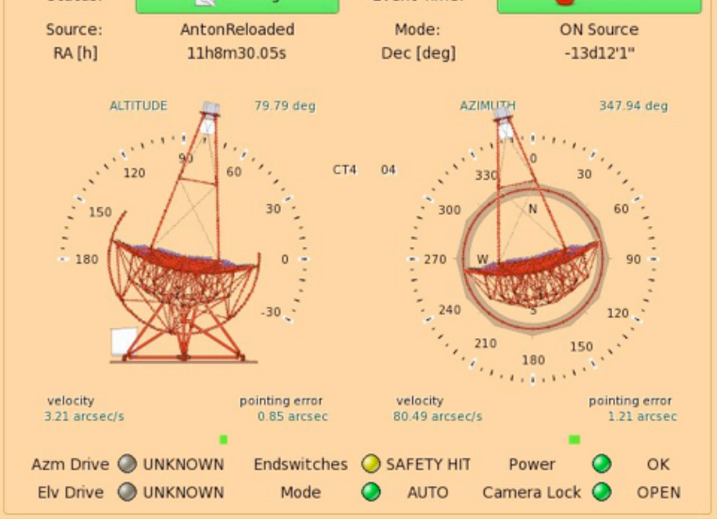
The Central DAQ-GUI

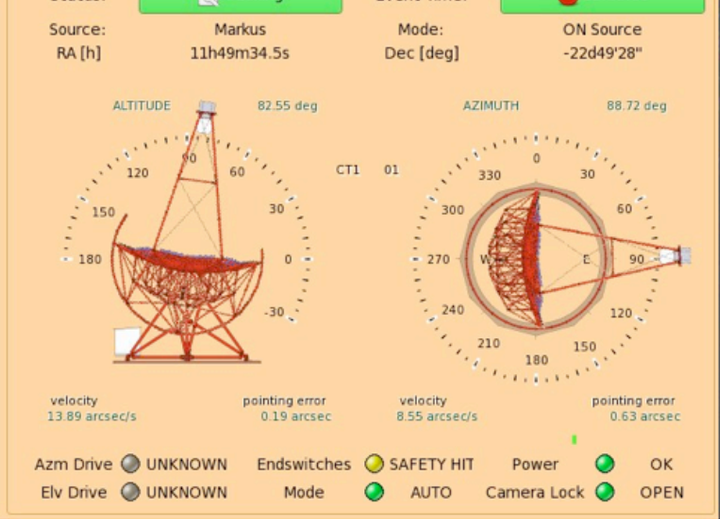


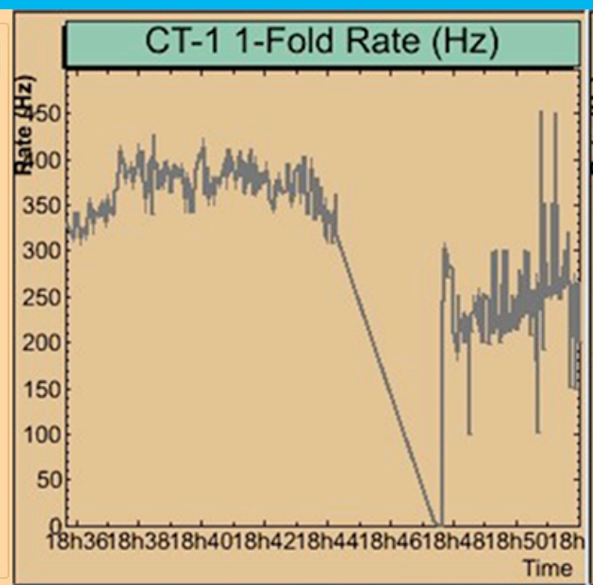
Multiple Simultaneous Observations

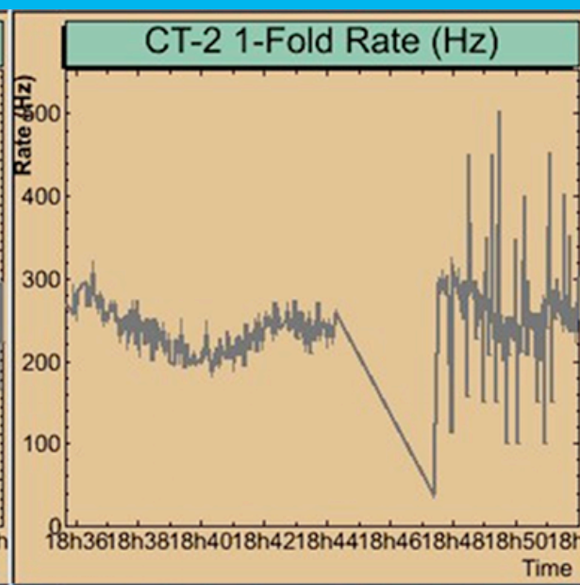


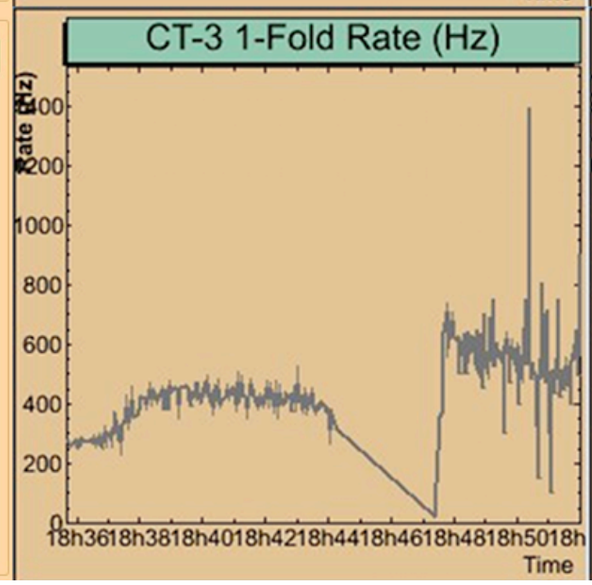


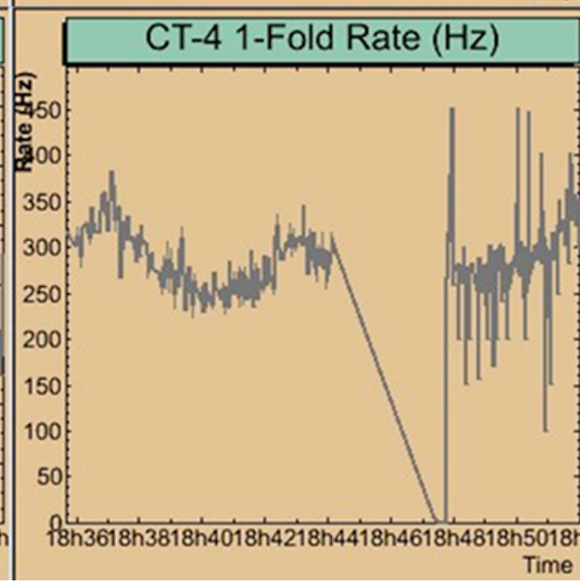








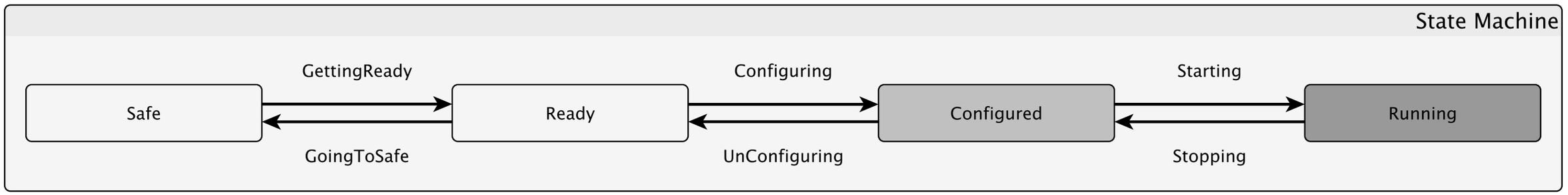




> Sole IACT array with this ability

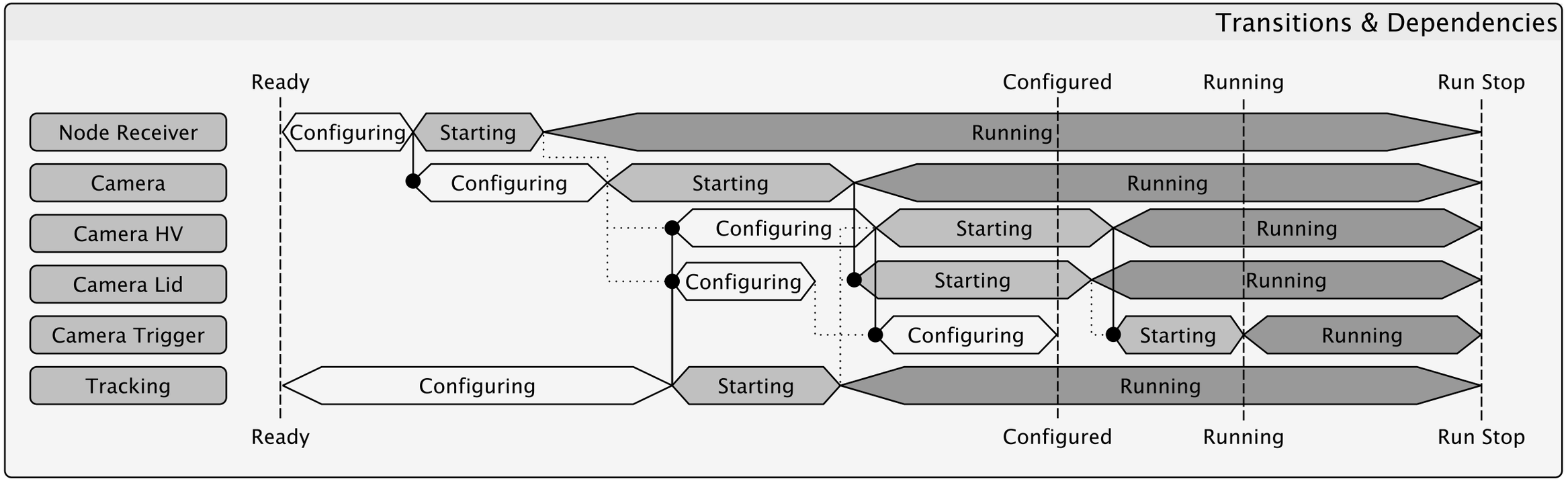
State Machine

- Every controller implements a common state machine
- There is only one transition for a given state and direction
- Default states
  - Day time: **Safe**
  - Night time: **Ready**
  - Data taking: **Running**



Transitions & Dependencies

- Controller only receive a target state
- Target state does not need to be an adjacent state
- Controller will wait for its dependencies to finish their current state transition before proceeding with their own
- “Immediate” transitions will ignore dependencies



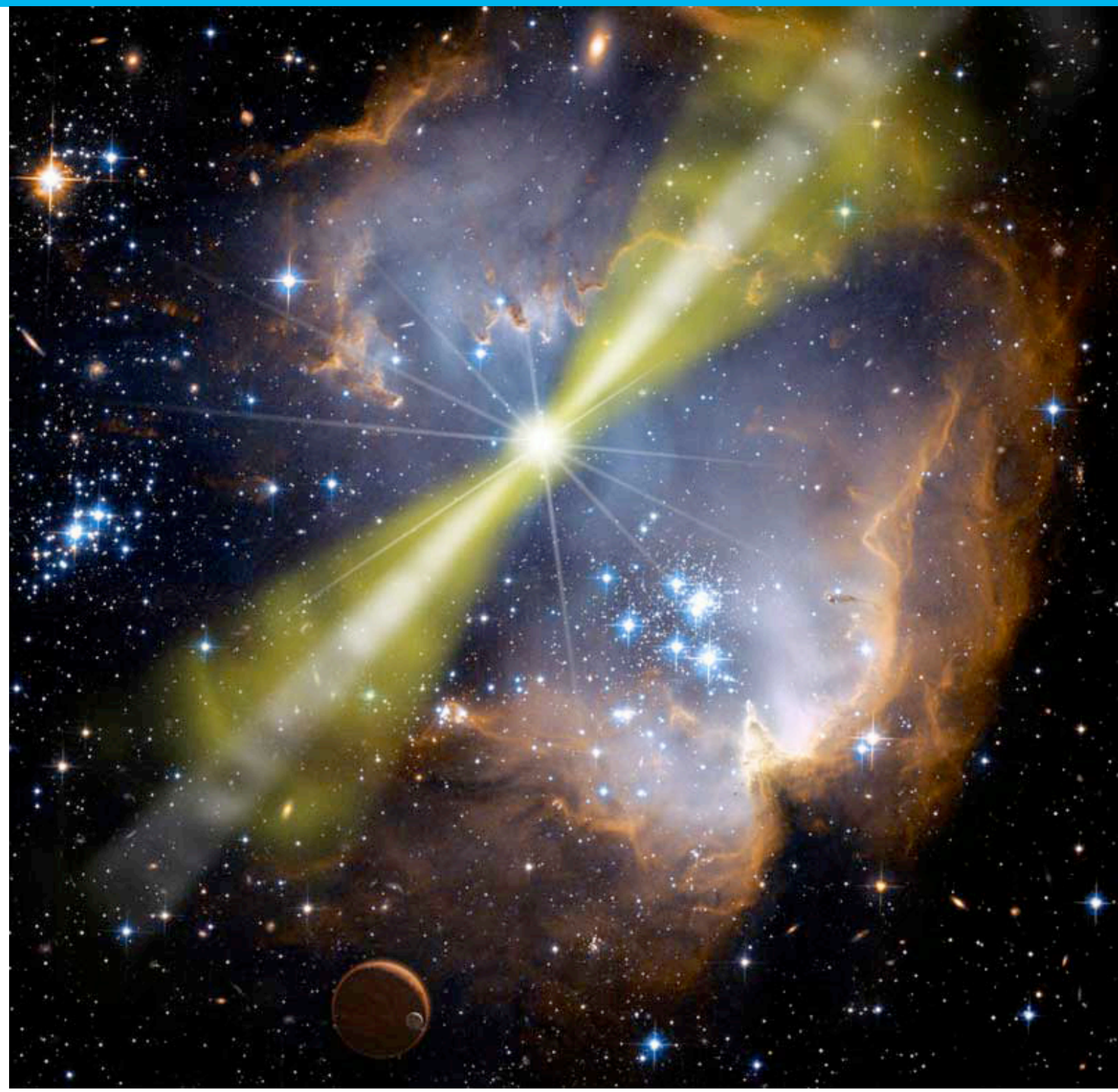
Reaction To ToO Alerts

> Motivation

- GRBs are the primary science goal for H.E.S.S. II
- Mean duration of “long” GRBs is 30 seconds

> Design Goals

- As quick as possible
- Fully automatic
- Ready for alerts in every possible state



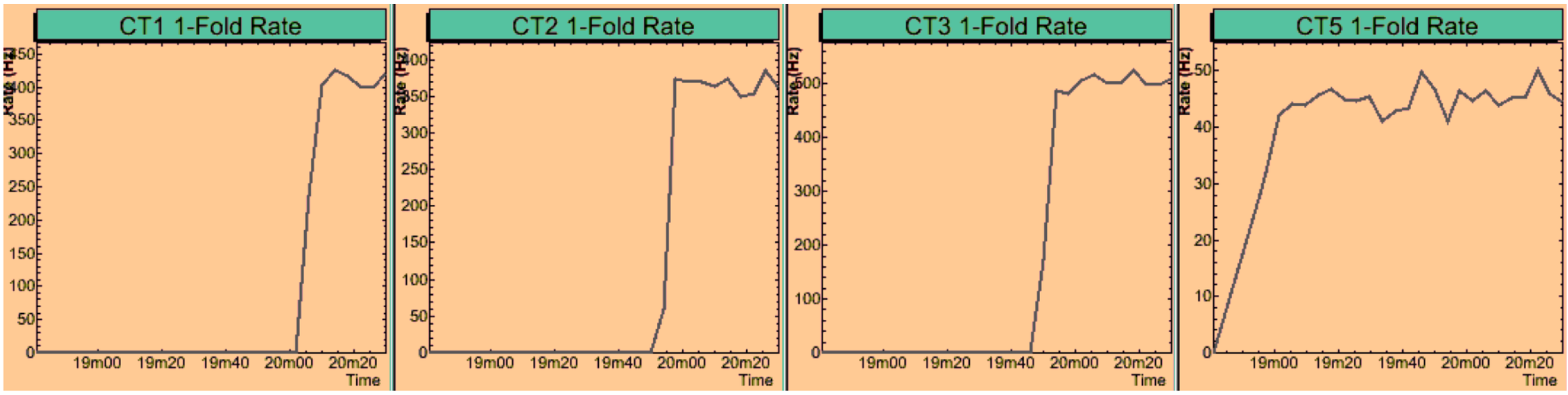
http://imagine.gsfc.nasa.gov/docs/features/news/10sep08.html

Implementation of the ToO Alert System

- Slewing time of the telescopes can't be reduced
  - CT5 immediately moves to new target if ToO alert is received ✓
  - DAQ notified once target within field of view ✓
  - CT1-4 are optional ✓
  - Fine positioning after data taking has started ✓
  - Use of reverse pointing
- Use time to stop ongoing runs and start joined ToO alert run
  - Use only available telescopes ✓
  - Clean DAQ state after ToO alert ✓
- Keep transition times of other processes minimal
  - Camera is just paused
  - Camera HV is not turned off
  - Camera Trigger remains configured

Performance of the ToO Alert Scheme

- H.E.S.S. Array able to react to ToO Alerts in 58 seconds
  - CT5 Tracking: 32 seconds
    - Angular distance was 59°
  - CT5 Camera: 31 seconds
  - Central Trigger: 5 seconds
  - Central DAQ overhead: 1 second



- Mean transition time for normal runs: ~3 minutes
- MAGIC: ~30 seconds (GRB 050713a)[1]

[1] http://iopscience.iop.org/1538-4357/641/1/L9

Summary & Outlook

- The H.E.S.S. DAQ is the most complex array control system of current IACT experiments
- Lost dark time from 2009 to 2012 due to Central DAQ problems was less than 1%
- Reaction time to ToO Alerts is smaller than 60 seconds
- Further improvements are planned
- H.E.S.S. Central DAQ Paper is going to be published soon

Thank you for your attention